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French phonetic and phonological development in simultaneous bilingual acquisition

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Individual trajectories and cross-linguistic effects in French-Italian/Arabic/Mandarin bilingual preschool children

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Abstract

The current study consists in a longitudinal follow-up of French phonetic and phonological development in preschool children exposed to one of the three following language pairs: French-Italian, French-Arabic and French-Mandarin. Developmental patterns and individual trajectories have been examined over four successive recording sessions, focusing on differences and similarities across linguistic groups. The impact of subject-related (i.e., linguistic dominance, lexical development in French and in both languages, gender, presence of older siblings) and item-related independent variables (i.e., elicitation technique, phonological complexity and lexical frequency) on the children's speech productions has also been investigated. Analyses have focused on different levels of phonological organization – i.e., segments, syllabic structure and whole-word forms – and have been based on both acoustic measures and phonetic transcriptions of the words produced by the bilingual children in a customized word-naming task. Results show differences between the three linguistic groups, as French-Arabic bilinguals globally exhibit a more advanced development of consonant production compared to the other two groups. Vowels are overall less impacted by the different variables under consideration than consonants and whole-word forms, presumably because the children have already achieved a later stage of development with regards to vowel production. The developmental variables of session and chronological age, together with lexical development in French and in both languages and the elicitation technique are the factors that more robustly impact the children's speech productions. In contrast, linguistic dominance, gender and the presence of older siblings only marginally influence phonological proficiency and might be confounded with other variables. These findings provide new insights about typical French speech development in contrasted contexts of simultaneous bilingualism. Implications of the study include, amongst others, contributing to an earlier detection of a potential speech and/or language delay/impairment in bilingual toddlers.

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« La parole humaine est comme un chaudron fêlé où nous battons des mélodies à faire danser les ours, quand on voudrait attendrir les étoiles »

Gustave Flaubert, *Madame Bovary*

INTRODUCTION

Knowledge about typical phonetic and phonological development in bilingual toddlers is currently still limited, as acquisition studies have for long focused on monolingual children. For the child exposed to two languages from birth, language development is influenced by the nature of language input and use as well as by the sociolinguistic context and specific language pair. Henceforth, the wide range of linguistic experiences leading to bilingualism makes the definition of developmental norms even more challenging than it already is for monolingual children. Consequently, it is not unusual that what constitutes normal variability characterizing the speech productions of bilingual toddlers would be confused with a potential language/speech delay or disorder. Given the great variety of bilingual experiences, one might indeed expect a higher inter- and intra-individual variability in early speech productions.

An increasing number of researchers have taken a keen interest in the issue of simultaneous bilingual acquisition in the last decades. Numerous studies have shown that bilingual development is similar but not identical to monolingual development and that bilingual toddlers display specific developmental trajectories. It is currently acknowledged that children exposed to two languages from birth would develop two distinct but interacting phonological systems and that this cross-linguistic interaction could manifest itself in different manners, depending on the specific languages as well as on the degree of exposure to each of them. Still, studies about bilingual production have yielded mixed results which are partly due to methodological issues. Many investigations involved restricted participant samples and differed by the methods used. Furthermore, most studies included children exposed either to English and/or to Spanish. Consequently, the way the two phonological systems of a bilingual toddler would develop – and eventually, interact – is not yet well understood.

The project of our doctoral dissertation emerged on the basis of these observations and is aimed at assessing the development of phonetic and phonological skills in preschool bilinguals exposed to different language pairs. More particularly, we have chosen to focus on three specific language combinations, all of which include French and another language differing by its degree of similarity to French; namely: French-Italian, French-Arabic and French-Mandarin. Our particular objective is thus to observe the evolution of speech production skills and the emergence of the phonological system in French in contrasted situations of simultaneous bilingualism. In parallel, our research also aspires to contribute to acquiring a better knowledge of "normality" and the potential deviations from it in the specific context of bilingual speech acquisition. To this end, we have developed a specific experimental protocol involving multiple tools in order to longitudinally collect complementary data from our participants. More precisely, hetero-reported data have been gathered through parental questionnaires and allowed us to document the specificities of the bilingual experience as well as the children's lexical development in both languages. Speech productions have been collected via a self-developed word-naming task and have been subjected to varied types of analyses including acoustic measures on the recorded speech sounds and phonetic transcriptions of the words produced by the bilingual children. Gathering these different data about our participants has permitted to consider a series of factors, both endogenous and exogenous, susceptible to impact early phonetic and phonological development.

This doctoral dissertation is structured in five main chapters: (1) the theoretical background, (2) the method, (3) the results, (4) the general discussion and (5), the conclusion and perspectives. These chapters are sub-divided into different sections described in the following paragraphs.

The first chapter (theoretical background) includes four sections. The first two sections are devoted to the description of phonetic and phonological development in first language acquisition (Chapter I. section 1.) and in bilingual language acquisition (Chapter I. section 2.). Both sections 1. and 2. propose a review of the literature about speech perception and speech production studies. The third section is dedicated to the phonetic and phonological description of the different languages involved in the selected language pairs (Chapter I. section 3.). Finally, the fourth section concludes the chapter by presenting the research problematic and strategy as well as the working hypotheses of the current study (Chapter I. section 4.).

The second chapter provides a detailed description of the method and includes four sections involving the description of: (1) the participant sample (Chapter II. section 1.), (2) the data collection paradigm (Chapter II. section 2.), (3) the procedures used for data processing (Chapter II. section 3.) and (4), the analyses conducted on the children's speech productions (Chapter II. section 4.).

The third chapter is devoted to the presentation of the results and contains three sections corresponding to the different structures analysed: a first section about vowels (Chapter III. section 1.), a second section about consonants (Chapter III. Section 2.) and a third section about whole-word forms (Chapter III. Section 3.). Preliminary specific discussions of the results will conclude the sections about vowels and consonants.

The fourth chapter includes a general discussion of the results and is followed by the fifth and last chapter devoted to the conclusion and future research directions.

Chapter I:

Theoretical background

I THEORETICAL BACKGROUND

I.1 PHONETIC-PHONOLOGICAL DEVELOPMENT IN FIRST LANGUAGE ACQUISITION

I.1.1 SPEECH PERCEPTION

I.1.1.1 Categorical perception and early discrimination capacities

Infants start experimenting auditory stimuli during their prenatal development, albeit passively, and this experience would give rise to post-natal familiarity effects. Indeed, newborns preferentially respond to their mother's voice and to the ambient language (DeCasper and Fifer, 1980; Mehler, Jusczyk, Lambertz, Halsted, Bertoncini & Amiel-Tison, 1988). Moreover, they are particularly sensitive to prosody[1], especially as exaggerated in the kind of talk addressed to babies (referred to as "Infant-directed speech" - IDS or "motherese") which is characterized by higher pitch patterns, longer pauses and more prosodic repetition (Fernald & Kuhl, 1987; Majorano, Rainieri & Corsano, 2013). This would allow them to discriminate between their mother's and a stranger's voice, as well as between normal and IDS speech (Hepper, Scott & Shahidullah, 1993) for which they show a significant preference.

Besides, newborns are also able to discriminate between utterances in different foreign languages as they use rhythmic cues to classify utterances into broad language classes according to global rhythmic properties (Nazzi, Bertoncini & Mehler, 1998). Investigating newborns' ability to differentiate between low-pass filtered sentences in different foreign languages, Nazzi and colleagues (1998) found that French infants discriminated between languages with different underlying rhythmic units (English and Japanese) but failed to discriminate between languages belonging to the same rhythmic class (English and Dutch)[2]. Likewise, Mehler and colleagues (1988) tested French newborns' responses to utterances in both French and Russian using the high-amplitude sucking technique (HAS). The HAS technique consists in assessing the infant's reaction to changes in a speech stimulus presented to him/her by measuring the rate at which the infant is sucking at a pacifier attached to a pressure transducer recording the sucking responses. This technique is based on two premises: infants would react to newness by increasing their sucking rate, whereas a decline in it would show a habituation process. Different sucking rates between the experimental and control conditions would thus indicate discrimination between the two stimuli. Interestingly, Mehler and colleagues (1988) measured higher sucking rates when the newborns were listening to French, thus indicating that they were discriminating between the two languages.

The HAS technique was first used by Eimas and colleagues to observe early discriminatory capacities (Eimas, Siqueland, Juscyk & Vigorito, 1971), as studies about phoneme identification in adults had revealed a phenomenon of categorical perception (Liberman, Cooper, Shankweiler &

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[1] The term « prosody » designs the phonological organisation of segments into higher-level constituents structuring sound. It is an intrinsic determinant of the form of spoken language as it consists in a system involving the modulation of different acoustic parameters, which allows for the realisation of supra-segmental features such as pitch, rhythm, intensity and length (Cutler, Dahan et Donselaar, 1997).

[2] Indeed, languages can be categorized into different classes based on their underlying rhythmic unit supposed to occur at regular intervals (Stridfled, 2005). Therefore, languages are referred to as stress-timed (such as English), syllable-timed (such as French) and mora-timed (such as Japanese), as their underlying rhythmic unit would respectively be stress, syllable and mora.

Studdert-Kennedy, 1967). Categorical perception is the ability to ignore acoustic differences between speech sounds but those necessary to recognise a language's phonemes, which entails removing irrelevant acoustical variability and allows for the development of the phonological organisation of the categories of this specific language. Findings had indeed indicated that adult listeners showed poor discrimination of sounds within each category but discriminated sounds belonging to different categories. Results from Eimas et al. (1971) demonstrated that pre-babbling infants, aged 1 and 4 months, could discriminate speech sound contrasts and showed categorical-like perception of speech sounds. Indeed, infants differentiated between two synthetic syllables [ba] and [pa], respectively involving a voiced and a voiceless stop[3] consonant, and thus only differing by a voicing contrast. Furthermore, infants reacted only to the categorical VOT contrasts characteristic of English – i.e., when the synthetic syllables cross the VOT category boundary characteristic of English – but not to pairs of stimuli from within the same phonemic category (namely two different [ba] sounds or two different [pa] sounds).

Following their research, categorical perception was demonstrated for other consonantal contrasts and more precisely, for: (1) voicing contrast between other consonants ([ta] vs. [da]) (Trehub & Rabinovitch, 1972), (2) contrasts in place of articulation for stop consonants in both syllable-initial and final positions (Miller & Morse, 1976; Jusczyk, 1977) and (3) contrasts in manner of articulation for stops *vs.* nasals and glides[4] (Eimas & Miller, 1980; Hillenbrand, Minifie & Edwards, 1979). In contrast, infant vowel discrimination was shown to be gradual rather than categorical, as also observed with adults, meaning that infants were equally capable of discriminating between vowels from the same phonemic category and vowels across category boundaries. In addition, the ability to discriminate vowels seems to emerge before consonants' discrimination (Bertoncini, Bijeljac-Babic, Jusczyk, Kennedy & Mehler, 1988).

From a theoretical perspective then, what investigators (Eimas et al., 1971) initially intended to determine was whether phonetic categories would result from learning the contrasts underlying the phonological system of the native language or if there were specific mechanisms supporting speech perception. Based on their findings, they hypothesized that categorical perception was innate and that infants would be "biologically endowed with neural mechanisms that respond to the phonetic contrasts used by the world's languages" (Kuhl, 2000: 2). In that perspective, the environment plays a minimal role and categorical perception would not depend on prior linguistic exposure, as young infants perceive categories that are not present in their native language(s). In other words, early perceptual abilities allow infants to initially discriminate "the universal set of phonetic contrasts, regardless of language experience" (Werker & Tees, 2002: 121).

However, the hypothesis of a specialised human processing for speech sounds was subsequently challenged by several studies about non-speech perception and non-human speech perception. Indeed, a categorical effect was also found in the perception of non-speech signals (Pisoni, 1977) and other animals, mammals (chinchillas and monkeys) and non-mammals (quails), were also found to categorically perceive voicing contrasts and contrasts in place of articulation (Kuhl and

[3]Also called a plosive or an occlusive in phonetics, a stop is a consonant whose production involves blocking the vocal tract so that no air can flow (such as [p] or [t]).

[4]Also called semi-consonants or semi-vowels, glides are intermediary phonetic elements between consonants and vowels.

Miller, 1975; Kluender, Diehl & Killeen*,* 1987). These findings would thus suggest that categorical perception of speech could be based on more general psychophysical mechanisms and auditory skills, or, in other words, that underlying mechanisms would not be speech-specific (Kuhl, 2000). Nevertheless, general auditory processing mechanisms might have evolved especially for speech perception and consequently, species-specific mechanisms could be involved in speech perception by humans.

I.1.1.2 Influence of the native language and perceptual narrowing

During the first six months of their life, infants are thus able to accommodate phonetic categories from any language. In the latter half of the first year, their perception begins to be influenced by their native language(s) and there is a decline in sensitivity to non-native speech contrasts. Infants begin to capture specific properties about how sound patterns are structured within their mother tongue(s) (Jusczyk, 1997) and start integrating its segmental and supra-segmental characteristics (Maillart, 2007). As they develop language-specific perceptual patterns, they evolve from broad discriminatory abilities to more adult-like language-specific biases and progressively, their initial auditory biases are shaped into phonetic categories derived from the ambient language(s) (Vihman, 2014).

More concretely, infants become specialised to discriminate consonant contrasts only relevant to their native language(s) around 10-11 months. Indeed, in a critical study, Werker and Tees (1984) investigated the discrimination of non-native place of articulation contrasts in English-speaking infants aged 8-10 and 10-12 months by making them hear contrasted consonants in both Hindi (dental *vs.* retroflex[5] stops) and Thompson, a Native American language (glottalised[6] velar *vs*. uvular stops) as well as English place-of-articulation contrasts (bilabial vs. alveolar stops). At 8-10 months, more than half of the infants perceived the non-native contrasts, whereas most infants aged 10 to 12 months did not. Besides, they could discriminate the native English contrast at every age range. Thus, the decline in the ability to discriminate all phonetic contrasts is occurring at the same time as infants are starting to understand and produce sounds relevant to their native language(s). According to the authors, “this perceptual reorganisation is closely related to the acquisition of phonological contrasts” (Werker and Tees, 1984: 132), as infants’ initial sensitivities are aligning with their native phonological system. In contrast, the development of vowel categories seems to be more complex. Indeed, and as previously mentioned, vowels are perceived in a continuous rather than categorical fashion. Then, some areas of the perceptual space would serve as prototypes for vowel categories because they show greater perceptual stability. According to Kuhl and colleagues, vowel categories would be organised around these prototypical instances from native-language input at about 6 months of age (Kuhl, Williams, Lacerda, Stevens & Lindblom, 1992). More concretely, these prototypes would function like “perceptual magnets” that reduce the perceptual distance between the centre and the periphery of a vowel category. Furthermore, this magnet effect would lead to the decline in sensitivity for non-native vowel contrasts. Polka and Bohn (1996) suggested a different developmental path: instead of prototypes, “vowels with extreme articulatory-acoustic properties[7]... [would] act as natural referent vowels – that is, perceptual attractors – and play an important role in

[5] A retroflex stop is a type of consonant made with the tongue curled back and in contact with the hard palate.
[6] Glottalization designs the complete or partial closure of the glottis during the articulation of a sound.
[7] Vowels located at the extremes of the vowel space.

shaping vowel perception" (Polka & Bohn, 2011: 174)[8]. Still, a similar developmental pattern can be globally observed for vowel and consonant perception – that is, a decline in sensitivity to non-native speech sounds and phonetic learning of the native-language sounds – but those changes would occur earlier for vowels than for consonants. This could be due to the fact that vowels would initially attract infants' attention given their relative prominence in the flow of speech (Jusczyk, 1997). Indeed, vowels are longer and louder than consonants and convey both prosodic and phonetic information.

During their first year of life, infants are thus learning to perceive their native language's contrasts and by 10 months, they become insensitive to acoustic differences not applying to their language(s). This perceptual adjustment results from the process of developing mental categories of sounds based on acoustic signals that children are hearing (Kuhl, 1985). However, it remains unclear which mechanism would underline this shift toward the phonological organisation of the native language(s). Moreover, there is still controversy about the developmental change(s) that could explain the emergence of native-language influence, whether the increasing interest for the meaning potential of speech, the sensitivity to the probabilities of segmental distribution in the linguistic input, or the emergence of adult-like syllable production (Vihman, 2014).

I.1.1.3 Word segmentation and early word learning

We should point out here that early studies about infant perception previously mentioned were focusing on the processing of minimal phonetic contrasts between speech sounds and supported the idea that the acquisition of sound organisation of the native language(s) was a bottom-up process, starting with basic units (such as phonetic-phonological categories) and combining them into larger ones (syllables and then, words). If it could actually be the case, this view does not account for the fact that language learning is driven by the will to communicate and that infants' priority could be to learn larger units of sound organisation directly related to meanings. In that perspective, speech perception capacities would evolve in line with this need to learn words in order to communicate with other people (Jusczyk, 2002).

Lexical acquisition requires extracting word forms from fluent speech. This segmentation of the input into words is challenging for infants, as spoken words are not presented in isolation and their frontiers do not have clear acoustic markers. The question arises as to how do they become able to detect words in the utterances produced in their environment. The prosodic structure of utterances would enable a first segmentation of the speech signal into shorter units through the use of certain characteristics, such as the final syllable lengthening or a decrease of intonation, which generally mark the end of a prosodic group. Moreover, the IDS and its specific prosodic characteristics would also ease word segmentation (Thiessen, Hill & Saffran, 2005). The notion of "prosodic bootstrapping" follows from such phenomenon. Indeed, given that natural prosodic units match syntactic units, infants' sensitivity to prosody would allow them to break into grammar (Vihman, 2014).

Besides, it could also be assumed that infants should learn about the sound organisation of their language(s) before being able to segment words. Indeed, in parallel of their perceptual reorganisation, infants are also acquiring knowledge about the phonotactic constraints specific to their language(s)

[8]More specifically, these referent vowels would guide the development of vowel perception by "attracting infant attention and providing stable perceptual forms" (Polka & Bohn, 201&; 16) and would even support production, as they would be easier to encode and to memorise.

(Maillart, 2007; Goswami, 2012) as well as the prosodic characteristics of native language words, which would help them extracting words from fluent speech. In addition, by 9 months of age, infants do not only detect phonotactic patterns from native-language input but have also become responsive to the frequency of occurrence of these patterns within words (Jusczyk, 2002). As shown by pionneer research lead by Saffran and co-workers (Saffran, Aslin & Newport, 1996), infants draw on their statistical learning abilities to segment words. More precisely, they analyse transitional probabilities between different phonemes; that is, the statistical likelihood of one phoneme following the other. Through their distributional analysis of the input, infants would identify frequent *vs.* infrequent sequences of phonemes and, based on the correspondence between the sequences' frequency and their position, would detect transitions within words and frontiers between words.

As soon as infants begin to segment words from the fluent speech, they start storing information about words' sound patterns and building phonological representations. Consequently, they begin to develop a lexicon in which sound sequences are linked to specific meanings (Jusczyk, 2002). Infants need to store mental phonological representations of words not only to acquire them but also to map them into speech forms/productions. Forming a central link between perception, comprehension and production, phonological representations allow children to recognize as well as to produce word (Ingram, 2008) and facilitate new word learning by enabling the processing of unknown words as sequences of stored – and thus, known – sub-lexical units (Munson, Edwards and Beckman, 2012). Different hypotheses about the degree of specificity of infant's initial phonological representations in perception have been postulated (Swingley, 2005; Zesiger, 2011). Most probably, early phonological representations would be, by nature, fragile, and as a result of their instable nature, differentially accessible in more and less demanding contexts. Moreover, information they encode more and less robustly would vary depending on the specific phonological properties of the native language[9]. Besides, the beginning of word learning generates cognitive overload and consequently, could result in a potential loss of precision. With lexical growth and increasing exposure to words, representations would become more and more stable and fully specified, encoding information about segmental and supra-segmental units.

At the end of the first year of life, infants would understand an average of forty to fifty words; however, they might only understand the meaning of words in their most frequent occurrence context (Florin, 2003). Moreover, there are indications that infants store information about sound patterns of words that they hear frequently, even when they do not have a specific meaning to link to them (Jusczyk, 2002). Besides, it is worth noting that there is an asymmetry between the development of word perception and word production. Indeed, children already recognise, and even understand, many words before starting to produce them. As previously explained, perception skills evolve rapidly during the first year whereas production skills will develop most rapidly between 1;5 and 4 years. This discrepancy could be due to the fact that processes underlying the perception of word sound patterns differ from those underlying their production. Therefore, children would be able to perceive sound patterns that they are not yet able to produce. Moreover, perception of adult sound patterns

[9]For example, French is a syllable-timed language in which the stress is fixed and falls on the last syllable when Dutch is a stress-timed language in which the stress is free but presents a predominant trochaic pattern in disyllabic words. Consequently, initial consonants, mostly stressed in Dutch, would be more robustly represented in this language than final consonants and conversely, initial consonants would be less well represented in French, in which final consonants would be more salient (Zesiger, 2011).

need not be totally specified phonologically to allow children to recognise frequently used words whereas word production requires a motor plan (Vihman, 1993).

To sum up this section about infant speech perception, we have seen that the first year is marked by a perceptual narrowing by which infants become attuned to their native language(s). Then, it appears that infants are using different types of cues – distributional and rhythmic cues – to segment words from the speech stream and that they start to integrate these cues at about 12 months (Jusczyk, 2002). Moreover, there would be inter-linguistic differences in speech segmentation processes as the rhythmic unit cue for frontiers between words varies depending on the specific language. Therefore, children would develop a process of rhythmic segmentation based on their native-language rhythmic unit (Nazzi, Goyet, Sundara & Polka, 2012). Finally, early word learning entails the encoding of phonological information and the building of a referential link between speech forms and their meaning.

I.1.2 Speech production

Similar to perception, infants' development of speech starts with language-universal production patterns which subsequently become language specific (Meltzoff & Kuhl, 1996). During their first two years, infants go through different developmental phases in speech production[10], as shown in the Figure 1 below.

[10] The timeline of these developmental stages varies from one source to the other, except for the stage of canonical babbling.

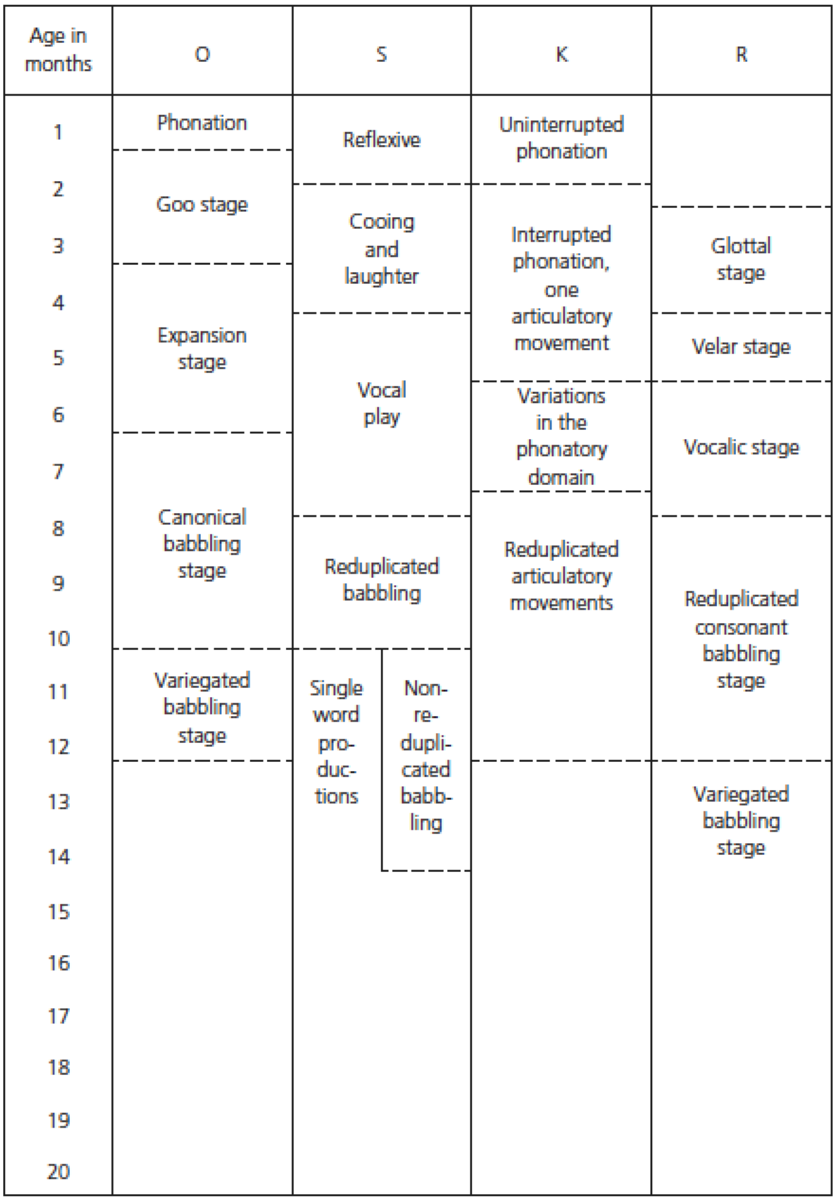

Figure 1: Stages in vocal production (in Vihman, 2014, based on Oller, 1980; Koopmans-van Beinum & Van der Stelt, 1986; Roug, Landberg & Lundberg, 1989; Stark, 1980).

I.1.2.1 First production patterns: from early vocalisations to variegated babbling

To produce speech sounds, the infant has to learn to gain control over a very complex vocal apparatus (Boysson-Bardies, 1996). At birth, respiratory and phonatory control allows the newborn to produce cries expressing pain or distress. During the six first months of life, infants produce different kinds of shrieks, gurgles and vocalisations. Until 2 or 3 months of age, vocal production is limited to "reflexive phonation" (Meltzoff & Kuhl, 1996) such as cries, vegetative or reactive sounds, due to the physiology of the infant's vocal tract and his/her immature control over breath and digestion. However, and as early perceptual abilities show it, newborns are really attuned and responsive to surrounding speech sounds – infants listen to adult speech productions, following their mouth's movements and trying to imitate them – but this interest is not yet reflected in their productions. Then, from the age of 2 or 3 months, infants start cooing and laughing. More precisely, they are producing vocalisations consisting of oral vowel-like sounds often occurring with incomplete velar closures.

From the age of 5 months, infants begin to master these vocalisations, intentionally producing them. They go through an expansion stage in which they experiment their new skills resulting from maturational changes. As the child investigates the potential of his/her vocal tract, this period is characterised by the occurrence of clear and fully resonant vowels as well as by other new sounds like squeals, whispers, nasal murmurs, trills (etc.). Consequently, infants start engaging in vocal plays and manipulate acoustic features of speech sounds, such as height and intensity. Besides, another factor that could potentially contribute to developmental changes in infants' vocalisations is "vocal learning" (Meltzoff and Kuhl, 1996). In that perspective, infants would try to produce speech patterns based on what they hear and phonetic and phonological acquisition would be made through vocal imitation. Until 7 months, infants are thus in a run-up period to babbling: they play with sound intonation or length, produce various sound effects and learn about articulatory configurations and gestures by repeating sounds.

A very important developmental production milestone marks the middle of the first year. Indeed, around 6 or 7 months, "canonical" or "reduplicated babbling" emerges. Infants start producing sequences of rhythmic speech-like consonant-vowel syllables. Moreover, this change is robustly observed, no matter the conditions, based on rhythmic motor advances. More concretely, canonical babbling is the first adult-like production pattern involving movements of jaw opening and closing – or basic "mandibular oscillation" – with labial or dental stop closure (stop consonants) and low vowels (such as [a]) in a CVCV frame, such as « baba». Within this articulatory framework, infants would gradually develop their favourite sound patterns, also called "vocal motor schemes" (VMS) which consist in "generalised action patterns" yielding "consistent phonetic forms" (McCune & Vihman, 2001: 673).

Although the production of CV syllable structures emerges as a salient feature, vowels are predominant in infant's productions during the first year. Still, they have been less studied than consonants due to the difficulty to reliably transcribe and characterize them. Besides, the acquisition of control over vowel production is slowly taking place. Consequently, the first year is characterized by the production of low and central vowels (Kent and Murray, 1982) resulting from the lack of mastery of the tongue as a phonetic articulator. A review about published developmental acoustic and anatomic data on vowel production led by Vorperian and Kent (2007) indicates that early vowel development is characterized, amongst others, by: (1) a reduction of formant-frequencies and of F1-F2 area, (2) a decrease in formant-frequency variability, (3) the emergence of gender differences in formant-frequencies from 4 years and on and (4), a decline of F0 by age 1. However, results of the studies mentioned in that review show that the lengthening of the vocal tract in the first two years does not affect formant frequencies as expected.

From 10 to 11 months, sounds become more clearly and confidently articulated. Furthermore, syllable production become more diversified as there is a systematic variegation of consonantal and vocalic elements. Therefore, the term « variegated babbling » is used with respect to the second stage in the second half of the first year (Boysson-Bardies, 1996). However, it seems that the two kinds of babbling co-occur from the beginning of canonical babbling and that variegated syllable production becomes predominant around the end of the first year. Besides, while this production of different consonants indicates phonological progress, infants greatly differ in the choice of consonants and preferred sound patterns that they produce.

According to Jakobson (1968), the babbling stage would be "prelinguistic". In that view, there would be a discontinuity between babbling and first words, as babbling would be followed by a silent period, itself followed by speech or "linguistic" stage. Moreover, babbling would be characterised by a variety of sounds not found together in a single language. However, little evidence of discontinuity has been shown and babbling is nowadays seen as a "springboard" for entering articulated and complex language. Indeed, the sounds used in late babbling and in early word productions are closely linked and early words often continue patterns that are prevalent in babbling. In other words, the relation between babble and first word forms has been well established.

While emerging earlier in perception, native-language influence start being observed in production between 10 and 14 months, either at a segmental or prosodic level. Indeed, certain dimensions in vowel and consonant production would mirror the child's exposure to the specific ambient language(s). Boysson-Bardies and her coworkers (1989) have conducted a cross-linguistic study about vowels in 10-month-old infants exposed to different languages (English, French, Arabic and Cantonese) and have demonstrated ambient language effects on vowel production based on acoustic analyses of the infants' babbling. More concretely, they selected a sample of oral vowels from the canonical babbling of infants recorded in their homes. Acoustic analysis showed characteristic patterns of vowel production, such as more front vowels in children exposed to English, more mid-central vowels for those exposed to French and finally, more low central vowels for children exposed to Cantonese. Regarding consonant production, Boysson-Bardies and Vihman (1991) found a higher production of labial consonants in the vocalisations of 10-month-old infants exposed to French, in comparison to infants exposed to Japanese and Swedish, reflecting different rates of labials' occurrence in adult language. According to Vihman (2014), the development of babbling patterns could play a role in the perceptual reorganisation towards native-language contrasts described in the previous section. In that view, the child's favourite speech sound patterns will exert a "top-down" influence or "articulatory filter" on the language patterns heard.

In sum, the first year sees the emergence of speech-like vocal production and at the end of that year, children are not only babbling and start to produce adult-like syllables. Besides, from 10 to 18 months, infant speech will be characterised by a mix of babbling and meaningful speech. Although vocalic utterances remain predominant, children are able to steadily produce at least two consonants, generally stops or nasals, from 9 to 16 months. Furthermore, this appears to be a prerequisite to be able to remember associations of word forms and meanings in different contexts of occurrence and to start using words in a referential way. Still, there is also a pragmatic requisite for referential word use. Therefore, advances in vocal production are due to both anatomical and neurophysiological changes, as well as to the emergence of socio-communicative competences.

I.1.2.2 Early word production: from "protowords" to early word forms

From the age of 10 months, infants will progressively introduce recognisable structures, also called "protowords", in their sequences of babbling. The term "protowords" is given to any relatively stable vocal forms regularly used by the child and recognised by the adult while not yet constituting a form-meaning unit. Therefore, these recurrent vocal forms are qualified as pre-referential or pre-symbolic. Intentional communication would be initially demonstrated through the use of deictic gestures and protowords, which have a more or less consistent but global or child-derived meaning. While these vocal forms would mark the emergence of phonological organisation, they would also be characterized by greater variability in form than adult-like words.

Between 12 and 16 months, infants start producing their first words which initial use generally does not completely share the same meaning as the one known in adult speech, as first words are very dependent on the context. If continuity has been established between babbling and first words, production of these latter involves new phonetic trends. Indeed, early words are generally simple in phonetic structure, based on equally simple adult targets, and generally include a single consonant type, particularly in the syllable-onset position, which is more perceptually salient. More precisely, infants predominantly use labials and stops (Boysson-Bardies & Vihman, 1991) which involve basic articulatory patterns; therefore, they become more frequent in early words than in babbling. On the contrary, use of fricatives[11] would follow the opposite path, as their voluntary production requires more articulatory control. Likewise, early word production mostly includes mono- or disyllabic forms.

First words are also relatively accurate with respect to their evenly simple target forms. However, this could stem from the fact that the adult words whose phonetic pattern is part of infant babbling repertoire are excessively salient. Moreover, the earliest word productions could result from a correspondence between a frequent adult word form and the child's babbling pattern. Besides, the development of early word shape does not go straightforwardly from simple to complex structures. Instead, their phonological structure might be influenced by early individual production preferences and the salience of specific structures in the adult phonology (Khattab & Al-Tamimi, 2013). In addition, children might initially produce accurate forms and subsequently go through a "regression stage" followed again by the production of accurate forms as they achieve real acquisition of adult-like phonology. In other words, a U-shaped curve, or nonlinear progress, can be observed in children's phonological development (Fikkert and Levelt, 2008).

From 12 to 18 months, a new systematicity emerges in production, in parallel to the onset of referential word use, as infant production is characterised by the development of recognizable word production patterns. By 17 months, children have a productive vocabulary of about 50 words and their speech productions start becoming more phonologically stable while still presenting systematic errors, reflecting the building of the phonological system (Maillart, 2006). Moreover, the age of 18 months would correspond to the beginning of a significant word production (Bassano, 2005) and of the lexical burst (Hilaire, Kern, Viguié, Dudognon, Langue, Romieu, 2001), a phenomenon nevertheless challenged by some authors (Zesiger & Jöhr, 2011). Around two years, the child would be able to produce about 200 words.

To sum up this section, we can say that the emergence of speech production consists of a series of stages ensuing from both the acquisition of articulatory control and the evolution of perceptual abilities more and more attuned to the native language(s). Moreover, these successive developmental steps shaping the early development of speech are likely to be universal, although individual differences are also observed. Figure 2 presents a tree structure of the different hypothesized stages in phonetic and lexical development during the first year of life, from reflexive phonation to first word productions.

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[11]Fricatives are consonants characterized by continuous aperiodic noise (such as [f]and [s] as opposed to stops [p] or [t]).

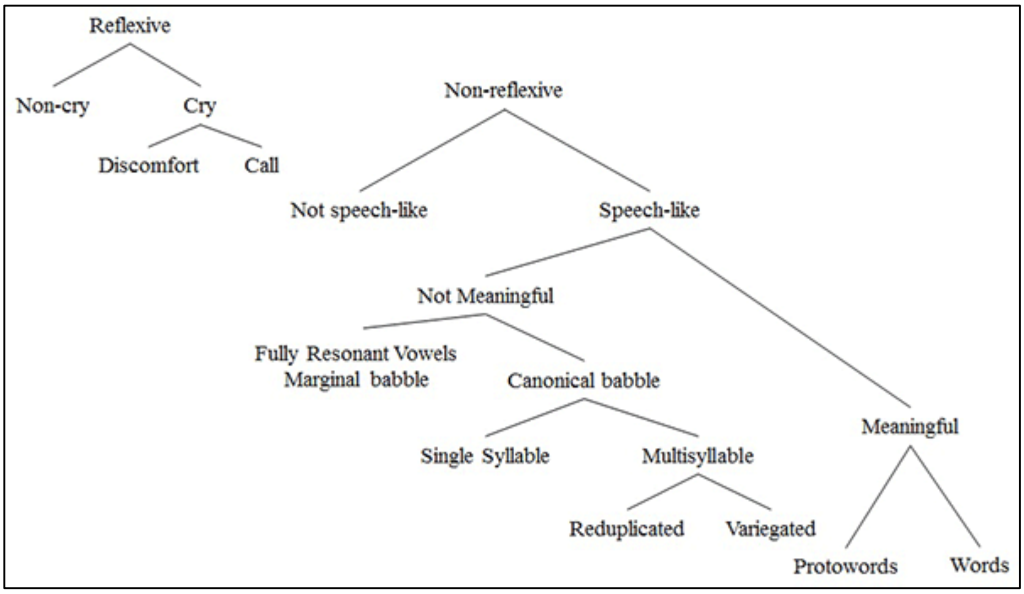

Figure 2: Classification of infant vocalizations, drawn from Rvachew and Alhaidary (2018).

I.1.2.3 Phonological development: theoretical models

Various theoretical models of phonetic-phonological development have been proposed to account for the chronology of the emergence and acquisition of speech sounds as well as for early word production patterns characterised by phonological processes, such as phoneme deletions, substitutions or epentheses. These models can be broadly classified into two categories: formalist-linguistic and functionalist-emergentist models[12]. Formalist approaches to phonological development are based on adult phonology as these models relate children's productions to the adult reference system. "Top-down" or deductive models within this approach presuppose the existence of an underlying phonological structure that will progressively establish itself in the course of development. Functionalist-emergentist or "bottom-up" models consider phonological development as an emergent process rooted in speech-motor and perceptual systems. We present some of these models of phonological development in the next sub-sections. However, it should be noted that these are not closed categories and that certain models incorporate elements from the two approaches, such as a templatic model discussed in the last sub-section about Whole-word phonology.

I.1.2.3.1 Formalist models

I.1.2.3.1.1 Structuralist theory and notion of markedness

One of the earliest, and still influential, theoretical model for phonological development was the structuralist account proposed by Jakobson (1968) based on the notions of distinctive features[13] and markedness. In this structuralist approach of phonological development, Jakobson put forward

[12]Although perception models have also been developed, they will not be discussed here, as our study focuses on speech production.
[13]Phonemes can be classified by mutual opposition based on a bundle of distinctive features. These binary phonetic features involve, amongst others, features of place, manner and voicing. For example, the voicing feature allows distinguishing /p/, which is voiceless, from /b/, which is voiced, as in the French minimal pair "paon" [pɑ̃] and "banc" [bɑ̃]. In addition, these features are universal but each language may use a subset of these features as distinctive.

the thesis that the phonological system is built based on the opposition of distinctive features characterising the phonemes and on their degree of markedness. Numerous definitions of the notion of markedness have been proposed in linguistics. In the wake of Trubetzkoy (1939), Jakobson defined it in terms of distinctive features; that is, the idea that within the two values that a feature can take, one is in some way less complex that the other. In this view, the acquisition of distinctive features underlies the acquisition of phonemes, as children are not acquiring phonological units independently one from another but categories in contrast with each other. Within this scope, speech sounds characterised as unmarked sounds are considered as less complex to produce and more common in the world's languages whereas marked sounds are considered as more complex or difficult to articulate. Therefore, children would acquire the less marked structures prior to the more marked ones.

Following this, Jakobson (1968) established a predefinable sequence of the system's sounds acquisition. To begin with, vowels are less marked than consonants and thus, appear first in infant speech. The vowel system development would start with open/wide vowels and more specifically, the low vowel [a] would be the first vowel to emerge. Children would then acquire the vocalic opposition between the low vowel [a] and the high vowel [i] and then, either between the front vowel [i] and the back vowel [u] or between the high vowel [i] and the mid-high vowel [e]. Besides, the three-vowel system /a, i, u/ would constitute the minimum vocalic system of the world's languages. Finally, nasal vowels are more marked and predicted to be acquired after unmarked oral vowels. Then, for consonants, stops are predicted to be acquired before fricatives, fricatives before affricates, voiceless consonants before voiced consonants and liquids[14] would emerge later. Moreover, the consonantal opposition between labial and nasal stops would be acquired before the opposition between labials and dentals.

In sum, Jakobson (1968) claimed that the phonological acquisition follows a precise and fixed order and that there would be a universal chronology in the appearance of sounds in childrens' phonemic repertoire based on their distribution in the world's languages. If his predictions proved to be valid to a large extent, Jakobson' s account has also been subject to criticism. First, and as previously mentioned, his conception of babbling as a pre-linguistic stage with no link with early words has been rejected. Then, even if phonological acquisition is globally led by markedness and if universality is found across children, the frequency of distribution in the ambient language(s) should be considered as well. Indeed, cross-linguistic differences are observed and therefore, the developmental path would be more language-specific. In addition, Jakobson's conception of phonological acquisition does not account for prosodic aspects potentially involved in segmental acquisition.

I.1.2.3.1.2 Generativist approach

Generative phonology was introduced by Chomsky and Halle (1968) within the framework of generative linguistic theory that aims at characterizing the linguistic competence of a language's native speakers and explaining how the child acquiring language can achieve that competence (White, 2007). In that view, Generative linguistic theory postulated the existence of a limited set of rules and principles (or constraints) efficient to produce the surface forms of all natural languages – i.e., the

[14]Liquids are a class of consonants consisting of voiced lateral approximants like /l/ together with rhotics like /r/.

observable linguistic behaviour qualified as the speaker's performance – and to modelize the native speaker's internalized linguistic knowledge or competence. In these framework, the set of principles is innate (child do not have to learn these principles as they are encoded in the Universal Grammar) and language acquisition amounts to set up the right parameters for the specific language being acquired. In that view, linguistic experience would trigger the appropriate parameter values available in the Universal Grammar. As such, language acquisition is based on an innate formal device (the LAD, for "language acquisition device") and involves a minimal role of the linguistic input, considered as grammatically poor, degraded and variable.

Following this, the modelization of phonological acquisition proposed by generative phonology involves an innate underlying structure corresponding to the abstract level of linguistic competence that is mapped to the surface or phonetic realizations corresponding to the linguistic performance. Phonological acquisition would thus be structured by this underlying representational unit. Moreover, the mapping between presumed underlying and surface forms is realized through the automatic application of innate rules – also called phonological processes – supposedly following a particular order. These processes would explain the error patterns frequently observed in child productions that gradually disappear as the child gets more and more exposed his/her native language(s).

Different theoretical approaches have been developed in the frame of generative phonology, depending on what specific conception of phonological learning and of the underlying representational unit they imply. An important theoretical development of generative phonology is the Optimality Theory (Prince & Smolensky, 1993). In this framework, phonological systems are conceived as a set of innate and universal constraints governing the links between the child's lexical representation and his/her output form. Surface realizations would be generated from underlying forms by means of ranked and violable constraints allowing or precluding certain phoneme sequences (Peperkamp, 2003). Moreover, the sequencing of constraints would be specific to each language and language acquisition would lie in the adjustment of the initial constraints' hierarchy to the ambient language. In other words, this modelization postulates the existence of an identical phonological representations in adults and children but differences in production patterns are explained in terms on constraints, instead of rules.

Another theoretical proposal within the frame of Generative phonology is non-linear or auto-segmental phonology. Initially developed to study tonal languages, it involves autonomous representational levels. More particularly, phonological representations include several representational layers whose basic level corresponds to a sequence of segmental positions occupied by phonemes on which are anchoring the elements of the other layers (including syllabic, prosodic and tonal levels). Therefore, this approach allows considering all hierarchical levels of phonological representation – from the phonological phrases to phonological features – and their interaction in order to explain children's early production patterns (Bernhardt, 1990, 1992).

I.1.2.3.2 Functionalist-Emergentist models

As previously mentioned, functionalist-emergentist approaches envision phonological development as a progressive organisation of speech sounds into a system of distinct phonological categories under the effect of articulatory-perceptual constraints and exposure to the mother tongue(s). Contrary to formalist proposals, these models do not presuppose the existence of an innate grammar and underlying representational units structuring phonological acquisition. Instead, they posit a continuity between babbling and speech and postulate that the development of speech production is based on articulatory, perceptive and cognitive abilities. Several models have been proposed within this framework, including articulatory (Davis & MacNeilage, 2004) and probabilistic or statistical models (Bybee, 1999; Pierrehumbert, 2001, 2003). Some of them are presented in this section.

The "Frame, then content" theory proposed by Davis and MacNeilage (2004) is a self-organizing model that postulates that the evolution of speech would emerge from the coexistence of two articulatory mechanisms: the mandibular oscillation (the frame), consisting in a rhythmic alternation between closed and open jaws, and the passive movement of the articulators (the content), namely tongue and lips. In this articulatory approach, the rhythmic mandibular oscillation provides a dynamic model for early syllable frames which are initially produced without control over the other articulators. Therefore, the content of these syllable structures is filled by a limited set of consonant-vowel combinations based on available gestures already used for sucking or chewing. This model posits that early syllables of CV type are characterised by the following consonant-vowel associations: (1) dental-alveolar consonants and front vowels (such as [di]), (2) labial consonants and central vowels (such as [ba]) and (3), velar consonants and back vowels (such as [ku]). Moreover, sequences of labial consonants and central vowels are initially the most frequent as they require less complex movements of the articulators and fricatives, affricates and liquids emerge later due to the motor control difficulties that they imply. In sum, this approach focuses on phonetic development and modelizes speech acquisition around the articulatory features of speech sounds. Early speech forms – in both babbling and first word patterns – are thus primarily conditioned by the infant's physiological and articulatory abilities and only then, by the input's properties.

Other models have been developed within the exemplar and usage-based approach (Bybee, 1999, 2002, Pierrehumbert, 2001). These models give a preponderant role to the frequency of occurrence and co-occurrences of phonological structures and their basic principle is that the acquisition of phonetic-phonological knowledge can be conceived in terms of the acquisition of memory traces based on individual patterns of use. Indeed, speech input sequences are encoded by memory with each exposure and these traces persist in memory for a certain period of time. Initial productions will be characterized by high phonetic variation and then, frequent exposure leads to an abstraction process and to the development of phonological representation. Based on repeated speech patterns and coordinated sets of articulatory gestures, children will build their inventory of phonological units; that is, segments and syllables (Bybee, 1999).

I.1.2.3.3 "Whole-word" or templatic phonology

We finish our discussion of theoretical approaches of phonological development with the "Whole-word" hypothesis or templatic phonology. Models falling within this approach put forward the idea that phonological development is structured by "whole-word" representations, or word templates. Practically, the first word forms selected and produced by children provide accessible (motor) patterns on which they can rely to utter more complex structures. Developmental templates are thus those well-practiced patterns used by the child to produce more difficult word forms and to which dissimilar adult target words are adapted. Therefore, they are defined as idiosyncratic child phonological patterns or "emergent neuromotor routines that lead to increasing similarity among the child's early word forms – often at the expense of accuracy" (Vihman and Wauquier, 2018: 28). Moreover, they are responses to challenges arising from both production and perception constraints and allow children to develop a multilinear phonological representation capturing the large amount of information that they have to process. In that perspective, templates can be seen as “adaption to the structural complexity of speech with its multiple levels of information” (Vihman and Wauquier, 2018: 7). Besides, similar formal characteristics as well as differences between children (and even in the same child) and across languages have been observed. Therefore, templates are not fixed or innate; instead, they are individual dynamic and transient child production patterns resting on a general cognitive capacity.

A template hypothesis falling within auto-segmental phonology has been postulated specifically for French (Wauquier & Yamaguchi, 2013) based on the model of accentual arc of Di Cristo (1999) according to which the metric structure of French would be based on the existence of a final and an initial counter-stress. The French templatic unit is defined as “a prosodic unit that is perceptually available, bounded by stress and counter-stress, and therefore segmentable in the input” (Wauquier & Yamaguchi, 2013). The developmental prediction of this hypothesis is that early words forms in French would reflect this structure of accentual arc as well as French typological constraints; that is the tendency to CV-CV syllabation and to the insertion of an initial filler on content words. Therefore, this template would initially be made of two external pillars – the stressed and prosodically salient initial and final syllables – and formed by CV units to subsequently become more complex via the progressive addition of structures in medial position(s).

We have reviewed several models of speech and phonological development falling within different theoretical approaches. Formalist (top-down) models are aimed at explaining the developmental path and the phonological patterns of the child in relation to the adult system. According to these models, phonological systemacity arises from an innate linguistic knowledge and pre-existing abstract representation. Criticisms that may be made of these models is that they give minor importance to the input and that the empirical validation of their premises is problematic. Based on the principle of self-organization, functionalist approaches attempt at modelizing phonological development by integrating cognitive and articulatory-motor abilities of the child as well as the characteristics of the ambient language. Therefore, these models envision phonological development as emerging from both production and perception. Finally, models incorporating principles from both formalist and functionalist-emergentist approaches can be found within Whole-word phonology.

I.2 PHONETIC-PHONOLOGICAL DEVELOPMENT IN BILINGUAL ACQUISITION

I.2.1 INTRODUCTION: MULTIDIMENSIONALITY OF BILINGUAL EXPERIENCE

In recent years, there have been an increasing number of studies about the phonological development of bilingual children, based on the significant expansion of research in the psycholinguistics of bilingualism during the last decades. However, if we go back to initial approaches towards bilingualism, it consisted in assimilating it to complete and "native-like" mastery of two languages (Bloomfield, 1933). According to this "monolingual" approach, the bilingual speaker would thus have a linguistic level comparable to a monolingual in each of his/her languages. Such a definition of bilingualism emphasized the notion of competence and presented the profile of an ideal bilingual not reflecting the reality.

As Grosjean (1998) underlined it, an experienced bilingual is not two monolinguals in one head. Therefore, he described the bilingual in a more holistic approach as an individual using his/her two languages in every-day life for different purposes and with different persons (Grosjean, 1989). This broader view of bilingualism in contrast with the idea of a perfect bilingual allowed for the inclusion of individuals with various levels of proficiency in their two languages. Furthermore, he introduced the notion of "linguistic mode" (1998): depending on the interlocutor, the subject and the type of interaction, a bilingual speaker would more and less activate his/her two languages. The linguistic mode would thus constitute a continuum from a monolingual mode, in which only one language would be activated, to a bilingual mode, in which both languages are activated, with an in-between intermediary mode.

However, in practice, a person is seldom, if ever, to be found at either end of the continuum from monolingual to bilingual mode postulated by Grosjean (1998). Currently, most researchers acknowledge that the process of language production is generally "non-selective" in bilingual adults but there is still controversy about the point at which the selection is finally made (Kroll, Bobb & Wodniecka, 2006). Besides, both languages would necessarily be activated and potentially available for use in whatever situational context – and thus, even in fully monolingual contexts. In that perspective, the two linguistic systems would constantly be in competition in any conversation. Moreover, this acknowledgment of "non-selectivity" implies the following premises: (1) language choice remains conscious, (2) the unselected language must be inhibited in each speech act and (3) talks between familiar bilinguals are characterised by occurrence of code-switching (Myers-Scotton, 1993a, 1993b, 2006).

Then, another important issue is that of a bilingual advantage extending beyond language. Peal and Lambert (1962) were the first to report such an advantage in bilingual children, speaking of a greater "mental flexibility". However, this finding had resulted from a methodological flaw as there was a bias in favour of the bilingual sample. Still, their seminal research marked a turning point, leading to a positive vision of the impact of bilingual experience on cognitive capacities. Much later, Bialystok and her co-workers (2004) demonstrated in numerous studies that bilingual children would have a more advanced inhibitory control compared to age-matched monolingual children (Bialystok &Martin, 2004; Bialystok, 2001). Moreover, this finding of a bilingual advantage in control would be in line with the notion of competition between linguistic codes in bilingual language use. To put it another way, it is the same non-selectivity as found in bilingual adults that would be responsible for the strengthened inhibitory control in bilingual children, most probably through their regular use of two languages with continuous competition between two sets of linguistic exemplars. However, this is in contradiction with the theoretical stance according to which the two languages of bilingual children show "autonomous development" with little or no interaction between them, as will be discussed subsequently.

Finally, it must be noted that bilingualism is a multidimensional experience giving rise to different types of bilinguals characterised by different levels of proficiency. Therefore, numerous typologies of bilingualism have been proposed based on linguistic, cognitive, developmental and social dimensions (Butler & Hakuta, 2004). An opposition is made between early and late bilinguals based on the age of acquisition of each language (Beardsmore, 1986), with early bilinguals acquiring both languages during infancy, possibly simultaneously, whereas late bilinguals acquire their second language at school or later. Another important distinction is made between "balanced bilingualism" and "non-balanced" or "dominant bilingualism" according to the degree of language exposure and use and resulting competence in the two languages (Peal and Lambert, 1962). A balanced bilingual possesses similar skills in his/her two languages, whereas a dominant bilingual presents a higher level of proficiency in one of his/her languages.

In addition, there also exist different types of early bilingualism reflecting the circumstances in which children have experimented a bilingual acquisition of language, as children become bilinguals in different conditions and for different motives such as family, education, immigration and place of residence. Moreover, these different types would depend on factors such as the parent's mother tongue(s), the language(s) spoken at home *vs*. in the community or school, as well as the strategy used by parents to talk to their children. Indeed, parents can use the strategy "One person-one language" (Ronjat, 1913) – i.e., parents keep languages separate by addressing the child in only one language – or the strategy "one context-one language" – i.e., each language is used in a specific context. Besides, another possibility is that both parents speak the same language and the child is exposed to another language in a day-care centre or later, at school. Finally, the child's degree of bilingualism can also be affected by other factors, such as parents' education level and expectations. The bilingual experience is thus complex and children often differ in several aspects.

The next sub-sections are devoted to an overview of research investigating phonetic-phonological development of bilingual children, including both speech perception and speech production studies. However, as our study focuses on the development of production skills in bilingual toddlers, speech production studies will be more extensively discussed.

I.2.2 SPEECH PERCEPTION

I.2.2.1 Language differentiation and early discrimination abilities

Distinguishing between the two languages and building separate representations is paramount to bilingual acquisition. As previously mentioned, monolingual newborns are able to differentiate languages belonging to different rhythm classes (Mehler et al., 1988; Nazzi et al., 1998). Bilingual infants were therefore supposed to discriminate their languages from early on, at least those involving a different underlying rhythmic unit. This was demonstrated in a study conducted by Byers-Heinlein, Burns and Werker (2010) involving English (stress-timed language), Tagalog and Chinese (syllable-timed languages). Indeed, English monolingual newborns showed only interest in the language to which they had prenatally been exposed, whereas bilinguals, either English-Tagalog or English-Chinese, listened equally to both their languages.

Logically, the same question arose for languages belonging to the same rhythmic class, assumed to be more difficult to differentiate for the bilingual child, which could possibly lead to later discrimination and potential cross-linguistic interference. Pioneer study by Bosch and Sebastián-Gallés (1997) compared 4 months-old monolingual and bilingual infants exposed to either Catalan or Spanish or to both languages in their ability to discriminate between similar and distant familiar and unfamiliar language. Practically, they presented speech samples in similar languages (Catalan-Spanish)[15] as well as in a distant language, English (stress-timed), for which discrimination was supposed to be easier. They measured infants' visual orientation times; that is, the time from the start of the audio stimuli to the visual orientation to the sound source. When presented with samples from native *vs.* non-native language, infants should react faster to their maternal language. Results showed that monolinguals were able to distinguish their native language from both an unfamiliar distant (English) and a close (either Catalan or Spanish) language. When tested with both their native languages, bilinguals showed no difference in their reactions but unexpectedly, they responded with increased latencies toward their maternal language than toward English. The authors assumed that the method measured recognition and not familiarity with the language and that bilinguals reacted slower because their recognition process take more time than monolinguals as they have to choose between their two languages. In a follow-up study with the same population using a familiarization-reference procedure (Bosch and Sebastián-Gallés, 2001), no differences were found among monolingual and bilingual infants' abilities to discriminate Spanish from Catalan at four months of age, showing evidence of early language discrimination in simultaneous bilingual exposure.

Another important issue investigated is the bilingual impact on the perception of native contrasts and the building of phonemic categories. To recall, young monolingual infants can initially discriminate any phonetic contrasts, regardless of their language. Then, they exhibit a decline in sensitivity to non-native contrasts and increased sensitivity to native speech sounds during their first year of life. This pattern of perception narrowing lead to questioning the development of native language phonetic representations in children exposed to more than one language. Again, the first studies addressing this issue were led by Bosch and Sebastián-Gallés (2003a; 2003b). They compared 4-, 8- and 12-months old Catalan-Spanish bilinguals to both Catalan and Spanish age-matched monolinguals on their abilities to discriminate the vowel contrast /e/ - /ɛ/, present only in Catalan. As expected, all 4-months old infants were able to perceive the contrast. However, at 8 months, only Catalan monolinguals were successful at the task. Bilinguals regain the ability to discriminate the speech contrast by 12 months. This study showed an unexpected U-shaped developmental pattern in bilinguals, from an early sensitivity to all contrast to a temporal decline around 8 months and finally, recovery of discrimination abilities around 12 months. The authors hypothesized that bilinguals could be confused due to the presence of similar sounding vowels in their two languages, which could result in an overcrowded perceptual vowel space and overlapping distributions of some of the phonetic properties of the vowels.

Relying on neurophysiological measures, Garcia-sierra and collaborators conducted a longitudinal study with English-Spanish bilingual infants, using event-related potentials (ERP) to assess early discriminative reactions to phonetic contrasts by means of the mismatch negativity (Garcia-Sierra et al., 2011). They used three CV syllables, differing in voice-onset time: the voiced

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[15] Catalan and Spanish are considered as close for they are rhythmically (both syllable-timed) and phonologically similar.

/da/ phonemic in Spanish only, the voiceless unaspirated alveolar consonant common to both languages heard as /ta/ in Spanish and as /da/ in English, and the voiceless aspirated /ta/ phonemic in English only. Bilingual brain measures revealed no discrimination of the contrast in either Spanish or in English at 6-9 months but by 10-12 months of age. These results indicate different perceptual patterns in monolingual and bilingual infants, as monolingual studies using the same method (Rivera-Gaxiola, Silva-Pereyra & Kuhl, 2005) exhibited neural discrimination for both native and non-native contrasts at 7 months and only for the native contrast by 11 months of age. The authors suggested that bilinguals may remain more open to language experience and become neurally "committed" to their native languages later in order to adapt to the greater variability characteristic of their language input. Taken together, results from studies by Bosch and Sebastián-Gallés (2003a and 2003) and Garcia-Sierra et al., (2011) suggest a specific development of perceptual reorganization in pre-linguistic bilingual infants and that different processes could underlie monolingual *vs.* bilingual phoneme category formation.

However, other investigations yielded contrasting results. Burns and collaborators found similar discrimination abilities in English-French bilinguals and English monolinguals tested on a French and an English voice onset time distinction (Burns, Yoshida, Hill & Werker, 2007). Indeed, 6- to 8-month-olds responded similarly irrespective of language environment and by 10–12 months of age, the two groups of infants displayed language-specific perceptual abilities. Similarly, Sundara and colleagues demonstrated that English-French bilinguals and French monolinguals aged 6 to 8 months were able to distinguish a French /d/ (dental place of articulation) from an English /d/ (alveolar place of articulation) and that only bilinguals were able to do so at 10-12 months (Sundara, Polka & Molnar, 2008). In addition, Albareda-castellot et al. (2011) tested again Catalan-Spanish bilinguals and their monolingual peers on the vowel contrast /e/ - /ɛ/ using an anticipatory eye movement paradigm. Their results demonstrated that bilinguals were as able as monolinguals to discriminate this contrast at 8 months. They attributed the opposite results from the previous studies (Bosch and Sebastián-Gallés, 2003a, 2003b) to both the familiarization-preference procedure and the high rate of cognates[16] shared by these specific languages.

In sum, these three last investigations suggest that bilinguals could keep pace with their monolingual peers and that the development of phonetic representation is neither delayed nor compromised by additional languages. However, given the mixed results from the different studies mentioned, it appears that no conclusive evidence has yet been reached about the existence of differences in the development of monolingual and bilingual infant's early abilities to discriminate early phonetic contrasts. Bilingual infants might be slower than monolinguals to develop phonological representations stable enough to perceive a change for certain contrasts, possibly due to reduced exposure to phonetic categories and to the more complex and variable linguistic input they have to process.

[16] Cognates are translation equivalents with full or partial form overlap, e.g., Dutch-English: sport-sport (Dijkstra, Miwa, Brummelhuis, Sappelli & Baayen, 2010).

I.2.2.2 Early lexical processing and word learning

Few studies have investigated bilingual toddlers' knowledge of the phonological forms of word. In a study of word recognition using a preferential looking procedure (Ramon-Casas, Swingley, Sebastián-Gallés & Bosch, 2009), Spanish-Catalan bilinguals aged between 17 and 27 months were able to detect vowel mispronunciations in cognate words forms in their two languages when it involved vowels present in both their languages (/i/ - /a/) but not when it involved a contrast present only in Catalan (/e/ - /ɛ/). Older bilingual children aged 31 to 50 months were also tested both with the same procedure and contrast (/e/ - /ɛ/) and only the Catalan-dominant detected the mispronunciation. The authors suggested that bilingual children whose two languages contain phonetically overlapping vowel categories may not treat those categories as separate in language comprehension. However, both the specific contrast and the use of cognates would make this discrimination particularly difficult.

Using ERP techniques to examine word development, a study led by Conboy and Mills (2005) showed that English-Spanish bilinguals aged from 19 to 22 months display less mature brain responses than those of same-aged monolinguals. ERPs to known *vs.* unknown Spanish and English words were measured as well as the sizes of children's expressive vocabulary in both Spanish and English in order to determine language dominance for each child. Brain measures appeared to depend both on language dominance and size of the vocabulary. More precisely, bilingual toddlers with higher vocabulary scores, like monolinguals with larger vocabularies, showed more effects of known *vs.* unknown words at shorter latencies, especially for their dominant languages. The authors assumed that the bilingual learning environment may give rise to patterns of neural activity that are qualitatively different from those found in monolingual development and that their results could be explained in terms of the reduced exposure to each language that bilinguals experience.

Then, Fennell, Byers-Heinlein and Werker (2007) assessed the ability to learn minimally different words (such as "bih" and "dih") in bilingual toddlers aged from 14 to 20 months, replicating a study lead by Werker, Fennell, Corcoran and Stager (2002) with monolinguals. Werker et al. (2002) had demonstrated that monolingual English toddlers successfully learn similar-sounding words from the age of 17 months. They used the same Switch-task in which minimal-pairs non-words are taught as labels for novel objects. They found that bilinguals begin to learn similar-sounding words from 20 months of age. Possibly, bilingual children might start to use relevant language sounds – that is, consonants – to direct novel word learning later than monolinguals due to the increased cognitive load of learning two languages. However, this apparent developmental delay could instead be the result of maintaining certain degree of flexibility adaptive for bilingual word learning. Besides, Mattock, Polka, Rvachew and Krehm (2010) found that English-French bilingual toddlers of 17 months of age accommodate phonetic variation better than age-matched monolinguals in a study similarly using a switch procedure to compare bilinguals and monolinguals in their ability to learn new words.

In sum, the studies just described demonstrate the complexity of lexical processing in bilingual children. They showed evidence that the building of stable lexical representations proves to be challenging for bilinguals and that their robustness would depend both on the patterns of exposure and language dominance as well as on the type of contrast (for example, vowel *vs.* consonantal differences) involved in the stimuli. Moreover, the various findings also highlight the considerable variability in language acquisition. We now move to the next section devoted to bilingual studies of speech acquisition.

I.2.3 Speech production

Far more numerous than those addressing speech perception, studies targeting speech production in bilingual children have generally been intended at assessing the qualitative and quantitative differences between bilingual and monolingual children. Besides, most studies have been underpinned by the key issue of "language differentiation"; that is, the question of whether children exposed to two languages initially use a single system or develop two separate systems from the start. First studies were not centred on phonology but rather on morphosyntactic, lexical or pragmatic development. In their framework, language differentiation in bilingual children involved, on the one hand, differentiation of their two languages' representations – the underlying competence in the Chomskyian sense – and on the other hand, pragmatic differentiation of the two languages' use – the actual linguistic performance.

These early studies about simultaneous bilingualism postulated that children go through an initial developmental stage in which the two systems are mentally merged into a single one to subsequently develop into two discrete systems, first lexically then syntactically, by 3 years of age. The investigation carried out by Volterra and Taeschner (1978) involving the observation of three bilingual children during interactions with their parents (who claimed to follow the principle "One person – one language" of Ronjat, 1913) suggested indeed that bilingual children do not initially differentiate their languages and start with a "unitary system" separating into two systems around 3 years. Therefore, occurrence of language mixing during early stages of bilingual language acquisition was interpreted as a lack of language differentiation and subsequent decline of language mixing as a consequence of emerging pragmatic language differentiation (Köppe, 1996). Despite the fact that bilingual adults also mix their languages while differentiating them, child and adult language mixing were nevertheless considered in totally different ways. Indeed, adult language mixing, labelled as "code-switching", was considered as a sophisticated pragmatic skill governed by syntactic and sociolinguistic rules, whereas child language mixing, labelled as "code-mixing", was thought to exhibit lack of systematicity and not to follow any linguistic rules (Genesee, 1989). It was thus commonly thought that simultaneous exposure to more than one language would lead to some confusion in the early stages. However, many authors subsequently refuted this Unitary language system hypothesis, arguing that children could differentiate their languages from the earliest stages of their development as toddlers seem to be aware of their two languages and to know which one to use according to the interlocutor's identity and specific context.

Regarding phonetic-phonological development, different hypotheses have been postulated about the degree of language differentiation and the nature of early representation, as explained in the next sub-sections. Moreover, this question has been addressed through the investigation of different speech structures, whether segmental and/or supra-segmental, and the use of various measures targeting, amongst others, children's speech sound inventories and/or the degree of accuracy and complexity of early productions. Then, despite the fact that there has been an increasing number of research assessing phonetic and phonological abilities in bilingual children in the last two to three decades, no general conclusions have yet been reached as studies have for long mainly consisted in (observational) case studies. In addition, they also differed with respect to their theoretical framework. Table 1 incorporates the bilingual speech production studies to be mentioned in this section and summarizes the following information: (1) sample involved, (2) structure(s) targeted, (3) method and analyses conducted and (4), results-findings. Studies are subsequently discussed according to the nature of bilingual phonological representation they imply.

References	Sample	Structure(s) investigated	Method - Analyses	Results - Findings
Vogel (1975)	1 English-Romanian bilingual, age=2;0	Segments and syllables structures, phonological processes in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of segmental inventories and phonological processes/error patterns.	Similar phonological processes in both languages – Unitary system
Ingram (1981)	1 English-Italian bilingual, age=2;0	Segments, word lengths and syllable structures in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of segmental inventories, word lengths and syllable structures.	Dissimilarities in syllable structures and word shapes – Separate systems
Schnitzer & Krasinski (1994)	1 English-Spanish bilingual, age=1;1 to 3;9	Segments - consonants and vowels in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of segmental production, focus on context, regression and interference.	Separate phonemes for the two languages at about 2;3 years – Unitary system
Schnitzer & Krasinski (1996)	1 English-Spanish bilingual, age=1;6 to 4;6	Segments - consonants and vowels in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of segmental production, focus on context, regression and interference.	No phenomena of interference between the two phonological systems – Separate systems
Johnson & Lancaster (1998)	1 English-Norwegian bilingual, age=1;2 to 1;11	Segments and word forms/types in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of segmental inventories and word types.	Larger number of consonants in both languages – Acceleration
Kehoe (2002)	3 German-Spanish bilinguals, age=1;0 to 3;0	Vowel production in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of vowel duration.	Vowel length contrast acquired later in German later – Delay
Khattab (2002)	3 English-Arabic bilinguals, 3 English- and 3 Arabic-speaking monolinguals, age=5;0-7;0-10;0	Liquid /l/ in both languages	Single-word samples elicited via word-naming task. Auditory and acoustic analyses.	Separate /l/ production patterns – Autonomy
Keshavarz & Ingram (2002)	1 English-Farsi bilingual, age=0;8 to 1;8	Segments, stress patterns, syllable structure in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of segmental inventories, stress patterns, syllable structures and phonological processes (substitutions).	Transfer of stress patterns
Lleó, Kuchenbrandt, Kehoe & Trujillo (2003)	5 German-Spanish bilinguals, 3 German- and 3 Spanish-speaking monolinguals, age=1;1 to 2;3	Final codas in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of codas productions (segments, number-rates), percentages of mono/di/trisyllabic words, calculation of PMLU.	Faster acquisition of Spanish word-final codas – Acceleration
Kehoe & Lleó (2003)	3 German-Spanish bilinguals, 3 German- and 2 Spanish-speaking monolinguals, age=1;0 to 3;0	Final codas in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of codas productions (segments, number-rates), percentages of mono/di/trisyllabic words, calculation of PMLU.	Faster acquisition of Spanish word-final codas – Acceleration

References	Sample	Structure(s) investigated	Method - Analyses	Results - Findings
Brulard & Carr (2003)	1 English-French bilingual child, age=1;8 to 2;6	Phonological patterns and word templates in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of phonological patterns (consonant harmony and reduplication), iambic stress contour and word templates.	Distinct phonological patterns in each language – Autonomy
Kehoe, Lleó & Rakow (2004)	4 German-Spanish bilingual children, age=1;0/1;3–3;0	VOT values in both languages	Acoustic analyses of VOT patterns based on word-initial stops.	Slower acquisition of long lag stops in German – Delay Transfer
Gildersleeve-Neumann, Kester, Davis & Peña (2008)	20 English-Spanish bilinguals (English-dominant and balanced) and10 English-speaking monolinguals, age= 3 ;0 to 4 ;0	English segments, consonantal clusters and syllable structures	Single-word samples elicited via word-naming task. Analyses of segmental inventory (initial-medial-final consonant singletons and clusters), phoneme accuracy (PCC-PVC), syllable structures and word types and error patterns.	Slower acquisition of codas and consonants clusters – Deceleration Productions of Spanish phonemes in English – Transfer
Gildersleeve-Neumann & Wright (2010)	14 English-Russian bilinguals, 28 English-speaking monolinguals, age=3;3 to 5;7	English segments, consonantal clusters, syllable structure and word types	Single-word samples elicited via word-naming task. Analyses of segmental inventory, phonetic complexity, phoneme accuracy (PCC-PVC) and error patterns.	Higher error rates – Deceleration Productions of Russian-influenced consonants in English – Transfer
Lin & Johnson (2010)	35 sequential English-Mandarin bilinguals, 23 Mandarin-speaking monolinguals, age=4 ;0 to 5 ;0	Segments of the two languages, phonological processes, English stress patterns	Single-word samples elicited via articulation tests. Analyses of phoneme accuracy (PCC and PVC), phonological processes and Mandarin-influenced English stress patterns.	Mandarin-influenced English phonological processes – Transfer
Fabiano-Smith & Barlow (2010)	8 English-Spanish bilinguals, 8 English- and 8 Spanish-speaking monolinguals, age=3 ;0 to 4 ;0	Consonants of both languages	Single-word samples elicited via the *Bilingual English-Spanish Assessmen*t (Peña et al., 2018). Analyses of segmental inventories, classification along complexity levels.	Bi-directional transfer in the phonetic inventories
Fabiano-Smith & Goldstein (2010)	8 English-Spanish bilinguals, 8 English- and 8 Spanish-speaking monolinguals, age=3 ;0 – 4 ;0	Consonants in both languages	Single-word samples elicited via the *Bilingual English-Spanish Assessmen*t (Peña et al., 2018). Analyses of segmental inventories, consonant accuracy, substitution processes, phonological transfer.	Overall lower consonant accuracy Deceleration and bi-directional transfer
MacLeod, Laukys & Rvachew (2011)	21 English–French bilinguals, 19 English-speaking monolinguals, age=1;6 to 3;0	Consonants and word forms in English	Spontaneous speech and single-word samples elicited via word-naming task. Analyses of consonant accuracy (PCC), whole-word proximity (PMLU, PWP and PWC).	No differences between English-French bilinguals and English-speaking monolinguals – Autonomy

References	Sample	Structure(s) investigated	Method - Analyses	Results - Findings
Almeida (2011)	1 Portuguese-French bilingual, age=1;0 to 3;10	Simple and branching onsets, medial codas and final consonants in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of production patterns by manner classes, phonological processes.	Faster acquisition of branching onsets in Portuguese – Acceleration Slower acquisition of codas in French - Deceleration No CLI for the acquisition of singleton onsets and word-final consonants – Autonomy
Kehoe, Lleó & Rakow (2011)	6 German-Spanish bilinguals, 3 German- and 3 Spanish-speaking monolinguals, age=3;0	Speech rhythmic patterns in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of speech rhythmic patterns via rhythmic metrics.	Merging pattern
Goldstein & Bunta (2012)	10 English-Spanish bilinguals, 10 English- and 10 Spanish-speaking monolinguals, age= 5;10 - 6;10	Segments and word forms in both languages	Single-word samples elicited via the *Bilingual English-Spanish Assessmen*t (Peña et al., 2018). Analyses of phoneme accuracy (PVC and PCC), whole-word proximity (PMLU and PWP) and phonological processes	Better results for whole-word and segmental measures and lower frequency of phonological processes – Acceleration
Fabiano-Smith & Bunta (2012)	8 English-Spanish bilinguals, 8 English- and 8 Spanish-speaking monolinguals, age=3;0	VOT values in both languages	Single-word samples elicited via word-naming task. Acoustic analyses of VOT patterns.	Slower acquisition of long lag VOT in English – Deceleration
Mok. (2013)	5 English-Cantonese bilinguals, 5 English- and 5 Cantonese-speaking monolinguals, age=2,6.	Speech rhythm patterns in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of speech rhythmic patterns via rhythmic metrics, syllable structure and lexical stress.	Merging pattern
Ezeizabarrena, Alegria & Perpiñán (2015)	1 Basque-Spanish bilingual, age=1;9 to 2;1	Medial and final codas in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of coda productions and phonological processes.	Inter-linguistic differences in coda position – Autonomy
Tamburelli, Sanoudaki, Jones & Sowinska (2015)	16 English-Polish bilinguals, 16 English-speaking monolinguals, age=7;1 – 8;11	Consonantal clusters of different types and in different positions	Single-word samples elicited via non-word repetition task. Analyses of cluster productions, percentages of correct productions.	Faster acquisition of word-initial clusters in English – Acceleration
Yang, Fox & Jacewicz (2015)	1 English-Mandarin emergent bilingual, age=3;7 to 5;3	Vowel systems of both languages	Single-word samples elicited via word-naming task. Acoustic analyses of F1-F2 frequencies and vowel space areas	Deflecting pattern

References	Sample	Structure(s) investigated	Method - Analyses	Results - Findings
Kehoe (2018)	4 German-Spanish bilinguals, 5 German- and 3 Spanish-speaking monolinguals, age=1;9 to 3;0	Rhotics /r/ in both languages	Longitudinal recordings of spontaneous speech samples. Analyses of /r/ productions in different phonological environments.	Faster acquisition in Spanish – Acceleration Slower acquisition of /r/ within branching onsets in German – Deceleration Spanish alveolar taps produced in German branching onsets - Transfer
Keffala, Barlow & Rose (2018)	10 English-Spanish bilinguals, 5 Spanish- and 12 English-speaking monolinguals, ages=2;1–4;10	Singleton medial and final codas and initial and medial onset clusters in both languages	Single-word samples elicited via the *Assessment of English/Spanish Phonology* (Barlow, 2003b; 2003c), the *Shorter Protocol for the Evaluation of English Phonotactics* (Barlow, 2012). Analyses of singleton coda and onset cluster accuracy, phonological processes.	Faster acquisition of: (1) singleton codas in Spanish and (2), onset clusters in both Spanish and English - Acceleration
Kehoe & Havy (2019)	23 French-speaking bilinguals (with different language pairs) and 17 French-speaking monolinguals, aged=2,6	Segments, palatal fricatives /ʃ, ʒ/, word-final codas, obstruent-liquid word-initial clusters	Single-word speech samples elicited via word-naming task. Analyses of phoneme accuracy (PVC and PCC), word-final coda and word-initial cluster productions.	Higher accuracy of consonants, codas and clusters productions - Acceleration

Table 1: Characteristics of sample, structure(s) of investigation, method-analyses and results from the bilingual speech production studies discussed in the section.

I.2.3.1 Early studies – the Unitary or single system

The first study about bilingual phonological development falling within the language differentiation issue was conducted by Vogel (1975). Her study involved a single 2-year-old participant raised bilingually in English and Romanian. She conducted a phonological analysis of the child's spontaneous speech and compared phonological processes applied in the two languages[17]. The analyses revealed that by age two, the child was using sounds in a non-specific manner and that she used similar phonological processes in both languages. Indeed, the child used long-lag – or voiceless aspirated – stops characteristic of English, alveolar English and dental Romanian stops in both English and Romanian words. In addition, her productions involved final consonant deletion and truncation of unstressed initial syllables in either language. Since the same phenomena were shown to occur both in English and in Romanian, the author concluded that at age 2, the two languages are being processed through a single system. The hypothesis of separate systems was thus rejected, based on the idea that separate systems should involve the use of specific phonetic patterns and processes in each language.

Schnitzer and Krasinski (1994, 1996) also questioned the existence of a unitary system in bilingual children in two investigations focusing on the development of phonemic repertoire. More precisely, they assessed the production of both consonants and vowels in two English-Spanish siblings (aged from 1;6 to 4;6) in the frame of a three-year longitudinal diary study. They investigated each phoneme and took context into account. The first study yielded confusing results. Indeed, production of consonants was shown to be instable and not following a linear developmental path. Moreover, the child began to produce separate phonemes for each language at about 2;3 years of age. Vowel production was characterised by even more variability. Based on consonant development, the authors hypothesized that the child evolved with a single system until about 2;3 and achieved clear separation between the two languages only by 2;7. However, they could not reach a conclusion regarding vowel development. Interestingly, the child observed in the second study appeared to follow a totally different production strategy, as he seemed to avoid uttering sounds that he did not yet master. In addition, that child used English sounds in English words and Spanish sounds in Spanish words and no phenomena of interference between the two phonological systems was observed. Therefore, these findings were considered as consistent with the idea that two systems could be present from the start.

I.2.3.2 Separate/dual systems from the start

Increasing evidence that bilingual children are able to separate their languages from the very beginning of language production initially came from findings of studies about early pragmatic, lexical and morphosyntactic development (Meisel, 1989; Lanza, 1992; Genesee, Nicoladis & Paradis, 1995). Indeed, data from phonological acquisition studies were still scarce at that time. The hypothesis of separate systems for the two languages implies the idea that the bilingual child is learning his/her two languages as a monolingual and would therefore display a comparable acquisition order of phonological structures as well as similar phonological patterns as monolinguals for each of his/her languages. Distinct developmental paths/patterns are thus expected in each language of the child.

[17]In particular, she examined sound inventories, substitution and deletion patterns.

One of the first study to suggest that bilingual toddlers might have differentiated phonologies was conducted by Ingram (1981) and involved the analyses of segmental inventories, word lengths and syllable structures of an English-Italian bilingual aged 2. If results indicated similar segmental inventories for both languages, it also showed dissimilarities in syllable structures and word shapes. Indeed, words produced in Italian were multisyllabic and involved open syllables, whereas words in English were generally monosyllabic CVC forms. Based on these contrasts, Ingram stated that the child was using two separate systems in her phonological development. Then, as just mentioned in the previous point, Schnitzer and Krasinski (1996) also obtained results pointing towards the hypothesis of separate systems from the earliest period in their second study about segmental development.

Also arguing for the hypothesis of differentiated systems, Johnson and Lancaster (1998) assessed the production of lexical forms and speech sounds in an English-Norwegian bilingual aged 1;9, whose parents had followed the rule « one parent-one language ». Based on audio-recordings of the child in separated linguistic contexts, they established a list of word types produced by the child. Their analyses demonstrated that the child did not treat his two languages as a unified language system as he chose the right language depending on the specific interlocutor and maintained this distinction in several aspects of production. Indeed, the child showed a preference for monosyllabic words involving coda[18] consonants in English and disyllabic words in Norwegian. This study's results were thus also in line with the idea of an early language differentiation. However, it also uncovered specific aspects of bilingual phonological development as the child's phonetic inventories differed from those of both English and Norwegian age-matched monolinguals (this issue is returned to in the next section). Separation between the two systems was demonstrated perhaps more obviously in the study led by Brulard and Carr (2003) in which they longitudinally investigated phonological patterns and word templates in their English-French bilingual child aged from 1;8 to 2;6. Their results revealed distinct patterns in each language. More precisely, reduplications of CVCV structures were present exclusively in the child's first productions in French and consonant harmony of place affected only English words with codas.

Finally, Keshavarz and Ingram (2002) longitudinally assessed phonological acquisition in a Farsi-English bilingual child whose exposure pattern had changed during development. Indeed, the child had been predominantly exposed to Farsi during his first 15 months and English later became the dominant language in the input. Results showed that the child used preponderantly monosyllabic words in English and multisyllabic words in Farsi. He also appeared to transfer Farsi stress patterns to his first English word productions as Farsi initially was his dominant language. Once his language dominance had subsequently shifted to English, language-specific stress patterns start being observed: the child used trochaic pattern for English words and iambic pattern for Farsi words. However, he also began to produce English vowels in Farsi, a phenomenon considered to reflect English dominance in the later period of development. The authors concluded that the child was acquiring two separate systems but that (low) interference could occur between the two phonological systems.

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[18]As a hierarchically organised structure, the syllable can be divided into two constituents: onset and rhyme. Rhyme, in its turn, is sub-divided into a nucleus and a coda.

Even if results from these different studies suggested that the two phonological systems are initially separated, they did not necessarily imply that they develop independently of each other. In fact, many investigations produced mixed results – such these of Johnson and Lancaster (1998) and Keshavarz and Ingram (2002) – and suggested mutual influence between the two systems in the course of acquisition. It became thus clear that it was necessary to go beyond the question of "one system *vs.* two" and that neither the hypothesis of a unitary/single system nor that of totally separate systems were appropriate to describe bilingual phonological development (and more globally, language acquisition). Instead, another approach progressively emerged, whereby both separation and interaction between the systems are likely to occur.

I.2.3.3 Separate systems with interactions – the interdependence hypothesis

A large number of studies have highlighted the presence of discrepancies between monolingual and bilingual speech production patterns and rates of development as well as mutual influence between certain phonological features of bilinguals' systems, leading to the hypothesis that bilingual children develop autonomous but interacting phonological systems. This interaction between the two linguistic systems is referred to as cross-linguistic interaction (from now on, CLI). This hypothesis of CLI (or interdependence between the systems) was first introduced by Paradis and Genesee's (1996) for grammatical development. They defined it as a systemic influence of one grammar on the other. According to them, CLI can potentially manifest itself through three phenomena:

- Acceleration: a certain grammatical property is emerging earlier than expected in one language in comparison to monolingual acquisition due to its presence in the other language.
- Deceleration: the acquisition process is slower than that of monolinguals, possibly due to the burden of the dual language acquisition.
- Transfer: a grammatical property of one language is incorporated into the other. It is likely to occur when the child has a more advanced level in one of his/her language or, in other words, likely to occur from the dominant language to the less dominant.

Those hypotheses have been subsequently taken over by Keshavarz and Ingram (2002) and reformulated for phonological development. In this perspective, phenomena of acceleration and deceleration (also referred to as delay by Fabiano-smith and Goldstein, 2010) could result from constraints specific to each language that would ease or impede the acquisition of certain phonological structures in the other language. Transfer would consist in the transposition of phonological structure(s) specific to one language (generally, the dominant language) in the other language in which this/these structure(s) is/are absent[19]. Besides, the occurrence and directionality of these interaction effects would depend as much on the degree of exposure to each language (language dominance) as on the specific typological properties of each language and the degree of similarity between the two phonological systems.

There are also cases where no interaction between the two system – and consequently, no differences between bilinguals and monolinguals – has been found. Those cases can be referred to as autonomy between the two systems (or autonomous development). In addition, Kehoe has identified two other interaction patterns also occurring in early bilingualism labelled as "merging" and

[19]The term transfer has also been used in a more general way to refer to CLI and labelled either as positive (acceleration) or negative (deceleration) transfer.

“deflecting” patterns (Kehoe, 2015). These specific patterns cannot be slotted into existing categories of CLI as they capture the notion of contrast absent from the original proposal of Paradis and Genesee (1996). A merging pattern is observed when bilingual children display similar phonological patterns in their two languages as if they would be reducing the contrast between the two systems. As stated by the authors, merging would reflect a “pooling of phonetic and phonological resources rather than a lack of differentiation between the two phonetic systems” (Kehoe, 2015: 150). On the contrary, a deflecting pattern translates into the exaggeration of an existing contrast (or even in the creation of a new contrast) in order to “avoid a crowded phonetic space” (Kehoe, 2015: 163) and to maintain languages well separated.

We review examples of these different types of CLI found in the literature in the subsequent sub-sections, including: acceleration, deceleration, transfer, autonomy, merging and deflecting patterns. In each sub-section, we follow an order of presentation of the studies, going from segmental to supra-segmental level. As certain studies have yielded mixed results – that is, have shown co-occurrence of different types of CLI – they will appear in the different sub-sections.

I.2.3.3.1 Acceleration

A number of studies have demonstrated that early/simultaneous bilingualism can accelerate phonological development in speech production in comparison to a monolingual context of acquisition, for both segmental and syllabic structures. As previously mentioned, Johnson and Lancaster (1998) investigated speech sounds and word forms production in the two languages of an English-Norwegian bilingual aged 1;9. If their results demonstrated that the child was developing two separate systems, they also revealed that his productions involve a usually large number of consonants in comparison to monolinguals of either language. More precisely, the child being observed produced affricates and alveo-palatal fricatives in English and retroflex consonants in Norwegian. The authors concluded that the child followed a different developmental path than monolinguals of either language as he had already acquired speech sounds emerging only a few months later in monolingual children. Moreover, Johnson and Lancaster (1998) assumed that a higher phonetic sensitivity in each language, in order to keep them distinct, could have led to this earlier segmental development in their bilingual participant. Targeting the development of rhotic consonants in bilingual and monolingual children, Kehoe (2018) collected longitudinal data with German-Spanish bilingual and monolingual toddlers of either language aged from 1;9 to 3;6. Spanish has two rhotics: a voiced alveolar tap [ɾ] and a voiced alveolar trill [r]. On the contrary, German has only one rhotic: a voiced uvular approximant [ʁ̞]. Kehoe examined realizations of the German /r/ in two phonological environments (branching/complex[20] and simple onsets) and of the Spanish /r/ in four phonological environments (the tap in branching onsets and word-medial position, the trill in word-initial and word-medial positions). The bilingual children were shown to be more advanced in their acquisition of the Spanish tap and in their production of branching onsets involving /r/ in Spanish as well. However, patterns of deceleration and transfer were also identified (see next points).

Then, two studies examining the acquisition of codas have also demonstrated an acceleration effect of bilingualism (Lleó, Kuchenbrandt, Kehoe & Trujillo, 2003; Kehoe & Lleó, 2003). Both studies included German-Spanish bilinguals and age-matched monolinguals of either language

[20]The term branching/complex onset is used to refer to a consonantal cluster in onset position.

(respectively aged from 1;11 to 2;33 and from 1;11 to 3) and involved longitudinal recordings of children in naturalistic contexts. Lleó et al. (2003) observed that bilingual children produced Spanish codas earlier than Spanish monolinguals and displayed a greater segmental inventory in coda position in Spanish as well. Similarly, Kehoe and Lleó (2003) noted that bilinguals acquired codas in word-final position in Spanish earlier than Spanish monolinguals. German-Spanish bilinguals appeared to follow the same developmental path in coda acquisition as German monolinguals but differed from Spanish monolinguals. These two studies' results indicated a positive influence of German for coda acquisition in Spanish as bilinguals developed codas earlier than monolinguals in Spanish.

In a more clinical approach and focusing on segments and whole-word forms, Goldstein and Bunta (2012) compared the phonological skills of bilingual and monolingual children, taking language use and proficiency into consideration. Their sample involved English-Spanish bilinguals and control monolinguals slightly older (bilingual's mean age: 5;10 – monolingual's mean age: 6;0). Their analyses involved measures of both segmental and whole-word accuracy as well as measures of whole-word complexity[21]. The percentages-of-occurrence of phonological processes was also investigated. Their results indicated that bilinguals outperformed age-matched English-speaking monolinguals on both segmental and whole-word measures and also exhibited lower frequencies-of-occurrence of weak syllable deletion, spirantization and fronting.

An acceleration effect of bilingualism was also found in the acquisition of branching onsets by Almeida (2011) who studied the acquisition of syllabic structure in a Portuguese-French bilingual toddler (aged between 1;0 and 3;10) by focusing, amongst others, on branching onsets in both languages. The results of this longitudinal study showed that bilinguals acquired branching onsets earlier in Portuguese than Portuguese monolinguals (however, deceleration and autonomy patterns were also observed, see next points). Tamburelli and colleagues (2015) similarly found an acceleration effect in the acquisition of word-initial clusters in the English of English-Polish bilingual children. More recently, Keffala, Barlow and Rose (2018) compared accuracy rates of both codas (singleton word-medial and final) and onset clusters (word-initial and medial) in English-Spanish bilingual and monolingual children of either language. More specifically, they examined structural (i.e., the presence of the structure) and positional segmental (i.e., the specific segment used) accuracy. Their results also showed that bilingual children acquired faster singleton codas in Spanish and onset clusters in both Spanish and English in comparison to their monolingual peers[22].

Also dissociating the presence of a structure from its segmental accuracy in their analyses, Kehoe and Havy (2019) found an acceleration effect in the productions of word-final codas and word-initial consonantal clusters as well as in consonant accuracy (as measured by overall PCC). More precisely, they compared French-speaking monolingual and bilingual children aged 2;6. Their design differs from previously mentioned studies as they assessed phonological acquisition only in one

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[21]More precisely, whole-word measures used included phonological mean length of utterance (PMLU) and Proportion of Whole-word Proximity (PWP) and segmental accuracy measures included global percentage of vowels and consonants correct (PVC and PCC) and percentages of consonants correct by manner class (i.e., for different manners of articulation). Precise error patterns were targeted: unstressed syllable deletion, consonant cluster reduction, final and initial consonant deletion, stopping, fronting, final devoicing, and spirantization.

[22]More precisely, bilingual children were more accurate than monolinguals in their productions of: (1) singleton coda segments and structure in Spanish, (2) onset cluster structure in Spanish and onset cluster segments in both languages. However, they were not more accurate than monolinguals in their productions of onset cluster structure in English.

language of the bilingual participants, namely French, and examined potential CLI through the inclusion of a large number of language pairs (in total, 11 language pairs). Furthermore, they examined the impact of a series of factors on bilingual phonological acquisition: frequency and complexity of linguistic structures (considered as language-internal factors), language exposure, socio-economic status and gender (considered as language-external factors) as well as lexical development. Their results indicated that bilinguals whose second native language was characterized by high frequency and high complexity of codas and clusters displayed: (1) a higher coda presence and segmental accuracy and (2), a higher cluster segmental accuracy in comparison to monolinguals. Besides, bilingual children were globally more accurate than monolingual children in their overall consonant production as well as in their productions of codas and clusters. Kehoe and Havy (2019) attributed these discrepancies between bilinguals and monolinguals to a combination of cross-linguistic interaction and a more general bilingual effect. As bilingual children are exposed to a larger variety of sounds and syllable types, they may have a general advantage in phonological production in comparison to monolinguals.

I.2.3.3.2 Deceleration

Cases in which simultaneous/early bilingual acquisition slows down the emergence of a phonological structure in comparison to monolingual acquisition have also been reported in the literature. Kehoe (2002) investigated vowel production in German-Spanish bilingual children in both their languages, in comparison to monolingual children, in order to determine if interaction occur between the two languages. The two languages' vocalic systems quite differ, as German possesses a richer vowel repertoire than Spanish and involves a phonological opposition between short *vs.* long vowels that is absent from the Spanish system. Children were longitudinally audio-recorded in unstructured play situations from the beginning of word production until about 3 years of age. Word productions in both languages were transcribed and acoustically analysed. Bilingual children appeared to acquire the vowel length contrast in German later than their monolingual peers, while acquiring Spanish vowels similarly to monolingual Spanish-speaking children.

Kehoe, Lleó and Rakow (2004) examined VOT values in either language of German-Spanish bilingual children (aged 2;0 to 3;0) and compare them to that of monolingual German children (aged 1;9 to 2;6) and existing literature VOT values for Spanish. German and Spanish also differ by their VOT patterns, as German involves a contrast between long lag *vs.* short lag whereas Spanish has a contrast between short lag *vs.* voicing lead. Consequently, Spanish voiceless stops resemble voiced German stops. Spanish monolinguals generally acquire the voicing contrast later than German monolinguals. A delay was observed in two bilingual children who did not acquire long lag stops in German during the testing period. However, patterns of transfer and autonomy were also found (see the next points). Also focusing on voicing contrast, Fabiano-Smith and Bunta (2012) investigated VOT values of voiceless stops in English-Spanish bilingual and monolingual children. Their results indicated that the bilingual's English VOT values differed significantly from that of their monolingual peers and more particularly, showed a delay in the acquisition of English long lag, suggesting an influence of Spanish. Finally, a small delay in /r/ production within branching onsets in German was found by Kehoe (2018, see previous section).

Also focusing on English-Spanish bilingualism, Fabiano-Smith and Goldstein (2010) compared global consonantal acquisition in the two languages of bilingual children (aged between 3 and 4 years) as well as between bilingual and age-matched monolingual children of either language.

They examined consonant inventories, phoneme accuracy and substitutions patterns. Moreover, they assessed the degree of accuracy of shared *vs* unshared sounds – that is, the sounds common to both languages of the bilinguals or specific to each language – and investigated the predictive effect of sound frequency on the accuracy of shared sounds. Overall consonant accuracy was lower in bilingual children than in monolingual children. Delay was also found in bilingual's acquisition of glides in Spanish and stops in English and the acquisition of fricatives was slowed down in both their languages. Besides, bilinguals displayed higher accuracy for shared sounds but statistical analyses revealed that frequency was not a significant predictor of accuracy of shared sounds.

Targeting segmental and supra-segmental levels, Gildersleeve-Neumann, Kester, Davis and Peña (2008) investigated English phonological development in English-Spanish bilinguals and English monolinguals (age 3 to 4 years) considering the impact of language dominance. Their study similarly involved the analysis of phonetic inventory, phoneme accuracy, error patterns as well as syllable types and word shapes. They found a deceleration effect in the acquisition of codas and consonant clusters in some of their bilingual participants. Moreover, bilinguals also showed higher error rates than English monolinguals, particularly for syllable-level error patterns (such as final-consonant and cluster reduction), and more errors were observed in balanced bilinguals than in English-dominant ones. Using the same methodology, Gildersleeve-Neumann and Wright (2010) also focused on English speech acquisition in 3-to 5-year-old English-Russian bilinguals and English monolinguals. The productions of their bilingual participants were characterized by significantly higher rates of trills' substitution, final devoicing and vowel errors than those of the monolinguals, all phenomena consistent with delay/deceleration. However, their results also uncovered occurrences of transfer between the two systems (see next point).

Finally, a delay in the development of codas was also demonstrated in the previously mentioned longitudinal study assessing the acquisition of syllabic structure in a Portuguese-French bilingual toddler (Almeida, 2011). Indeed, the child acquired French codas later than French-speaking monolinguals, based on what is reported in the literature. Moreover, the child presented the same order of development of codas in his two languages since fricatives appeared first in this position, followed by liquids and then, stops. Similar to the developmental path reported for Portuguese, it is however not the order observed in French acquisition in which all manner classes of consonants would be simultaneously acquired. Therefore, Almeida claimed that coda acquisition is delayed in French due to the influence of Portuguese.

I.2.3.3.3 Transfer

Other investigations have shown that a transposition of certain phonological features can occur from one language to the other and that this influence can be seen either at the segmental, syllabic or prosodic levels. In the pre-cited study about VOT acquisition in bilingual German-Spanish children, Kehoe et al. (2004) not only observed delay but also transfer patterns in their participants. Indeed, one child produced German voiced stops with lead voicing features from Spanish and Spanish voiceless stops with long lag voicing features from German, which indicated a bidirectional transfer of voicing features. Then, rhotics' productions of the very same bilingual child were subsequently analysed (Kehoe, 2018; see previous sub-section) and also revealed a transfer pattern, as the child produced a large number of Spanish alveolar taps in German branching onsets involving /r/. Interestingly, this pattern could not be explained in terms of neither complexity/markedness (as the alveolar tap is not less marked than the uvular German /r/), nor language dominance. As it appeared that the child also displayed transfer of voicing contrast (Kehoe et al., 2004), these phenomena could be interpreted as child-specific production patterns (however, Kehoe proposed an alternate interpretation in terms of merging patterns to be discussed in a subsequent sub-section).

Focusing on global consonant acquisition, Fabiano-Smith and Goldstein (2010) also identified occurrences of bi-directional transfer in English-Spanish bilinguals in parallel to delay (see previous point). However, the rate of these transfer patterns was quite low and children seemed to globally maintain their systems separated. Similarly, Fabiano-Smith and Barlow (2010) examined the level of complexity and typological organization of consonantal inventories across English-Spanish bilinguals' two languages as well as in comparison to those of English and Spanish monolingual children. If phonetic inventories of the bilingual children were shown to be just as complex and organized in the same hierarchical fashion as those of monolinguals, evidence of bi-directional transfer was found in the phonetic inventories. This indicates that even though bilingual children maintain separation for most of their phonological structures, there is a very low level of interaction between their two languages

Other occurrences of segmental transfer have been noted by Gildersleeve-Neumann et al. (2008) and Gildersleeve-Neumann and Wright (2010). As already mentioned, they examined English speech development in respectively English-Spanish (Gildersleeve-Neumann et al., 2008) and English-Russian (Gildersleeve-Neumann & Wright, 2010) bilinguals in comparison to English-speaking monolinguals. Their results indicated productions of Spanish phonemes in English and of Russian-influenced consonants in English, such as palatalized consonants and alveolar trills. Focusing on phonological processes, Lin and Johnson (2010) investigated whether English-Mandarin sequential bilingual and Mandarin-speaking monolingual children (aged 4 or 5 years) would exhibit different production patterns in their two languages. Their results uncovered Mandarin-influenced English phonological processes in bilingual children, such as final consonant deletion or substitution and vowel substitutions. Indeed, errors affecting English word-final or coda consonants could result from the far more restricted set of consonants allowed in this position in Mandarin. Then, as Mandarin includes fewer monophthongs, unfamiliar English vowels would have been more prone to substitution patterns.

I.2.3.3.4 ***Autonomy***

There are also instances in which no interaction between the two phonological systems of the bilingual children could been identified. Investigating the extent to which bilingual children can establish phonetic-phonologically distinct patterns in each language, Khattab (2002) focused on the production of /l/ (in word-initial and final positions) in Lebanese English-Arabic bilingual children (aged 5; 7, and 10 years) and monolinguals of either language. Results showed that for each of their two languages, bilingual children developed separate /l/ production patterns similar to those of monolinguals, reflecting autonomy between their systems. As mentioned previously, Kehoe *et al.* (2004) noted no cross-linguistic influence in the phonetic realizations of voicing of one bilingual child included in their sample (whereas CLI were found in other children, see previous points).

Goldstein and Washington (2001) assessed consonant inventories and accuracy (measured by overall PCC and PCC for manner and place classes) as well as phonological processes in each language of English-Spanish 4-year-old bilinguals and compared it to existing data for English and Spanish monolinguals. They observed different patterns across the bilingual children's two languages as well as between bilinguals and monolinguals of either language, indicating that bilinguals maintain differentiated phonological systems which are both similar to and different from that of monolinguals. Macleod and colleagues focused more particularly on the impact of bilingual language acquisition on segmental accuracy and whole-word complexity (MacLeod, Laukys & Rvachew, 2011). They compared English phonological development in English-French bilingual and English-speaking monolingual children aged between 1;6 and 3;0. Their analyses involved measures of consonant accuracy (PCC) as well as whole-word measures of accuracy and complexity (PMLU, PWP and PWC for Proportion of Whole-word Correctness). Their results showed no significant differences between bilinguals *vs*. monolinguals, at least in bilingual children's dominant language.

In her investigation of the acquisition of syllabic constituents in a Portuguese-French bilingual child (see previous points), Almeida (2011) found no evidence of cross-linguistic interaction for the development of singleton onsets and word-final consonants. Indeed, the child appeared to follow distinct developmental paths for the acquisition of specific consonant features in her two languages and moreover, consonants occurring in these two syllabic positions became stable at different ages, depending on the language[23]. For all these reasons, Almeida hypothesized that the prosodic level of speech might be more prone to CLI than the segmental level. In a similar longitudinal case-study, Ezeizabarrena and collaborators examined early coda production in either language of one Spanish-Basque bilingual child aged from 1;99 to 2;11 (Ezeizabarrena, Alegria & Perpiñán, 2015). As shown by their results, codas were produced early by the child and continued to develop gradually in both languages. Moreover, the child displayed inter-linguistic differences in the inventory of segments in coda position as well as in the frequency of target-like productions. All these patterns suggest an autonomous or language-specific development in codas production and separate phonological representations.

I.2.3.3.5 Other patterns of cross-linguistic interaction

As mentioned above, Kehoe (2015) has proposed two other patterns of cross-linguistic interaction labelled as "merging" and "deflecting" in terms of which results from several studies can be interpreted.

I.2.3.3.5.1 Merging

Kehoe's study (2018) about the acquisition of rhotics showed evidence of both acceleration (in the acquisition of the Spanish tap) and deceleration (in their acquisition of German /r/ branching onsets). She proposed an alternate explanation for these co-occurring phenomena, claiming that there is a bi-directional influence between the bilinguals' languages which results in the two phonologies approximating each other. Indeed, two bilingual children's /r/ productions displayed reduced differences between languages. When acquiring two phonological systems, some bilingual children could thus choose to mitigate the contrast between the phonological categories of their two languages.

Other examples of merging are reported in studies about the development of rhythmic patterns in bilingual children. Mok (2013) examined speech rhythm patterns in English-Cantonese bilingual children in comparison to monolingual children of each language, at 2;6 of age. Cantonese and English have different rhythmic units, as Cantonese is described as a syllable-timed language and English as a stress-timed language. She analysed the children's productions using the metrics

[23] For example, fricatives [s, z] were acquired earlier in French whereas fricatives [ʃ, ʒ] were acquired in Portuguese before becoming stable in French.

proposed by Ramus and co-workers to quantify differences between the children's speech rhythms in each language (Ramus, Nespor & Mehler, 1999)[24]. Results indicated that rhythmic patterns displayed by the bilingual children in their two languages were not very distinct, whereas speech rhythms of age-matched monolinguals were already different. Mok (2013) assumed that, due to mutual influence between their phonological systems, bilingual children follow a particular developmental trajectory and may be "settling on patterns that are in between their two languages » (Mok, 2013: 702). In other words, the intermediate rhythmic patterns observed reflect a phonetic compromise between two extremes (especially with the two target languages involved), consistent with the notion of merging. Similarly, Kehoe and colleagues also found a compromised rhythmic pattern between the two languages of German-Spanish bilinguals aged 3;0 years, as Spanish syllable-timing evolved towards a stress-timed pattern and German stress-timing towards a syllable-timed pattern (Kehoe, Lleó & Rakow, 2011).

I.2.3.3.5.2 Deflecting

Cases in which children exaggerate phonetic contrast between phonological categories of their two languages have also been reported. An example of a deflecting pattern can be found in the longitudinal case study led by Yang and colleagues (2015) which investigated vowel development in an emergent bilingual English-Mandarin toddler. The child was recorded over a period of 20 months, starting at the moment he became exposed to English (L2) at the age of 3;7. They examined his initial vowel space in English and its influence on Mandarin (L1) vowel system, as well as the progressive differentiation between the two systems (L1-L2 separation). The child initially leaned on his L1 to build the English vowel system or in other words, assimilated English vowels to L1 vocalic categories. He subsequently went through a restructuring phase in which he reduced the English vowel space and slightly enlarged the L1 vowel space. The authors interpreted this pattern of phonetic restructuring as a strategy allowing the child to create maximal contrast between his two vowel systems. Ulterior development involved a gradual re-expansion of the reduced English vowel space.

I.2.3.3.6 Predictive/explanatory factors for cross-linguistic interaction

Based on the review of bilingual speech production studies, it appears that different explanatory factors have been invoked by authors to account for the occurrence and directionality of CLI patterns observed in the productions of simultaneous bilingual toddlers. Explanatory factors most frequently addressed involve: (1) language dominance, that is the quantity of input received by the child in his/her two languages, (2) the frequency and (3) the complexity of the phonological structure under investigation within the language and, to a lesser extent, (4) the structural ambiguity of the input. In her review about cross-linguistic interaction in bilingual studies, Kehoe (2015) referred to language dominance as a language-external factor and to frequency, complexity and structural ambiguity as language-internal factors (although she argues that frequency might be considered rather as a language-external factor). Each factor is discussed separately.

I.2.3.3.6.1 Language dominance

Bilingual children rarely get exposed at the same extent to both their languages and very often, one language is predominant in the input they receive. Indeed, balanced bilinguals are certainly

[24] In short, nine different rhythmic metrics were used in order to calculate, amongst others, consonantal and vocalic durations in speech as well as global durational variability of whole utterances.

not the most frequent type of bilinguals. When a child hears and uses more one of his/her languages, it is said that this child has a language/linguistic dominance in this particular language. It is expected that phonological acquisition would progress faster in that language and/or involve a developmental path similar to that of monolingual children. Moreover, the dominant language is likely to have an influence on the less dominant language. Besides, language dominance is likely to evolve or fluctuate during language development along changes in the children's linguistic environment.

Several bilingual studies mentioned above have referred to language dominance to explain the occurrence of cross-linguistic interaction, mainly for cases of transfer but also for delay or autonomy patterns. Instances of both prosodic and segmental transfer observed in Keshavarz and Ingram's study (2002) have been imputed to the child's specific exposure patterns to both languages and potential language dominance in the input. Language dominance has also been referred to in cases of deceleration. Indeed, Gildersleeve-Neumann et al. (2008) considered its impact on English phonological development in English-Spanish bilinguals in comparison to English monolinguals and found particularly more errors patterns in balanced bilinguals than in children with greater exposure to English. Then, Macleod and colleagues observed a similar degree of segmental/whole-word accuracy and complexity in the English productions of monolingual and bilingual English-dominant children, suggesting that bilinguals develop autonomous systems and can keep pace with monolinguals in their dominant language (MacLeod et al., 2011).

However, the degree of exposure to languages could not always account for patterns of cross-linguistic influence in bilingual children. Indeed, results from studies of Almeida (2011) and Kehoe (2018) have contradicted this hypothesis. Having an initial preference for Portuguese, the Portuguese-French child longitudinally studied by Almeida showed no Portuguese influence in her phonological development in French and displayed autonomous segmental development in her two languages. Then, patterns of mutual influence in the acquisition of syllabic structure (French influence allowing faster acquisition of branching onsets in Portuguese and Portuguese influence causing delay in coda acquisition in French) occurred at the same period. Therefore, cross-linguistic influence cannot be the result of dominance, as it would otherwise only have been observed in one direction; namely, from the dominant to the less dominant language. Kehoe (2018) could also not explain the fact that one of the German-Spanish bilingual children of her sample transposed Spanish taps into German branching onsets by advocating to a language dominance effect as the child was German-dominant.

I.2.3.3.6.2 Frequency

The hypothesis of a frequency effect on the occurrence and directionality of cross-linguistic phenomena is based on the premise that children are sensitive to the statistical properties of the ambient language(s) (Saffran et al., 1996) and that the frequency of a phonological structure – whether segments or syllable types – in a given language could predict its order of acquisition. A number of studies have indeed demonstrated that frequent structures are acquired earlier than less frequent ones (Kirk & Demuth, 2003; Zamuner, Gerken, Hammond, 2005)[25]. Then, given that languages differ with respect to their frequently occurring properties, discrepancies in the order of acquisition of these properties can be expected across languages. As such, a particular structure present in two languages

[25]However, some studies have not corroborated this frequency effect on the order of acquisition (Dos Santos, 2007).

but occurring more frequently in one of them will be acquired earlier in that language than in the other language.

The context of bilingual acquisition makes the issue more complex, as children are exposed to two phonological systems possibly sharing more and less structures and characterized by particular phoneme and syllable-type frequencies. In fact, different configurations can be distinguished: (1) a specific structure/property can be present in one language but absent in the other, (2) a specific tructure/property can be present in both languages but have a different frequency of occurrence in each of them (high frequency in one and a low frequency in the other) and (3), a specific structure/property can be present in both languages and have a similar frequency of occurrence in the two languages. As pointed out by Kehoe (2015), the way in which frequency impacts upon phonological development is not yet well determined, as it could ensue from a combination of a specific structure's frequency of occurrence in both languages' (a "pooling of the input", as she terms it) or from the transfer of a frequent structure in one language to the other for which the acquisition of this particular structure is accelerated.

Several authors have discussed frequency as a potential explicative factor for CLI and results of certain studies are in line with the hypothesis of a predictive role of frequency. Indeed, Lleó et al. (2003) and Kehoe and Lleó (2003) both detected a faster acquisition of Spanish codas in German-Spanish bilinguals, as compared to Spanish monolinguals, which they said could be due to the more frequent occurrence of codas in German. However, Lleó et al. (2003) also assumed that bilinguals' exposure to codas of greater complexity in German was responsible for the wider segmental inventory in Spanish codas (see further point). Accordingly, Goldstein and Bunta (2012) suggested that bilingual children's sensitivity to phonological properties common across their two languages resulted in frequent and strongly reliable cues allowing them to be more accurate in their productions and display lower frequencies-of-occurrence of error patterns.

On the other side, frequency was also shown not to be an explanatory factor in other studies. Fabiano-smith and Goldstein (2010) have focused on the frequency effect on consonant acquisition, by comparing segmental accuracy of shared *vs.* unshared sounds. Bilingual children did produce sounds shared by both their languages more accurately. However, frequency was not found to be a statistically significant predictor of the accuracy of shared sounds, leading them to hypothesize that frequency might not be the driving force and that other factors should be considered. Data from Almeida's study (2011) also conflicted with the frequency hypothesis as the sequences involving branching onsets first acquired by the child were those occurring the least frequently in both languages (namely, sequences of ClV[26] type). Besides, Almeida noted that, unlike the results of Lleó et al. (2003) which involved comparable input properties[27], no acceleration effect was found the acquisition of codas in Portuguese whereas a delayed coda acquisition was found in French.

More recently, studies lead by Tamburelli et al. (2015), Keffala et al. (2018) and Kehoe and Havy (2019) also questioned the role of the input's statistical characteristics, as their results did not

[26]ClV sequences involve a consonantal cluster made of a consonant and the liquid /l/ followed by a vowel.
[27]Indeed, similar to the German-Spanish pair, the consonant inventory in coda position is more restricted in Portuguese (only three manner classes: fricatives, laterals and rhotics) than in French (four manner classes: stops, fricatives, laterals and rhotics). Like German-Spanish bilinguals, Almeida's subject had thus been exposed to a wide range of codas through French.

show a straightforward effect of frequency. Indeed, Tamburelli and colleagues (2015) uncovered an acceleration effect in the acquisition of English word-initial s+obstruent consonantal clusters in English-Polish bilinguals, but not in word-medial position. As both word-initial and word-medial clusters are frequently occurring in Polish (and word-medial clusters even more frequently), bilingual children should have outperformed monolinguals on word-medial clusters as well. Then, results from Keffala et al. (2018) indicated a faster acquisition of singleton codas in Spanish and of onset clusters in both Spanish and English in English-Spanish bilingual children. If the accelerated acquisition of singleton codas in Spanish would have been due to their greater frequency of occurrence in English (to which the children were exposed too), a deceleration effect would similarly have been expected to occur in singleton codas acquisition in English, as a result of their lower frequency of occurrence in Spanish. However, delay was not observed and therefore, the authors could not reach a conclusion about the role of frequency. Thus, rather than a frequency effect, Tamburelli et al. (2015) and Keffala et al. (2018) invoked the exposure to patterns of linguistic complexity in each language – or both frequency and complexity factors – to explain acceleration phenomena in their data (see further point). Similarly, Kehoe and Havy (2019) partly attributed the more advanced development in French word-final codas and word-initial clusters to an association of frequency and complexity, given that faster acquisition was found for the bilingual children exposed to L1s involving high frequency and high complexity of both codas and clusters. Also, bilinguals exposed to L1s characterized by low frequency and low complexity codas or clusters obtained lower scores but no delay effect was observed.

I.2.3.3.6.3 Complexity

In the bilingual studies discussed (and as previously noted), the notion of complexity is often conflated with that of markedness, as defined by Jakobson (1968). In that view, structures labelled as complex or marked are those more difficult to produce and consequently, are acquired later than less complex or unmarked structures. Markedness is thus viewed as complexity from a structural or articulatory point of view. However, even if the two notions are linked, they do not equate with each other. Phonological complexity has also been variedly defined depending on the theoretical framework and appears to be multi-faceted, as complexity can lie at different levels of phonological representation, amongst which features, segments and syllables. In most studies previously mentioned, structures considered as complex involve particular segments, consonantal clusters as well as specific syllable types/constituents. As seen from the previous point, several authors have considered complexity as a decisive factor in explaining CLI. In Kehoe's investigation of vowel production in German-Spanish bilingual *vs.* monolingual children (2002), delay occurred in bilinguals' acquisition of the German vocalic system. As it involves a richer vowel inventory and phonemic vowel length distinction, the German vowel system is considered as more marked. Therefore, Kehoe attributed this deceleration phenomenon in the acquisition of the more marked German vowel system to the bilinguals' exposure to the less complex Spanish vowel system. Another example of deceleration explained in terms of markedness is that of the study led by Fabiano-Smith and Bunta (2012) which examined VOT patterns in English-Spanish bilinguals in comparison to monolinguals of either language. Indeed, bilinguals were found to be delayed in their acquisition of English long voicing lag. The authors claimed that this slower acquisition pattern may result from a conflict between the markedness values of the two languages resulting in the persistent use of the less marked feature, that is, short-lag VOT in both languages.

Other studies also referred to the bilinguals' exposure to patterns of linguistic complexity to account for acceleration phenomena. Still focusing on German-Spanish bilinguals, Lleó et al. (2003) attributed the wider segmental inventory observed in Spanish codas to the children's exposure to codas of greater complexity in German. Indeed, the set of consonants allowed in this position is less restricted in German than in Spanish. Similarly, and as mentioned in the previous point, English-Polish bilingual children involved in Tamburelli et al.'s study (2015) were said to have benefited from their exposure to complex word-initial clusters in Polish to produce more accurately less phonologically complex clusters in English. Keffala et al. (2018) attributed the higher accuracy rates in the production of Spanish singleton codas (for both structural and segmental accuracy) and of onset clusters (for structural accuracy in Spanish and segmental accuracy in both languages) to the fact that their English-Spanish bilingual participants had been exposed to various types of complexity in each of their languages. More precisely, the exposure to greater structural complexity in English codas accelerated the bilingual's acquisition of Spanish singleton codas in comparison to monolinguals. Indeed, English permits complex codas (i.e., consonant sequences in coda position) and permits a wide range of segmental combinations. Then, the bilingual's acquisition of Spanish branching onset structure and segments was eased by their exposure to increased structural complexity in English branching onsets, while being exposed to smaller sonority differences in Spanish branching onsets fostered their acquisition of English branching onset segments. Indeed, English and Spanish differ by their cluster complexity. English complexity lies at the structural level, as two or three-elements clusters are to be found in English, whereas Spanish phonotactics allow for smaller sonority differences between the cluster's consonants. Thus, results from these studies were in line with the idea that bilingual's exposure to patterns of increased phonological complexity in each language may stimulate phonological acquisition in the other language, leading to a more advanced development as compared to monolinguals.

I.2.3.3.6.4 Structural ambiguity/overlap

The hypothesis of structural ambiguity as an explanatory factor for cross-linguistic influence has been invoked to a much lesser extent in studies about bilingual phonological acquisition. In fact, this hypothesis originates in bilingual acquisition studies about morpho-syntax (Döpke, 1999; Hulk and Müller, 2000). It postulates that cross-linguistic effects are likely to occur for structures for which there is inter-linguistic structural ambiguity or overlap and that transfer is not to be expected in the absence of ambiguity (Nicoladis, 2006). To give an example, if one of the languages of a bilingual child is characterised by a fixed word order Verb-Object and the other language allows for different word orders, amongst which the fixed word order Verb-Object in some cases, there is an overlap in the two languages. Accordingly, the child could initially overextend the use of the Verb-Object word order to both languages. As no ambiguity is present in the language with the fixed word order, transfer is expected to occur from that language to the other.

Structural ambiguity has been put forward as an explanatory factor in one study previously discussed. In her case study involving a Portuguese-French bilingual, Almeida (2011) suggested that the acceleration effect in the acquisition of branching onsets in Portuguese could be attributed to the structural ambiguity present in the input. Indeed, branching onsets are present both in French and in Portuguese; however, these structures are only superficially similar as they can be analysed in different ways in Portuguese. Portuguese is characterised by frequent vowel elision in spontaneous speech, leading to surface realizations of consonant sequences which are not true consonantal clusters in a phonological sense. Monolingual Portuguese children thus have to learn identifying the consonant sequences that can be phonologically analysed as consonantal clusters. As a result, cases of vowel epenthesis are frequent in the early production of branching onsets. On the contrary, the input is less ambiguous regarding branching onsets in French and this, according to Almeida (2011), would have facilitated the identification of true consonantal clusters in Portuguese and therefore, accelerated their acquisition.

I.2.3.3.7 Link between lexical and phonological development

Few bilingual speech production studies have taken children's lexicon into account. Only one study mentioned in our previous literature review has investigated the link between lexical and phonological development (Kehoe and Havy, 2019). Indeed, Kehoe and Havy (2019) have included the children's level of lexical development in their attempt to consider and control different factors that may impact bilingual phonological acquisition (see above). More precisely, they assessed the children's productive vocabulary in their two languages, using adaptations of the Mac-Arthur Bates inventories (Fenson et al., 1993), in order to measure lexical abilities in each language as well as the total size of the vocabulary (i.e., in both languages). Interestingly, no correlations appeared between language-specific lexical abilities and phonological productions in French. However, their results indicated that total vocabulary significantly predicted overall consonant accuracy as well as coda presence and accuracy but had only a marginal effect on cluster accuracy. Kehoe and Havy (2019) interpreted it as a demonstration of inter-linguistic links at the lexical-phonological interface. In other words, lexical knowledge in one language would stimulate phonological acquisition in the other due to common phonological properties.

Similarly, another study not mentioned in our review also examined the link between lexical and phonological development. Involving a large cohort of English-Spanish bilingual children aged between 3;1 and 6;5, the investigation led by Scarpino (2011) showed that the children's phonological skills were predicted to an important extent by vocabulary scores in each language. Thus, it seems that both language-specific and global lexical competence can influence phonological skills.

I.2.3.4 Conclusion

Based on our review of bilingual production studies, it appears that bilingual phonetic-phonological development shares similarities with that of monolingual children but has its specificities as well. It is actually widely acknowledged that bilingual children are developing two linguistic systems from the earliest stages of production and that unintended interaction would be typical of the bilingual experience. Indeed, CLI would be part of their ordinary phonological development and the moment when they would acquire similar profiles as monolinguals – if they ever do – is not yet defined. Also, it is clear that assessing bilingual phonetic-phonological development requires taking account of a certain number of factors, both language-external and language-internal, as well as considering the impact of lexical development. Moreover, different cross-linguistic effects can co-occur and the predictive role of the different factors is still not well understood. Most probably, phonological acquisition might not be influenced by only one decisive factor but instead, by a combination of several intricately linked explanatory factors. As suggested by some recent studies, cross-linguistic interaction in bilingual phonological acquisition might result from cross-language differences in the linguistic complexity of phonological properties, or from cross-language differences in the frequency of occurrence of those properties, or from both. In addition, certain phonological structures might be more prone to CLI than others.

From a methodological perspective, then, several limits can be pointed out in the existing literature. A large number of investigations have consisted in case studies or have included small participant samples. Moreover, not all studies have adopted a longitudinal perspective, while only a longitudinal tracking permits the identification of developmental patterns. Then, a large part of bilingual production studies involved recordings of spontaneous/connected speech samples during interactions in unstructured play situations (with parents and/or an experimenter). If this kind of protocol favours ecological-naturalistic conditions, it also results in highly time-consuming subsequent analyses (as it does not target specific productions) and can make the identification of the target's productions more problematic. However, a number of investigations involved the collection of single-word samples mostly elicited through a word-naming task (two studies included a non-word repetition task) which enabled the authors to focus on the production of particular words involving particular phonological structures. Most researchers used existing language assessment instruments (Fabiano-Smith & Goldstein, 2005; Fabiano-Smith & Barlow, 2010; Lin & Johnson, 2010), while few of them developed a specific tool/task. If using a standardised tool permits subsequent comparisons, building one allows targeting specific phonological structures. Self-developed tools mostly focused on consonants – whether singletons or clustered – in different positions within words, such as words targeting word-initial stops (MacLeod et al., 2011) or consonants in syllable-initial and final positions (Lin & Johnson, 2010).

Accordingly, for a majority of the studies discussed, analyses focused on consonants' production, possibly in different positions in the word and/or in the syllable, depending on the approach taken. Very few studies have investigated vowel production in bilingual toddlers (Kehoe, 2002; Yang et al., 2015). Besides, the conducted analyses most often involved measures of accuracy and examination of phonological processes/error patterns with varying degrees of precision/nuance. Interestingly, acoustic analyses have rarely been carried out on data although they allow for a more objective assessment than analyses based on perceptual transcriptions which, even if more advantageous for several reasons (convenience and economy), are also prone to errors and/or bias. Finally, the last but not least mentionable point, studies about bilingual phonological development in production have dealt with a limited range of language pairs, which, in most cases, have involved English and/or Spanish. Moreover, if not the investigation led by Kehoe and Havy (2019), no study included more than one language pair. The methodological choices for the current study have been made with these limitations in mind. Indeed, it longitudinally assesses phonetic and phonological development of French paired with different languages and includes analyses based on acoustic measures (this will be developed in details in the Chapter II.). Besides, both concepts of acceleration and deceleration will be used for a different purpose than that for which they are generally used, namely to compare different bilingual children rather than to compare bilingual to monolingual children (this issue will be returned to in section I.4. in which are exposed the research problematic and working hypotheses).

I.3 PHONETIC-PHONOLOGICAL DESCRIPTION OF TARGET SYSTEMS

It follows from the review of bilingual speech acquisition/production studies that research about bilingual phonological development has focused primarily on children exposed to English and/or Spanish. Moreover, and to our knowledge, Kehoe and Havy's study (2019) is the only research to have involved several language pairs in order to study phonological acquisition within contrasted bilingual linguistic contexts. In light of this, and as mentioned in the introduction of this doctoral dissertation, our research also aims at contributing to address this gap by comparatively studying the impact of different linguistic combinations on phonetic and phonological development in French. Already listed in the introduction, the three linguistic combinations involved in this study are the following: (1) French-Italian, (2) French-Arabic and (3) French-Mandarin. These selected language pairs involve a different degree of distance/similarity between the two languages. Inter-linguistic distance is a multi-dimensional notion that can be measured at different levels, from phonetics and phonology to syntax[28]. More specifically regarding phonetic and phonological distance, languages can resemble each other or differ in several respects: phonemic inventories, syllabic structure or prosodic domains of rhythm, stress/accent and tone.

Phonetic and phonological properties of the different target languages involved in this study will now be described. Given that our study focuses on the impact of different bilingual contexts on French phonological acquisition, particular attention will be devoted to the description of French. The three other languages will be described rather from a comparative perspective; i.e., focusing on what properties they share or do not share with French. Furthermore, the description will be mainly centred on the specific structures we have chosen to investigate in the subsequent analyses, pertaining to both segmental and syllabic levels, and on their developmental patterns as documented in acquisition studies. More precisely, we will detail the vocalic and consonantal sub-systems, with a closer examination of a sub-set of consonants including voiced and voiceless sibilant[29] alveolar and post-alveolar fricatives /s, z, ʃ, ʒ/[30]. Rationales for this choice will be explained in the description of our research problematic (section I.4.). Then, we will concentrate on both segmental and structural characteristics of different syllabic constituents, namely word-final singleton codas, word-initial branching onsets and word-final complex codas. Word-final singleton and complex codas as well as word-initial branching onsets have already been investigated in several monolingual and bilingual acquisition studies and have been shown to be of particular interest with respect to the issue of cross-linguistic interaction. In addition, their development has rarely been studied concomitantly with an examination of vowel and/or fricatives production.

Note that rhythm, stress or intonation phenomena will not be considered here. Although similarities and differences of interest do exist between French and the target languages on these respects, they are beyond the scope of the present study. Indeed, as mentioned earlier, this study aims at identifying developmental patterns in the acquisition of French speech sounds in contrasted bilingual linguistic environments, with a peculiar attention given to vocalic and consonantal

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[28] In addition, existing classifications constitute very often a simplification and languages should rather be located on a continuum than in distinct, binary classes.

[29] Sibilants are fricative consonants of higher amplitude and pitch, made by directing a stream of air with the tongue towards the teeth.

[30] Voiced fricatives /z, ʒ/ are produced with accompanying vibration of vocal folds, as opposed to voiceless fricatives /s, ʃ/.

acquisition within particular syllabic constituents in specific positions in the word. Each targeted structure will be described both in phonetic and phonological terms whenever it is possible (i.e., depending on the amount of available information in the literature).

Before moving on to the description of the target languages, a word should be said about the notions of linguistic norm and variation. The languages involved in the current study relate differently to the norm issue and are characterized by different degrees of language variety. Indeed, both French and Italian are characterized by a high degree of regiolectal and sociolectal varieties which can be more and less contrasted (Lengert, 2015; Cerruti, 2011). Arabic, then, comprises numerous dialectal varieties, the use of which mainly depends on the region. As for Chinese, *Pûtônghuà* (literally "common speech") is the official prescribed standard derived from the Mandarin used in Bejing, while a large number of other dialects are spoken in China (Dong, 2010). We are well aware of this existing varieties – whether dialectal, regiolectal or sociolectal – and of the differences that they might involve with regards to phonetics and phonology. Still, we are not going to discuss these different variations in details but rather, we take the position of giving a consensual description of the most widely accepted norm.

I.3.1 French

I.3.1.1 Vowels

I.3.1.1.1 Phoneme inventory

The description of the French vowel system varies slightly depending on the scholars as well as on its regional varieties and types of corpus under study. Walter (1976) has identified 16 vowels, with 11 oral short vowels /i, y, e, ø, ɛ, œ, a, ɑ, ɔ, o, u/, 1 oral long vowel /ɛː/ and 4 nasal vowels /ɛ̃, œ̃, ɑ̃, ɔ̃/. She also noted that the central vowel /ə/ could be added to these 12 oral vowels. Indeed, /ə/ can be considered as a phoneme on the same terms as the other vowels even if it behaves in a slightly different way. More specifically, /ə/ can be phonetically realized as a [ø] or an [œ] and can also be reduced or elided in conversational speech (particularly in final syllable but also within words, such as in [ʃvø] for /ʃəvø/, i.e., cheveux). Therefore, it has often been referred to as optional or neutral. Besides, the contrast between several phonemes becomes neutralized in some contexts, such as contrasts between /ø/ and /œ/ and between /ɔ/ and /o/ in final open syllable, and contrast between /e/ and /ɛ/ in final close syllable. In addition to contrast neutralization, a merging phenomenon occurs for the contrasts between the nasal vowels /ɛ̃/ and /œ̃/ and between the oral vowels /a/ and /ɑ/. Indeed, the phonetic evolution of the language has led to a gradual disappearance of the nasal anterior rounded vowel /œ̃/ and the posterior oral vowel /ɑ/ for the benefit of, respectively, the nasal anterior unrounded /ɛ̃/ and the anterior oral vowel /a/. Léon (2000) has attributed this to the low frequency of occurrence of the vowels /œ̃/ and /ɑ/. Furthermore, minimal pairs involving /ɛ̃/-/œ̃/ (as in « brin » and « brun ») and /a/-/ɑ/ (as in « patte » et « pâte ») are quite rare and contrasts between these vowels are therefore not fundamental in the system. Consistent with this view, Fougeron and Smith (1993) report 11 oral vowels (i, e, ɛ, y, ø, œ, ə, a, u, o, ɔ) and 3 nasal vowels (ɛ̃, ɑ̃, ɔ̃) (see Figure 3).

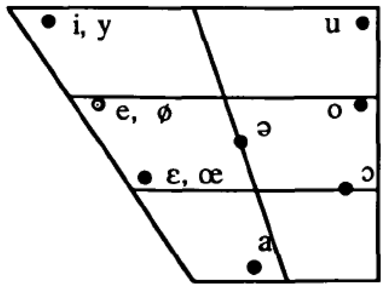

Figure 3: Representation of French vowels, extracted from Fougeron and Smith (1993).

Regarding vowel's distribution, we present in Table 2 a list of French vowels' frequency of occurrence drawn from the work of Wioland (1972). Wioland's distribution was measured based on a large corpus combining spoken (from radio broadcast) and written French. It should be noted that the frequencies' total does not reach 100% given that Wioland had estimated the frequency of all French phonemes, including the consonants (see next section). The vowels /a, i, e, ɛ/ have the highest frequency of occurrence, whereas the vowels /ø, œ, ɑ, œ̃/ are the less frequent vowels. Compared to other languages, French has a high proportion of vowels against consonants (43,5% of vowels and 56,5%, based on Wioland, 1972).

Vowel	Distribution
a	8,11%
ɛ	5.55%
e	5,28%
i	5.08%
ə	3.39%
ɑ̃	3.21%
u	2.62%
ɔ̃	2.27%
y	2.01%
o	1.97%
ɔ	1.28%
ɛ̃	1.16%
œ̃	0.54%
ø	0.51%
œ	0.44%
ɑ	0.05%

Table 2: Frequency of occurrence of French vowel phonemes, extracted from Wioland (1972).

I.3.1.1.2 Phonetic description

The production of vowels is characterized by the free circulation of the pharyngeal flow through the vocal tract where it gets its particular timber from the specific configuration and form of the supra-glottal cavities. There are a number of articulatory criteria along which vowels can be classified; however, not all criteria are necessary to describe the vowel system in phonological terms. That is, some of them might be considered redundant in an economic phonological description. A phonetic description of French vowels can be achieved based on the following criteria:

- aperture/height: based on the degree of aperture (i.e., the openness of the mouth) and the height of the tongue (i.e., a more and less elevated tongue), it is possible to distinguish between open or low and close or high vowels. In French, four types of vowels are attested based on this criteria: [i], [y] and [u] are close/high vowels, [e], [ø] and [o] are mid-close/high vowels, [ɛ], [œ] and [ɔ] are mid-open/low vowels, and [a] and [ɑ] are open/low vowels.
- frontness/backness: based on the position of the tongue on a horizontal axis (i.e., its degree of frontness or backness), vowels are categorized either as anterior or posterior. In French, [i], [e], [ɛ], [y], [ø], [œ] and [a] are anterior vowels and [u], [o], [ɔ] and [ɑ] are posterior vowels.
- labialization/roundness of the lips: based on the degree of labialization or roundness of the lips, a distinction is made between labial or rounded vowels *vs.* non-labial or unrounded vowels. In French, [y], [u], [ø], [œ], [o], [ɔ], [ɔ̃] and [œ̃] are labial vowels and [i], [e], [ɛ], [a] and [ɑ] are non-labial vowels.
- nasalization: nasal vowels are characterized by a lowered velum and by a combination of oral and nasal airflow, whereas oral vowels involve a raised velum and air passing only through the buccal cavity. French includes four nasal vowels [ɑ̃], [ɛ̃,], [ɔ̃] and [œ̃].

Additional articulatory criteria used to categorize vowels in other languages than French include, amongst others, vowel length/duration[31] (short *vs.* long vowels), vowel tension (tense *vs.* lax vowels), diphthongization, position of the tongue root, vowel pharyngealization and stridency (Ladefogged & Maddieson, 1996). Table 3 summarizes the French vocalic system according to the relevant articulatory criteria mentioned above (height/aperture, frontness/backness, labialization/roundness and nasalization) and following Figure 4 shows sagittal views of the vocal tract configuration for the production of French vowels (similarly organised along the same criteria).

	Anterior vowels	Central vowels	Posterior vowels
Close/high vowels	i, **y**		**u**
Mid-close/high vowels	e, **ø**	(ə)	**o**
Mid-open/low vowels	ɛ, ɛ̃, **œ** (œ̃)		**ɔ, ɔ̃**
Open/low vowels	a, ɑ̃		(ɑ)

Table 3: French vowels (with rounded vowels in bold characters and vowels prone to merging and consequently, not present in all descriptions into parentheses).

[31]Indeed, vowel duration is not phonologically significant in the French vocalic sub-system.

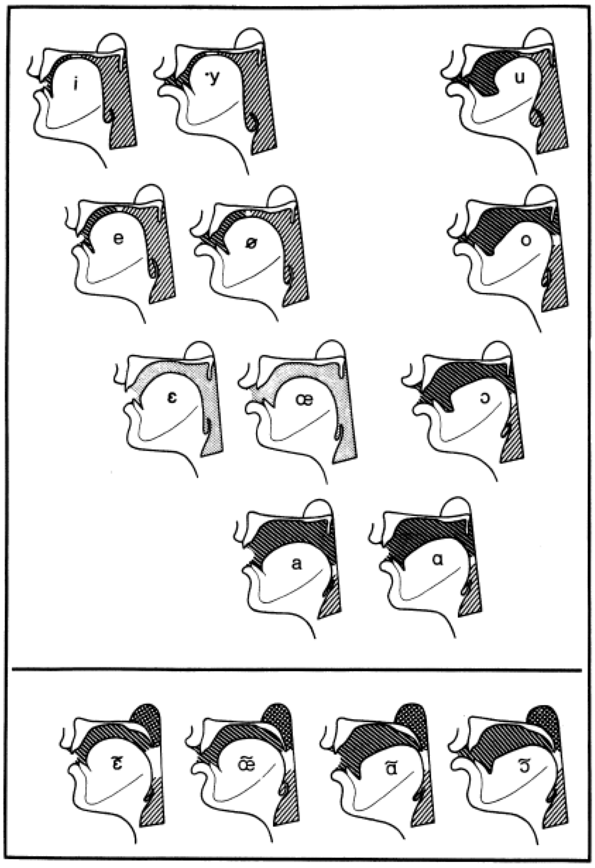

Figure 4: Articulatory representations of the French vowels, extracted from Delattre (1968).

From an acoustic perspective, and as modelled by the "source-filter" theory (Fant, 1960), the production of vocalic sounds starts with an initial periodic sound resulting from the vibration of vocal folds and consisting in a fundamental frequency (F0) and its harmonic components. While this laryngeal sound source progresses through the vocal tract (filter), the supra-glottal cavities act as resonators by reinforcing the harmonics the closest to their resonance frequencies. The reinforced frequency zones in the output signal are called formants which vary according to the size and configuration of the vocal tract. The first three formants – referred to as F1, F2 and F3 – are the most informative for vowel analysis, though there may be a greater number of them. Given that the configuration of the bucco-pharyngeal cavities differs for each vowel, each of them will be characterized by specific formant values. There is thus a link between the acoustic and articulatory characteristics of vowels. Even though this link is complex and nonlinear, some general tendencies may be outlined. First, the value of the first formant (F1) mainly depends on the position of the jaw and of the tongue as the F1 typically increases while both articulators lower. The value of the second formant (F2) mainly relates to the horizontal movement of the tongue: F2 is expected to rise as the tongue moves forward in the mouth. Finally, the value of the third formant (F3) is particularly affected by the relative rounding of the lips and decreases as they become more rounded. In other words, values of F1, F2 and F3 are decisive for contrasts between close and open vowels (F1), posterior and anterior vowels (F2) and unrounded and rounded (front) vowels (F3). Figure 5 provides, on the left, a schematic representation of the French oral vowels on a F1-F2 plan and, on the right, a schematic representation of the dispersion (i.e., the variability) around the centre of the vocalic category.

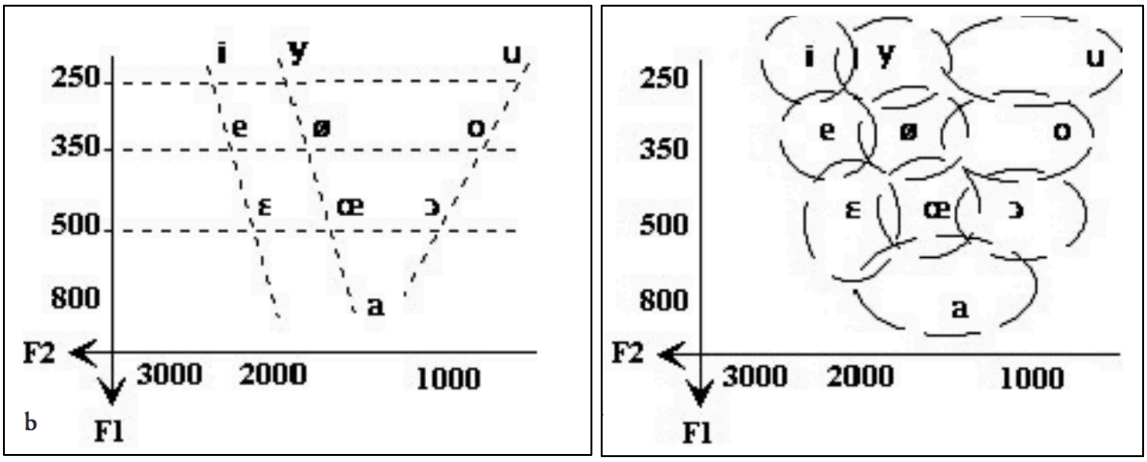

Figure 5: Schematic representation of French oral vowels on a F1-F2 plan with typical formant values (left) and schematic representation of the dispersion around the centre of the vocalic category (right), extracted from Ghio and Pinto (2007).

Vaissière (2006) has classified French oral vowels based on their acoustic features and more precisely, based on the distance between their formant values. She has distinguished three groups of vowels:

- (1) front vowels /i, e, ɛ, y/ which are characterized by a greater distance between F1 and F2 than between F2 and F3. Moreover, /i/ is the most acute vocalic sound displaying a very high F3 (around 3200 Hz for male speakers and higher for female speakers and children) and a convergence between F3 and F4 values. In contrast, the vowel /y/ is characterized by a grouping of F2 and F3 values (around 1900 Hz for men and 2300 Hz for women) (Vaissière, 2007). Besides, the F3 allows distinguishing between the vowels /i/ and /y/ and /i/ and /e/.
- (2) labial and posterior vowels /u, o, ɔ/ which are characterized by smaller distance between F1 and F2 than between F2 and F3. Furthermore, these vowels involve a convergence between F1 and F2 below 1000 Hz and the vowel /u/ is the gravest vocalic sound (Vaissière, 2007).
- (3) acoustically central vowels /ø, œ, a/ which are characterized by a uniformly distributed energy and a F2 situated midway between F1 and F3. Still, the vowel /a/ presents a very high F1 and the F1 of /ø/ is higher than that of /œ/.

This convergence or proximity between two consecutive formants is also termed vowel focalization within the framework of a theory of vowel systems called the Dispersion-Focalization Theory (Schwartz, Boë, Vallée & Abry, 1997). In sum, this theory is based on the principle that vowels produced on peripheral zones of the vowel space consequently present a convergence of certain formants. This formant convergence or focalization facilitates their perception as more focal spectral configurations would be easier to process and thus, preferred to less focal ones (Schwartz, Abry, Boe, Ménard & Vallée, 2005). In other words, focal vowels such as /i, y, a, u/[32] are more easily identified and function as perceptual referents supporting the perception of other vowels.

[32]However, Vaissière (2007) identifies six focal vowels /i, y, ɑ, ɔ, o, u/.

Finally, it should be said that nasal vowels involve a different configuration of the vocal tract than oral vowels. Indeed, their production is characterized by a coupling of both oral and nasal cavities via an opening of the velo-pharyngeal port and a lowering of the velum (Carignan, 2014), as well as by an overall shift towards the back of the vowel space.

In conclusion to this section, it appears that French has a quite complex vocalic system including 10 to 12 oral vowels and 3 to 4 nasal vowels, depending on the descriptions found in the literature, characterized by particular articulatory and acoustic features. Given that two thirds of the word's languages have a vocalic system comprising between 5 to 7 vowels, this makes French one of the less frequent languages to possess more than 9 vocalic qualities and as a result, to involve a "parallel" system of nasal vowels (Vallée, Boë & Stefanuto, 1999).

I.3.1.1.3 Data from developmental studies

I.3.1.1.3.1 Order of acquisition

A limited number of studies have focused on the acquisition of vowels in French. With respect to vowels' order of acquisition, Rondal (1999) has proposed a timetable for the acquisition of French phonemes, distinguishing between emerging – i.e., occurring for the first time in the child's inventory – and acquired – i.e., systematically and appropriately used – phonemes (see Figure 6).

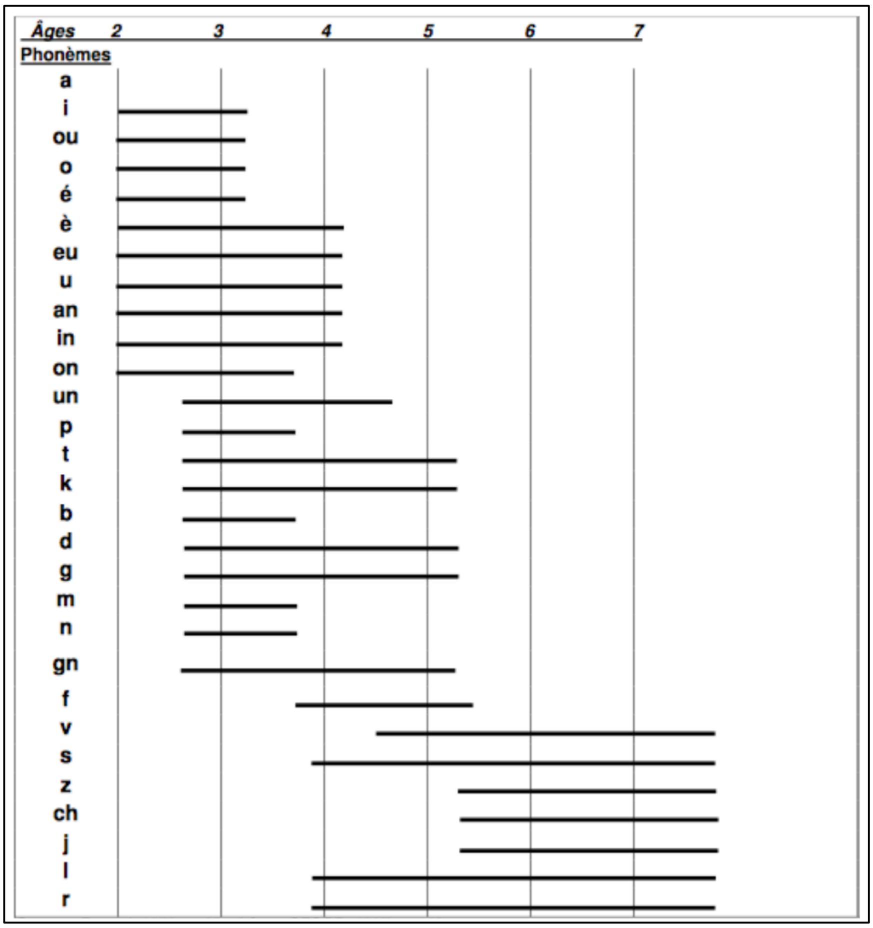

Figure 6: Table of French phoneme acquisition (Rondal, 1999; in which *ou* = [u], *é* = [e], *è* = [ɛ], *eu* = [ø], *u* = [y], *an* = [ɑ̃], *in* = [ɛ̃], *on* = [ɔ̃], *un* = [œ̃], *gn* = [ɲ], *ch* = [ʃ]).

According to his proposal, all vowels are acquired between three and four years, except for the nasal /œ̃/ mastered a little before 5 years, and most oral vowels are acquired before nasal vowels. More specifically, /a/ is the first vowel to emerge and be acquired, followed by other oral vowels /i, u, o, e/ then, /ɛ, ø, y/ and finally, by the nasals /ã, ɔ̃, ɛ̃/. It should be noted that we do not have precise information with regard to the empirical basis of this proposal and moreover, it does not provide a very nuanced view of the acquisition process. However, there is, to our knowledge, no more recent reliable source documenting the time course of acquisition of French vowels.

I.3.1.1.3.2 Vowel production

Amongst the developmental/acquisition studies involving acoustic analyses of French vowels, some of them have assessed vowel production in the frame of comparisons between normally hearing and hearing-impaired children. Given the restricted number of acoustic studies of vowel production in French-speaking children, we report here their results concerning children with no hearing loss. Ryalls, Larouche and Giroux (2003) have focussed on French-speaking Canadian children with the following profiles: (1) profound hearing-impaired, (2) moderate-to-severe hearing-impaired and (3), normally hearing children (mean age = 8;10). They examined the first three formant frequencies of the extreme vowels /a, i, u/ by eliciting the repetition of CV syllables (non-words) involving the stop /p, b, t, d, k, g/. They observed no significant between-group differences in F1 values but lower F2 values and smaller vocalic space in children with profound hear loss. Figure 7 displays extracted mean values of the first three formants obtained for normally hearing children (one above the other, from F1 to F3) and right next to it, the comparison of the three groups' vocalic space. As expected, F1 and F2 values are globally higher than that observed for adult speakers. Indeed, and as previously mentioned, early vowel development is characterized by a reduction of formant-frequencies (Vorperian & Kent, 2007).

	Vowel		
Subject groups	i	a	u
Normally hearing: boys	340	752	352
No. of tokens	149	109	149
Normally hearing: girls	391	1009	390
No. of tokens	148	114	150

	Vowel		
Subject groups	i	a	u
Normally hearing: boys	3008	1819	1468
No. of tokens	58	146	72
Normally hearing: girls	3257	1893	1223
No. of tokens	41	134	84

	Vowel		
Subject groups	i	a	u
Normally hearing: boys	3791	3636	3616
No. of tokens	137	129	97
Normally hearing: girls	3789	3631	3781
No. of tokens	125	120	88

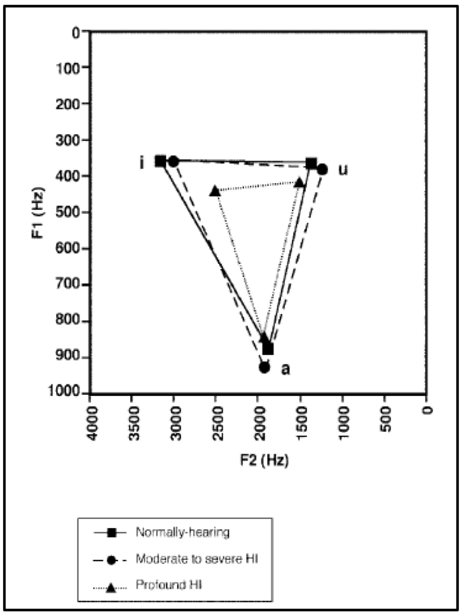

Figure 7: Mean F1-F2-F3 values of vowels /a, i, u/ for normally hearing boys and girls (left), comparison of the vocalic space of normally hearing, moderate-to-severe and profound hearing-impaired children (right), extracted from Ryalls et al. (2003).

In her doctoral dissertation, Grandon (2016) has similarly analysed the acoustic characteristics of vowels in normally hearing *vs.* cochlear-implanted French-speaking children (the latter being aged between 5;7 and 10;6), eliciting vowel production via both word-repetition and naming tasks. Her analyses also included measures of the vowels' first three formants. Moreover, the words to be produced by the children were mono- or plurisyllabic words, all involving an initial sequence CV or CVC, and vowels targeted for the acoustic analyses were the orals /i, e, ɛ, y, ø, œ, a, u, o, ɔ/. Normally-hearing children participating in her study were found to produce the French oral vowels with four distinct levels of vowel height and three levels of vowel frontness (respectively linked to F1 and F2 values), similar to French-speaking adult vowel production described in the literature (e.g., Fougeron & Smith, 1993). More specifically, the children produced appropriate F1 values, resulting in a clear distinction between: (1) high /i, u, y/ and mid-high /e, ø, o/, (2) mid-high /e, ø, o/ and mid-low /ɛ, œ, ɔ/, (3) mid-low /ɛ, œ, ɔ/ and low /a/. Furthermore, the F2 values of anteriors /i, e, ɛ/ were also distinct from those of less anteriors /y, ø, œ/ and central /a/, in turn different from posteriors /u, o, ɔ/. Besides, the rounded vowels /y, ø, œ/ were also characterized by a lower F3 than the unrounded /i, e, ɛ/ possibly indicating the acquisition of the roundness feature. Interestingly, she found no effect of age on formantic differences between the different categories, suggesting that even the youngest children of her sample (aged around 5) had already acquired the different vocalic categories determined by height and frontness. Finally, neither the type of task (repetition *vs*. naming) nor the complexity of the word (assessed based on lexical frequency, word length and presence of consonantal clusters) did significantly impact vowel production. Indeed, only the F1 of high/close vowels and of /a/ was subjected to an effect of the task and the complexity of words only affected the F1 of the vowels /u, a, y/, the F2 of the vowels /i, ɛ, o/ and the F3 of the vowels /i, u, o, ɔ/.

Within the frame of the Dispersion-Focalization Theory (Schwartz et al., 1997, see above), Ménard and collaborators investigated the link between articulatory and acoustic features for French vowels with a longitudinal perspective (Ménard, Schwartz, Boë & Aubin, 2005). The study included three experiments and involved two groups of children (4-year-olds and 8-year-olds) and one group of adults. The first experiment focussed on the production of vowels by speakers of all three groups in order to examine the acoustic organization of the vocalic system during growth. In the second experiment, vowels simulated with an articulatory model (Variable Linear Articulatory Model, VLAM, developed by Maeda, 1979) were compared to natural vowels in order to better understand articulatory strategies and in the third one, they assessed perceptual value of acoustic targets. For each speaker, they collected ten repetitions of the ten oral vowels /i, e, ɛ, y, ø, œ, a, u, o, ɔ/ inserted in initial position of French words and conducted acoustic analyses based on the measures of F1-F2-F3 values. More precisely, they examined the distribution of vowels over three-dimensional spaces. Their results showed that the productions of all speakers (both groups of children and adults) displayed the focalization feature; that is, all speakers produced vowels with extreme positions on a F1-F2-F3 space characterized by a regrouping of certain formants (/i/ F3-F4, /u, a/ F1-F2, and /y/ F2-F3). However, focalization resulted in lower intelligibility for the French vowel /y/ in 4-year-olds.

A longitudinal study involving Canadian either English- or French-learning children aged between 10 and 18 months (Rvachew, Mattock, Polka & Ménard, 2006; Rvachew, Alhaidary, Mattock & Polka, 2008) focused on developmental and cross-linguistic differences in infant vowel spaces. These studies included analyses of the mean F1 and F2 values of the babbling vocalic sounds. Results from both studies showed an early influence of the ambient language and cross-linguistic differences. Indeed, Rvachew and collaborators (Rvachew et al., 2006) observed a decline in mean

F1 values for Canadian French children with age, whereas mean F2 values were found to decrease for Canadian English children and to remain stable for French-learning infants, as shown by Figure 8 below. Moreover, they also found that the babbling of English infants was characterized by a higher frequency of occurrence of /u/ vowels in comparison to French infants (Rvachew et al., 2008) and they observed a peripheral expansion of the infants' vowel space towards high-front and high-back regions with age (Rvachew et al., 2006, see Figure 8).

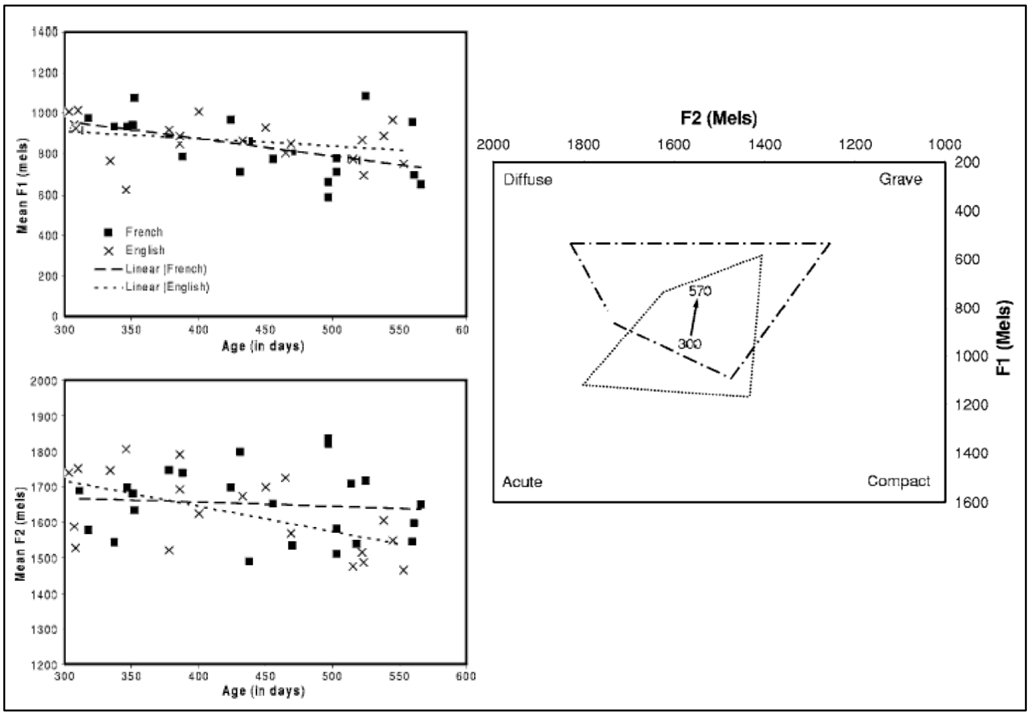

Figure 8: Mean F1 (top) and F2 (bottom) values in mels for French- and English-learning Canadian children (left), graphic representation of the vowel space and movement of the gravity centre from 300 to 570 days of age (right), extracted from Rvachew et al. (2006).

Besides, these studies emphasize the fact that an accurate description of vowel acquisition patterns requires more than an assessment of vowel production at a phonemic level and necessitate phonetic-acoustic analyses. Then, babbling studies do not permit precise identification of the target of the vowel sound that infants are willing to produce and hence, such investigations need being supplemented by other acquisition studies involving the production of vowels within words.

There are, to our knowledge, no acoustic studies of vowel production involving French-speaking bilingual children. As already noted, only a limited number of bilingual production studies have involved acoustic analyses and furthermore, vowels have been less investigated than consonants. Still, vowel accuracy in French was analysed (using the PVC measure, see above), amongst other things, by Kehoe and Havy (2019) in their study focusing on phonological acquisition in French-speaking bilingual toddlers in comparison to age-matched monolinguals. Their comparison of PVC results between bilinguals and monolinguals showed no differences across the two groups of children (with an approximate PVC value of 90% for the two groups). However, the bilingual children displayed greater variability in their vowel productions than the monolinguals. In addition, the authors assessed the impact of language-external factors (exposure to French, socio-economic status and gender) and of lexical development on the PVC values but none of these factors appeared to be significant predictors of the children's vowel accuracy.

From this review of studies focusing on vowel acquisition in French, it appears that there are actually still very few data about developmental patterns and acoustic characteristics of vowels in preschool French-speaking children. Moreover, almost all studies discussed involved monolingual children as (French) vowel production has very scarcely been focused on in bilingual acquisition studies. There is thus a need to address this issue. Besides, studies discussed differed by their methodologies for eliciting and analysing vowel productions. Indeed, some of them involved repetition of non-words (Ryalls et al., 2003) or words (Ménard et al., 2007; Grandon, 2016) and/or word naming (Grandon, 2016) and finally babbling studies (Rvachew et al., 2006; 2008) relied on speech sample recordings in the context of mother-child interactions. We now move forward to the description of the French consonantal (sub-)system.

I.3.1.2 Consonants

I.3.1.2.1 Phoneme inventory and articulatory characteristics

We provide a description of French consonants based on two main sources (Walter, 1976; Rose & Wauquier, 2007). French includes 17 to 18 consonants /p, t, k, b, d, ɡ, m, n, ɲ, (ŋ), f, v, s, z, ʃ, ʒ, l, ʁ/ and 3 glides (also called approximants, semi-consonants or semi-vowels) /w, j, ɥ/. Indeed, the phoneme /ŋ/ is not always included in the consonantal inventory as it occurs in English borrowed words. Regarding the frequency of occurrence of consonants, we present below (see Table 4) two lists of French consonant's distribution which were developed based on corpus of adult and child-directed speech. The first list (on the left) is drawn from the estimation of phonemes' frequency in spoken and written French realised by Wioland (1972, see above). Derived from the work of Le Calvez (2004) by Yamaguchi (2012), the second list (on the right) has been developed based on speech utterances of adults addressing children taken from the CHILDES database. In both lists, the frequency of consonants does not reach 100% since the authors had included vowels in their estimation of French phonemes' frequency. The two lists differ somewhat in their frequency ranking of French consonants as child-directed speech (CDS, see above) has specific characteristics potentially impacting the phoneme's frequency of occurrence. It should be noted that the list drawn from Le Calvez's work does not include the glides /w, ɥ/ as Yamaguchi did not include those two phonemes in her study. The most striking difference between the two frequency lists is the rank of the consonant /z/ which appears as the second less frequent consonant in the child-direct speech, right before the /ɲ/ (the least frequent consonant in both lists), while it occupies a higher rank in the list of Wioland (1972). In addition, /b/ would also be more frequent in the spoken language addressed to the child than in adult spoken and written language.

Consonant	Distribution
ʁ	7.58%
l	5.89%
s	5.75%
t	5.39%
d	4.24%
p	3.88%
k	3.75%
m	3.91%
n	3.09%
v	3.00%
j	1.76%
ʒ	1.57%
z	1.55%
f	1.38%
w	1.03%
b	1.08%
ʃ	0.61%
g	0.56%
ɥ	0.37%
ɲ	0.14%

Consonants	Proportion in %
s	6,05
l	6,02
ʁ	5,98
t	5,91
k	4,68
p	3,99
m	3,21
d	3,10
n	2,32
v	2,27
b	1,43
f	1,38
j	1,35
ʒ	1,08
ʃ	0,92
g	0,64
z	0,42
ɲ	0,01

Table 4: Frequency of occurrence of French consonants (left), drawn from Wioland (1972), Frequency of occurrence of French consonants in CDS (right), adapted from Yamaguchi (2012) based on Le Calvez (2004).

Consonants can be described and classified following articulatory criteria and more particularly, based on their manner (MoA) and place (PoA) of articulation. Moreover, consonant sounds are also categorized in relation to their voicing feature, as voiced *vs.* voiceless consonants[33]. Table 5 presents the French consonantal system based on descriptions found in the literature.

[33]A voiced sound is characterized by the vibration of vocal folds.

PoA / MoA	Bilabial	Labio-dental	Inter-dental	Dento-alveolar	Retroflex	Post-alveolar	Alveolo-palatal	Palatal	Velar	Uvular	Pharyngeal	Glottal
Stop	p b			t d					k g			
Nasal	m			n				ɲ	(ŋ)			
Trill				(r)						(ʀ)		
Tap or Flap				(ɾ)								
Affricate												
Fricative		f v		s z		ʃ ʒ				ʁ		
Lateral approximant				l								

PoA / MoA	Palatal	Labio-palatal	Labio-velar
Approximant	j	ɥ	w

Table 5: French consonants based on descriptions found in the literature (Walter, 1976; Rose and Wauquier, 2007).

Stop consonants result from a momentary obstruction of the vocal tract which impedes the free passage of the air at a supra-glottal level. The mechanism of production of stop consonants involves three stages: (1) an occlusion/closing phase during which the articulators are positioned, (2) a holding phase during which the air is blocked and (3), an explosion phase (or burst) which corresponds to the relaxing of the articulators and the liberation of the air stream. The six French stops can be organized in three pairs of voiced and voiceless consonants: (1) the bilabials /b – p/, (2) the dentals /d – t/ and (3), the velars /k – g/. Nasal consonants (/m, n, ɲ, (ŋ)/) are produced with the same mechanism as voiced stop consonants but are characterized by a lowered velum. Consequently, the nasal cavity starts resonating and gets involved in the filtering of the voiced source. In contrast, fricative (or "constrictive") consonants are produced by the continuous passage of air through a narrowed or constricted vocal tract resulting in a friction noise. Like the stops, the fricatives of French can be organized in pairs of voiced and voiceless consonants: (1) the labio-dental /v – f/ articulated with a constriction between the lower lip and upper incisor teeth, (2) the alveolar /s – z/ articulated with a constriction between the tongue and the alveolar ridge and (3), the post-alveolar /ʒ – ʃ/ articulated with a constriction between the tongue and the hard palate.

Besides, as underlined by the use of parentheses in Table 5 above, the phoneme /R/ has several allophones or free variants[34]: it can be phonetically realised either as the voiced uvular fricative [ʁ], or as the voiced uvular trill [ʀ] (as, for example, in Parisian French), or as the voiced alveolar trill [r] or flap [ɾ] (in dialectal varieties in France or Quebec). However, its most widespread realization in contemporary French is the uvular fricative [ʁ]. The phoneme /R/ is also labelled as "rhotic" and grouped together with the lateral approximant /l/ under the category of liquid consonants,

[34] Free variation is the interchangeable relationship between two phones, in which the phones may substitute for one another in the same environment without causing a change in meaning.

based on their similar phonotactic patterns (Dos Santos, 2007; Van't Veer, 2013). Indeed, the phoneme /R/, as well as the phoneme /l/, can occur in second or dependent position in a branching onset (see section I.3.1.3. for a general presentation of French syllable structure and syllabic constituents), whereas French fricatives can not (Dos Santos, 2007).

Finally, glides are produced with a vocal tract which is narrowed, but not sufficiently constricted to create a turbulent airstream like fricatives. Note that the glides /j, w, ɥ/ are also termed "semi-vowels", given that they share articulatory and acoustic similarities with vocalic sounds. The lateral /l/ is produced with a central constriction of the tongue towards the hard palate leaving a lateral passage for air on one or both sides of the tongues. Figure 9 presents the place of articulation of French oral and nasal stops, fricatives, lateral and variants (trills) of the phoneme /R/.

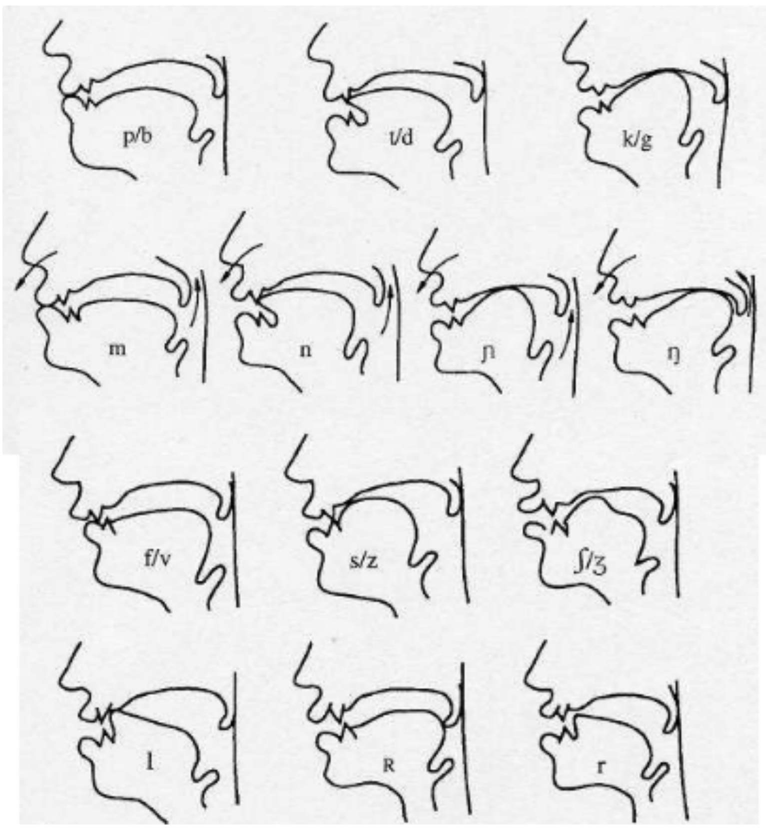

Figure 9: Articulatory schemes of French oral and nasal stops, fricatives, lateral approximant and variants of the phoneme /R/ (from Bothorel et al., 1986).

I.3.1.2.2 Acoustic description

We have just described the inventory as well as the articulatory characteristics of the French consonants. To sum up, the consonantal system of French is organized following the criteria of manner and place of articulation and of voicing. Since in the present study we have chosen to acoustically analyse a sub-set of the French fricative consonants (namely, the voiced and voiceless alveolars /s - z/ and post-alveolars /ʃ - ʒ/), the acoustic description here below is restricted to that class of consonants.

As noted above, fricative sounds are produced with a very narrow constriction in a specific area of the vocal tract. While the air rapidly flows through the constricted vocal tract, it generates turbulence which acts as the primary source of sound for these consonants (Stevens, 1971). he production of fricatives is thus characterized by a turbulence or friction noise resulting from the narrowing (but no total closure) of the vocal tract. Additionally, fricatives are either voiced or voiceless, i.e., the friction noise is accompanied or not by periodicity in low frequencies (associated with vocal folds' vibration). Voiced fricatives typically display a shorter duration than voiceless ones as well as a lower intensity of the friction noise due to the vocal folds' vibration which diminishes the supra-glottal pressure. Fricatives can be differentiated according to the acoustic parameters of duration, intensity and spectral shape. Consequently, the acoustic studies on fricatives have generally focussed on their spectral characteristics, as well as the amplitude and duration of the frication noise. In particular, the acoustic differences between "sibilant" fricatives (such as alveolars and post-alevolars /s, z, ʃ, ʒ/) and "non-sibilant" fricatives (such as labio-dentals /f, v/) have often been investigated. Coarticulation effects have also been explored based on formant transitions towards adjacent vowels.

The overall spectrum of a fricative sound is determined by the size and shape of the oral cavity in front of the constriction (Jongman, Wayland & Wong, 2000) or, in other words, by the consonant's place of articulation. Fricatives involving a longer anterior cavity, such as alveolar and post-alveolar ones, will be characterized by more well-defined spectral shapes than (labio-)dental fricatives (Stevens, 1998; Behrens & Blumstein, 1988). Indeed, both labio-dentals /f, v/ are characterized by a low intensity and a relatively flat spectrum with no clearly dominating peak or diffuse peaks located at two points, around 3500 Hz and 8000 Hz (Tubach, 1989). In contrast, the alveolars /s, z/ and post-alveolars /ʃ, ʒ/ typically exhibit a well-defined spectral peak located in a specific frequency region. Produced with a shorter anterior cavity, the alveolar fricatives /s, z/ mainly display friction noise between 4000 and 8000 Hz with a primary high-frequency spectral peak reaching 4000 to 5000 Hz. In addition, /s, z/ involve a contact of the air-stream against the teeth, which results in a particularly intense high-frequency turbulence. In contrast, the production of the post-alveolars /ʃ, ʒ/ is characterized by an intense turbulence noise located between 2000 and 7000 Hz with a mid-frequency spectral peak around 2500 to 3000 Hz (Jongman et al., 2000).

The common method used to describe the acoustic properties of fricatives is the analysis of spectral moments. It consists in treating the spectrum as a random probability distribution in order to compute mathematical moments; i.e., the central tendency, dispersion, asymmetry and shape of this distribution (Forrest, Weismer, Milenkovic and Dougleas, 1988). This statistical procedure allows quantifying the fricatives' spectral characteristics and therefore, to distinguish and model them (Shadle and Mair, 1996). Four spectral moments are usually considered:

- The first spectral moment is the spectral *centre of gravity* or *mean*, also called centroid frequency. Reflecting the average energy concentration, it corresponds to the frequency area primarily excited during the production of the fricative. It permits the differentiation between the two sibilants /s/ and /ʃ/ (Li, Edwards and Beckmans, 2009).
- The second spectral moment is the *standard deviation* or the dispersion of the noise. It reflects the average energy range and is used to distinguish a flat diffuse spectral shape (as in /f/) from a peaky compact one (as in /s/).

- The third spectral moment is the dissymmetry of noise energy in the frequency range under consideration, also called *skweness*. A skewness of zero reflects a symmetrical distribution of energy around the mean; a positive skewness reflects energy concentrated on the right tail of the distribution and a negative skweness energy concentrated on the left tail of the distribution. When applied to acoustic spectra, positive and negative skewness correspond to a concentration of energy respectively in the lower and higher sound frequencies (Jongman et al., 2000; Li et al., 2009). Thus, it may be used to make a distinction between the two sibilants /s/ and /ʃ/, as /ʃ/ should have a positive value and /s/ a negative value.
- The fourth spectral moment, called *kurtosis,* measures the peakedness of the distribution. A positive kurtosis reflects a relatively peaked distribution – i.e., a spectrum characterized by an important focalization of energy around a single peak – whereas a negative kurtosis corresponds to a flat distribution; that is, a flat spectrum without clearly defined peaks. This spectral moment allows distinguishing between fricatives involving different tongue postures as these articulatory differences entail modifications of the peakedness of the spectral shape.

I.3.1.2.3 Data from developmental studies

I.3.1.2.3.1 Spectral moments in developmental studies

The production of French fricatives has been relatively little studied, whether in adult or in child populations. Spectral moments analysis has been used in a couple of developmental studies to acoustically describe the production of fricatives by children. Given the limited amount of research investigating this issue, we will discuss developmental studies involving French as well as other languages.

Nissen and Fox (2005) used spectral moment analyses to examine the acoustic properties of English voiceless fricatives (/f, s, θ, ʃ/) produced by adults and children aged from 3 to 6 years of age. The aim of their study was threefold: (1) provide an acoustic description of adult and children's production of voiceless fricatives based on different measures, (2) assess the impact of factors either linked to the subject (age, gender) or to the targeted sound (place of articulation and vowel context) on the acoustic characteristics of fricative productions and (3), identify which combinations of acoustic parameters allow classifying fricatives in terms of place of articulation. Their results confirmed that the first and third spectral moments allow differentiating between the productions of non-sibilant (/f, θ/) and sibilant (/s, ʃ/) fricatives as well as between sibilant /s/ and /ʃ/. Then, the measure of spectral variance (second spectral moment) was found to significantly differentiate between sibilant and non-sibilant fricatives. Besides, their study also demonstrated a significant PoA by age interaction effect for spectral mean, skweness and kurtosis measures ensuing from a greater distinction between /s/ and /ʃ/ as age increased. More precisely, a sibilant contrast (between /s/ and /ʃ/) started emerging by 5 years of age in terms of spectral mean and in 4-year-olds for spectral skweness (see Figure 10). Indeed, and as shown in the Figure below, the spectral mean of targeted /ʃ/ is very elevated in 3-year-olds and 4-year-olds then starts decreasing from that age towards the adult variant. The absence of place-of-articulation contrast between the realizations for the two sibilants /s/ and /ʃ/ in the youngest children suggest a protracted period of acquisition for this specific contrast. This could be linked to the fact that toddlers are still in the process of acquiring the necessary articulatory skills for achieving constriction, as well as to the smaller size of their vocal tract.

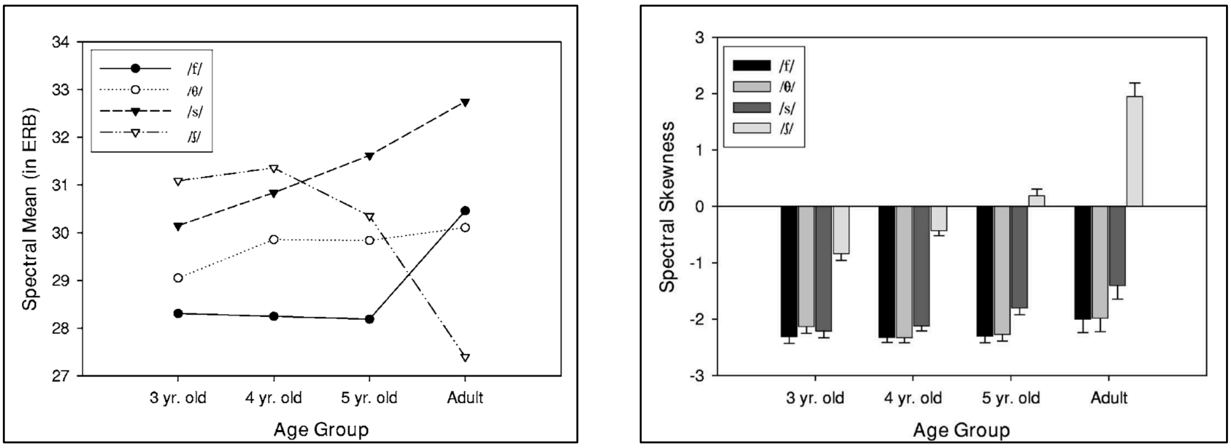

Figure 10: Spectral mean (left) and spectral skewness (right) as a function of speaker age group and place of fricative articulation, extracted from Nissen and Fox (2005).

In a cross-linguistic perspective, Li and collaborators used spectral moments analysis to investigate acoustic characteristics of voiceless sibilant fricatives in English and Japanese toddlers (Li, Edwards and Beckman, 2009). More specifically, they examined the acquisition of the place-of-articulation contrast between the alveolar /s/ (present in the two languages) and its post-alveolar counterpart /ʃ/ in English and /ɕ/ in Japanese in 2- and 3-year-old children. The production of fricatives was elicited with a word repetition task and fricatives were analysed combining spectral moment and transcription analyses. In addition, productions of both groups of children were compared to data collected from five adult native speakers of each language, using the same experimental procedure. Analyses of adult data revealed cross-linguistic differences in the acoustic parameters used to produce the contrast as well as in the degree of separation between the two voiceless sibilant fricatives. Amongst other things, a clear difference in the localization of the centre of gravity was observed for the English /s/ and /ʃ/, whereas, in Japanese, the /s/ and /ɕ/ were less clearly differentiated in terms of the first spectral moment. According to the authors, these different acoustic realizations may stem from cross-linguistic articulatory differences in the production of the alveolar /s/. Data from the two groups of children also revealed language-specific patterns, based on both transcription and acoustic analyses. First, transcriptions showed that English-speaking children generally produced the alveolar /s/ more accurately than the post-alveolar /ʃ/ while Japanese-speaking children displayed better performances for the post-alveolar /ɕ/. Then, acoustic analyses indicated that the children produce less distinctively the place-of-articulation contrast than adults. In sum, this study highlighted the fact that language-specific differences at a phonetic level might affect the acquisition of fricative sounds not yet mastered at two and three years of age.

Previously mentioned in our review of developmental studies about French vowel production, the last study to be discussed in this section investigated the acoustic characteristics of fricatives produced by normally hearing *vs.* cochlear-implanted French-speaking children (Grandon, 2016). As we did previously for vowels, we report here the results for the normally-hearing children aged between 5;7 to 10;6 years. The production of fricatives was elicited via both word-repetition and naming tasks whose stimuli involved the French voiceless fricatives /f/, /s/ and /ʃ/ in word-initial position followed by the vowels /i/ and /u/. Spectral moment analysis focused more specifically on the distinction between the alveolar /s/ and post-alveolar /ʃ/. Results showed that normally-hearing children produced fricatives with spectral mean values similar to those of normally-hearing children and adults reported in the literature. More precisely, their productions of the fricatives /s/ and /ʃ/ are characterized by distinct centres of gravity. These results are consistent with those of Nissen and Fox (2005) which showed an emergence of this contrast from the age of 4. Grandon (2016) also found similar standard deviations for /f/ and /s/, both higher to that of /ʃ/, indicating a more diffuse distribution of spectral energy for labiodental and alveolar fricatives. This finding is in contradiction to those of Nissen and Fox (2005) but are in line with the study of Li et al. (2009) which similarly showed different spectral variance for /s/ and /ʃ/. Finally, skewness values were similar to those of Nissen and Fox (2005), as post-alveolar fricatives were characterized by a higher skewness than alveolar ones. However, post-alveolar displayed a greater intensity around the centre of gravity than alveolar ones. Besides, this study also highlighted the effect of vocalic context on spectral moments. Indeed, the spectral mean of the alveolar /s/ was found to be higher when followed by the vowel /i/. While the spectral mean of labio-dental and post-alveolar fricatives was not subject to an effect of the vocalic context, it did impact the other three spectral moments of the fricatives. Finally, the production of fricatives was neither affected by chronological age nor by the task or the degree of lexical complexity.

In summary, the review of developmental studies about spectral moments has shown: (1) language-specific differences for the acquisition of fricative sounds which would not yet be mastered at two and three years of age and (2), a protracted period of acquisition for the place-of-articulation contrast between the two sibilants /s/ and /ʃ/ which would emerge around the age of 4.

I.3.1.2.3.2 Global order of acquisition

Albeit more numerous than works about vowels, a limited number of studies have investigated global consonantal acquisition in French with the purpose to identify general developmental trends and establish an order of emergence and acquisition of consonant phonemes. If we go back to the chronology proposed by Rondal (1999) for the acquisition of French phonemes (mentioned in the previous section about vowels), it indicates that the labial stops /p, b/ and the nasals /m, n/ are the first consonants to be acquired, before 4 years of age. They are followed by the dental and velar stops /t, d, k, g/, the nasal /ɲ/ and the labiodental fricative /f/, acquired a little after 5 years. The alveolar fricative /s/ and the two liquids /l, ʁ/ would emerge right before 4 years and be acquired after 7 years and the last emerging consonants are the alveolar and post-alveolar fricatives /z, ʃ, ʒ/.

More recently, a large-cohort study led by MacLeod and colleagues (2011) has focused on consonantal acquisition in 156 Canadian French-speaking monolingual children aged from 20 to 53 months (MacLeod, Sutton, Trudeau & Thordardottir, 2011). Consonants were elicited with a word-naming task and several analyses were involved, including analyses of consonant inventory and accuracy (measured with PCC and WWP). Given the gradual nature of phonological development, they distinguished three stages in consonant acquisition based on which they labelled consonants as: (1) "customary", when produced accurately by at least 50% of the children in at least two positions within the word (that is, word-initial/medial/final), (2) "acquired", when produced accurately by at least 75% of the children in all word positions and (3), "mastered", when produced accurately by at least 90% of the children in all word positions (as shown in Table 6).

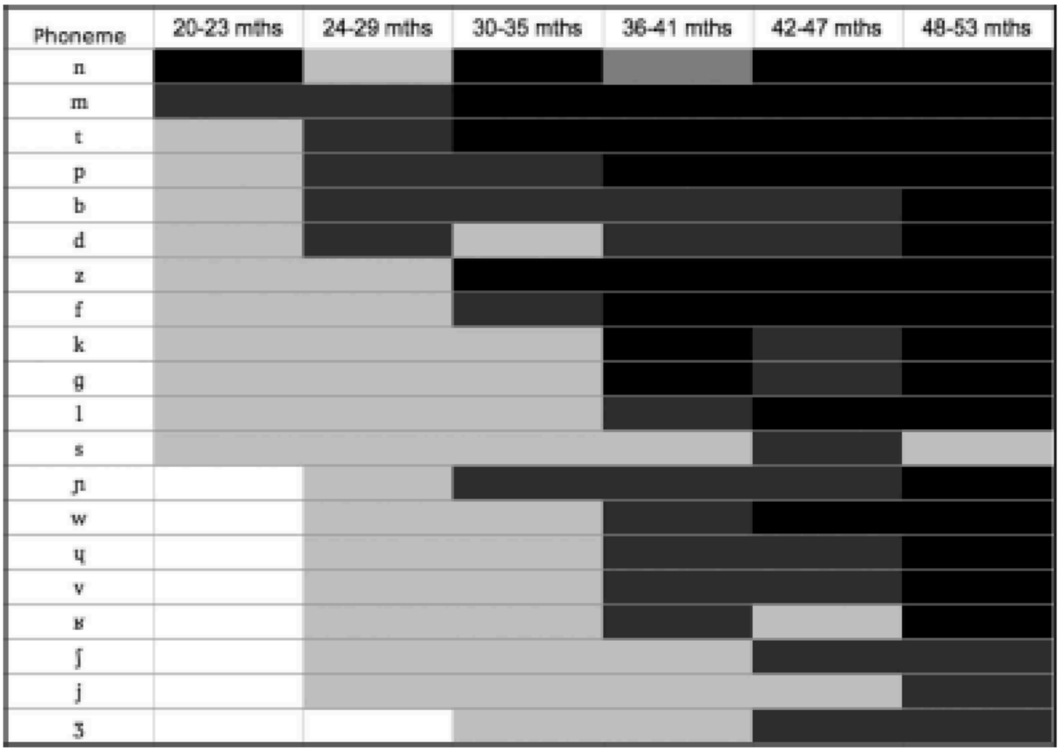

Table 6: Consonant acquisition across the six age groups with customary phonemes in light grey, acquired phonemes in dark grey and mastered phonemes in black, extracted from MacLeod et al. (2011).

Their results enabled them to identify three sub-groups of consonants:

- early consonants including the voiceless dental stop /t/, the nasals /m, n/ and the voiced fricative /z/, acquired and mastered before 36 months;
- intermediate consonants, including voiced and voiceless stops /p, b, d, k, g/, the nasal /ɲ/, voiced and voiceless fricatives /f, v/, the liquids /ʁ, l/ and the two glides /w, ɥ/, acquired and mastered between 36 and 53 months;
- late consonants, including voiced and voiceless fricatives /s, ʒ, ʃ/ and the glide /j/, acquired after 53 months.

These three sub-groups of consonants did not follow the same developmental pattern from their emergence (i.e., first appearance of the consonant, regardless of the appropriateness of its use) until their mastery. Indeed, early mastered consonants (/t, m, n, z/) were found to emerge early as well, suggesting a relative ease in establishing both phonetic and phonological representations for these consonants. Developmental trajectories for intermediate and late consonants are more variable, with some consonants (e.g., /v, ʒ, ʁ/) emerging and being mastered late, possibly due to a higher level of phonetic difficulty and ensuing protracted development of phonological representations, and consonants (e.g., /s, ʃ, l, j/) emerging early but being mastered much later. Globally, the degree of consonant accuracy was shown to significantly increase a little before 36 months reaching a relative plateau around 42 months.

Besides, and most interestingly, they identified different patterns of acquisition depending on the position of the consonant within the word (initial, medial or final), that is to say, word position was found to influence the order of acquisition of certain phonemes. Globally, their results revealed that consonants tend to emerge first in word-initial position, then in medial position and ultimately, in word-final position. More precisely, they observed the following acquisition patterns:

- the consonants acquired the latest in word-initial position are the fricatives /s, ʒ/, the liquids /l, ʁ/ and the glides /j, w, ɥ/;

- the consonants acquired the latest in word-medial position are the velar stop /k/, the post-alveolar fricatives /ʃ, ʒ/ and the liquid /ʁ/;

- the consonants acquired the latest in word-final position are the voiced stops /d, g/, the voiced fricative /v/ and the post-alveolar fricatives /ʃ, ʒ/.

Findings of this study demonstrated that consonants are not acquired in a uniform manner. It appears that certain developmental trends detected by MacLeod et al. (2011) are also found in the developmental timeline established by Rondal (1999), such as the early acquisition of /t, m, n/ and the late acquisition of the post-alveolar fricatives /ʃ, ʒ/. However, it is quite obvious that Rondal's acquisition order, albeit one of the few (if not only) chronologies proposed at that time, required some refinements. Indeed, other developmental studies have similarly highlighted the need to take into account the phoneme's position within the word and/or the syllable in order to determine a nuanced order of acquisition and phonemic inventory. As consonantal acquisition can hardly be studied in isolation from the consonant phonemes' status within syllabic structure – i.e., which syllabic constituent the consonant occupies – and position within the word, we will continue our review of developmental/acquisition studies about French consonant production in the next section devoted to the French syllabic structure.

I.3.1.3 Syllabic structure

The syllable is an intermediate linguistic unit between phonemes and words studied at phonetic and phonological levels of analysis. As already mentioned, the syllable, as a phonological unit, possesses an internal hierarchized structure organized into different constituents: the onset and the rhyme, itself sub-constituted of a nucleus and a coda (see Figure 11).

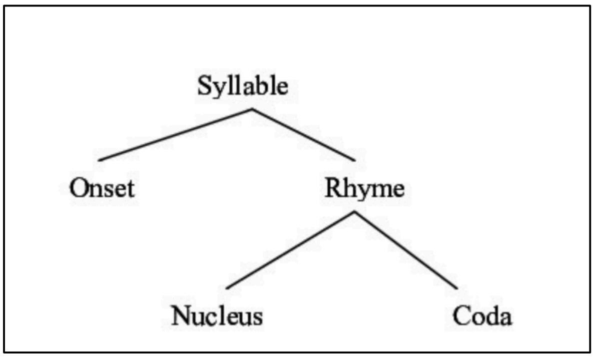

Figure 11: Representation of the internal structure of the syllable.

As defined by Laver (1994: 114), the phonological syllable is a “complex unit, made up of nuclear and marginal elements”. Indeed, the nucleus (also called syllabic segment) is the minimal and compulsory constituent of the syllable and is generally occupied by a vowel. The onset and the coda are optional constituents[35] of the syllabic structure (marginal elements also called non-syllabic segments) and are generally occupied by consonants. Moreover, onset and coda constituents are characterized by different segmental restrictions. Indeed, for a given language the consonantal inventory is generally more restricted in coda than in onset position and across languages, coda consonants would be more subjected to phonological processes of substitution or elision (Ridouane, Meynadier & Fougeron, 2011). In addition, onset and coda constituents can be structurally simple or complex or, in other words, be made up of singleton or clustered consonants. Complex onsets/codas are also referred to as “branching”. Besides, certain syllabic constituents, such as word-final codas or complex structures involving consonantal clusters (whether word-initial/media/final) can be subjected to different syllabifications (we come back to this in the subsequent sub-sections).

According to the Sonority Sequencing Principle (Selkirk, 1984; Clements, 1990), the syllable, as a phonological unit, is organized based on the segments’ degree of sonority. The Sonority Sequencing Principle (SSP) states that the sonority of a syllable’s segments tends to rise from the beginning to the nucleus – constituting the peak of sonority –, then subsequently decreases until the end of the syllable. The syllable is thus characterized by a cycle of sonority culminating in its nucleus. The sonority of a sound corresponds to its relative perceptual prominence (or perceived intensity) and speech sounds can be ranked based on their degree of intrinsic sonority following a sonority scale, such as the Sonority Hierarchy proposed by Clements (1990) in Figure 12:

$\underbrace{\text{Stops > Affricates > Fricatives}}_{\text{Obstruents}}\text{ > Nasals > Liquids > Glides > Vowels}$

LEAST SONORANTS ----------------------> MOST SONORANTS

Figure 12: Sonority Hierarchy, adapted from Clements (1990).

This account of syllabic structure thus entails an interaction between the syllable’s internal organization and the degree of sonority of its segments. Moreover, it presupposes that syllables from all languages would conform to this allegedly universal principle. In that perspective, violation of the sonority cycle would necessarily be interpreted as a syllabic break. However, the SSP cannot fully account for certain examples of consonantal sequences such as consonantal clusters involving a /s/ followed by two or more consonants (as in the French monosyllabic word “strie”).

In French, each syllable includes a single vowel (no diphthongs) and consonants cannot be syllable nuclei (as opposed to English where /r, l/ can be syllabic). Moreover, it is acknowledged that each consonant pertains to the same syllable as the following adjacent vowel. Therefore, syllabic breaks occur before single consonants in intervocalic position (Adda-Decker, Mareüil, Adda &

[35] However, the onset is syllabically optional but universally compulsory, since there is no language without syllable of CV type; whereas the coda constituent is both syllabically and universally optional (Meynadier, 2001).

Lamel, 2002). Overall, French favours open syllabification, a tendency reinforced by phenomena of *liaisons* and chaining in connected speech (Wioland, 1991). Open syllables represent 80% of all syllables and the CV type is the most frequent, reaching 55% of occurrence (Adda-Decker, Mareüil, Adda & Lamel, 2002). Table 7 presents French syllabic structures with percentages of occurrence based on a speech corpus involving approximately 300 hours of shows of radio interviews (Adda-Decker et al., 2002).

Syllable type	*W-syll isol*
CV	57.6
V	14.6
CCV	9.8
CVC	9.2
C	4.3
VC	2.6
CCVC	1.0
CCCV	0.5
CVCC	0.3
VCC	0.2
CCVCC	ϵ
CVCCC	ϵ
CCCVC	ϵ
VCCC	ϵ
CCCVCC	ϵ

Table 7: French syllabic structures and their percentage of occurrence (with W-syll standing for *written language syllables from isolated words* and $\in$ indicating a percentage < 0.05), extracted from Adda-Decker et al. (2002).

As is shown in Table 7, open syllables of CV type are clearly predominant but nevertheless, a wide variety of syllables exist in French, which syllabic structure allows for consonantal clusters of up to three consonants in both onset and coda positions. As stated above, our analyses will more particularly target the development of the following syllabic constituents: word-final singleton consonants, word-initial complex onsets, and word-final complex codas (i.e., consonantal clusters in word-final position). Before we move on to the description of these specific syllabic constituents in French, it should be noted that the status of word-final consonants in syllabic structure is still debated and that they are consequently subjected to different syllabifications across different theoretical frameworks. Indeed, certain scholars have assumed that word-final consonants should be analysed similarly as word-internal consonants, namely be incorporated to the previous rhyme as codas (Rialland, 1994; Dell, 1995). However, this analysis is rejected by other phonologists based on the fact that word-final consonants behave more like consonants occurring in onset and therefore, should be syllabified as onsets of empty-headed syllables (Kaye, Lowenstamm and Vergnaud, 1990). Figure 13 displays tree-structure representations for these two potential syllabifications of word-final singleton consonants in French.

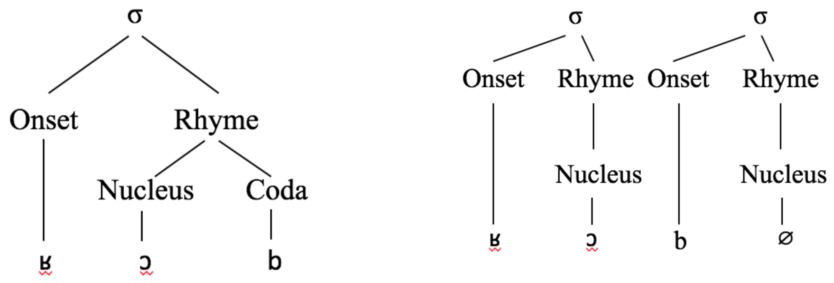

Figure 13: Tree-structure representations of word-final consonant syllabified either as coda (left) or as onset of empty-headed syllable (right).

An intermediary position put forward by Pigott (1999) consists in considering that word-final consonants can be analysed either as codas or as onsets of empty-headed syllable (from now on, OHES), depending on the segmental distributional properties of the language. In that perspective, the syllabic status of word-final consonants would be determined by the specific distribution of consonants both in onset and coda position in a given language. If similar types of consonants are allowed/restricted both in word-final and word-medial position, word-final consonants should be analysed as rhyme-dependent elements; that is, as codas. However, in cases where the inventory of consonants allowed in word-final position is similar to that occurring in onset position, while being more restricted in word-medial position, word-final consonants should be analysed as OEHS. Following that view, it has been argued that word-final consonants – whether singleton or clustered – should be analysed as OEHS in French (Charette, 1991; Dell, 1995). Indeed, the consonants' inventory permissible in word-final position is unrestricted, similarly as in onset position, whereas it is restricted in word-medial coda position. Moreover, different types of consonant sequences can be found in that position in French, whether involving a stop followed by a liquid (SL clusters, such as in *table*) or conversely involving a liquid followed by a stop (LS clusters, such as in *porte*). Given that SL clusters have the sonority profile of branching onsets and that similar SL sequences can be observed both in word-initial and word-final positions, such sequences in word-final position should be syllabified as branching onsets of empty-headed syllables (e.g., /*ta.blø*/). In contrast, word-final LS clusters are analysed as heterosyllabic sequences (thereby not violating the SSP), so that their first consonant is syllabified as a coda and their second consonant as OEHS (e.g., /*pɔʁ.tø*/). In addition, phenomena of final schwa epenthesis after a final consonant observed in surface realizations (whether in adult or in child speech) can also be interpreted as supporting this theoretical stance, as the final schwa would be added to fill the nuclear position of empty-headed syllables. Regarding the acquisition of syllabic structure, Goad and Brannen (2003) have advanced the hypothesis that word-final consonants would initially always be syllabified as onsets by children, independently of language-specific syllabification. This hypothesis is based on the idea that onsets are less complex to produce than codas, which involve a branching rhyme, and that the first syllables to be produced by children would be of CV type. However, and as will be discussed in the subsequent sections, developmental patterns for word-final singleton and consonantal clusters in French appear to be less straightforward as children are in the process of developing adult-like representations.

In the frame of this doctoral thesis, we have chosen not to adhere to any particular phonological theory regarding the underlying syllabic representation of word-final (singleton/clustered) consonants, in order to avoid any priori assumption and keep an exploratory and empirical approach towards the collected data. Therefore, our use of the terms "word-final codas" and "word-final complex codas" will not refer to an underlying representation but only to the surface syllabic position. In the remaining of this section, we will describe the characteristics of the different targeted syllabic constituents in French and we will review the acquisition studies that focused on these structures.

I.3.1.3.1 Word-final singleton codas

As already said, there is no segmental restriction for singleton consonants occurring in word-final position in French. Thus, all manners (stop/fricative/nasal) and places of articulation (from bilabial to uvular) are permitted in that position. Besides, French is characterized by a high proportion of open syllables, representing approximatively 80 % (Adda-Decker et al., 2002) of all syllables and consequently, word-final singleton consonants' frequency of occurrence is relatively low (approximately 20% of all syllable types). As shown in Table 8 (taken from Wioland, 1985), the liquid /ʁ/ would be the most frequent consonant in word-final position in French, followed by the stop /t/ and the other liquid /l/. Consonants least occurring in word-final position would be the stops /p, b, g/ and the labio-dental fricatives /f, v/.

Final consonants	Frequency in %
/ʁ/	42,4
/t/	9,7
/l/	9,4
/n/	8,5
/m/	7,2
/k/	5,5
/s/	4,6
/z/	3,5
/j/	1,9
/d/	1,7
/f/	0,8
/v/	0,8
/p/	0,7
/b/	0,3
/g/	0,3

Table 8: Frequency of word-final consonants in spoken French, drawn from Wioland (1985).

As already mentioned, it has been shown that word-final consonants are acquired later than word-initial and word-medial consonants in French (MacLeod et al., 2011). According to Fikkert (1994) word-final obstruents (i.e., stops and fricatives) would be acquired before word-final sonorants (i.e., nasals, liquids and glides). More precisely, the first consonants to be produced in that position would be voiceless stops and the last, voiced obstruents and the liquid /ʁ/ (Bernardt & Stemberger 1998; Kehoe & Stoel-Gammon, 2001). However, these developmental trends have been established based on data from Dutch- and English-speaking children and studies carried out with French-speaking children have yielded variable findings, either partly confirming or refuting these results.

In the frame of his doctoral dissertation focusing on the acquisition of syllabic structure in

French, Rose (2000) conducted a diary study involving two Canadian French-speaking toddlers. Results of this investigation indicated different developmental patterns in both children. Indeed, one child was found to have simultaneously acquired all word-final consonants by 2;04 of age, whereas the other child already produced almost all word-final singleton consonants at 1;7, except for the liquid /ʁ/. Interestingly, word-final /ʁ/ emerged at the same time as word-medial consonants in that child, around 2;3 years of age. Consequently, Rose (2000) claimed that several syllabifications of word-final singleton consonants can co-occur within the same child, depending on the underlying phonological representation of the consonant, and that this particular child initially analysed word-final /ʁ/ as codas and other word-final consonants as OEHS. Another longitudinal study involving two French-speaking children (Demuth & Tremblay, 2008) similarly showed that word-final singleton consonants started being produced between 1;3 and 1;8 years. However, both children showed word length effects, as word-final consonants were acquired later in disyllabic words than in monosyllabic words. These two studies suggest that word-final singleton consonants would emerge around 1;7 and that most consonants would be produced before 2 years in that position.

Conducting a cross-sectional study of French-speaking monolinguals aged 2;4, Hilaire-Debove and Kehoe (2004) have assessed the production of word-final obstruents and sonorants, elicited via a word-naming task involving monosyllabic and dissyllabic words. Their results indicated that: (1) voiceless stops were the first class of consonants to be acquired and accurately produced by the children, (2) sonorant consonants emerged earlier than obstruents and (3), production of word-final consonants is impacted by word length, as children produced significantly more word-final consonants in monosyllabic words. Besides, developmental trends allowed them to divide the children into different sub-groups as part of the children were found to be less advanced in the acquisition of word-final consonants and to display similar patterns as English-speaking children; that is, they produced more readily voiceless stops and nasals and less frequently voiced obstruents and liquids. In contrast, the other group produced almost as much liquids as voiceless stops in word-final position. Superposition of the production patterns of this latter group on the frequencies of consonant categories in word-final position established by Wioland (1985) revealed a correlation between the two, suggesting an impact of frequency on consonantal acquisition (see Figure 14).

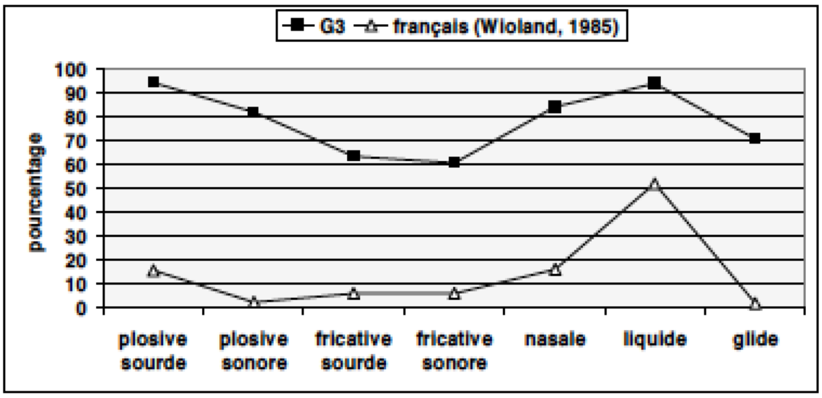

Figure 14: Frequencies of consonant categories in word-final position (Wioland, 1985) and production patterns of the group of children (G3), extracted from Hilaire-Debove and Kehoe (2004).

Investigating the development of French consonantal system, the longitudinal case study conducted by Dos Santos (2007) yielded somewhat different results. Indeed, the child observed appeared to initially produce only the voiceless alveolar fricative /s/ and stops in word-final position, at the age of 2. Then, all consonants were eventually acquired in that position by the age of 2;7, except for the liquid /ʁ/ which remained absent from the child's repertoire. A general devoicing process was observed for all word-final voiced obstruents, persisting longer for fricatives. In addition, late-acquired post-alveolar fricatives /ʃ - ʒ/ were found to be initially elided or substituted by the alveolar /s/ and subsequently replaced by the labio-dental /f/. Finally, both word-final sonorants /n/ and /l/ were acquired around 2;4 without being subjected to substitution processes. Similar to Rose (2000), Dos Santos postulated that the child initially syllabified sonorants (/n, l/) as codas to subsequently reanalyse them as OEHS at 2;4, which might explain the fact that they were acquired later than obstruents but before codas emerging only around 2;7 years of age.

Within a different approach, Yamaguchi (2012) has also studied consonantal acquisition in French, focusing on distinctive features and their associated principles. More precisely, her work was aimed at showing that consonantal acquisition can be modelled based on contrastive features. Data from her doctoral dissertation consisted of longitudinal recordings of spontaneous productions from two French-speaking children aged from 1;4 to 2;8 and from 1;09 to 4;00. Her results showed that the first features to be acquired by the children were [+sonorant] and [+approximant] and that [+posterior] and [+lateral] were the last features to be acquired. The order of acquisition of the other features was found to be variable. Besides, she also noted that the place-of-articulation contrast [Labial] *vs.* [Coronal[36]] was quickly acquired. Yamaguchi (2012) claimed that, according to the sonority principle (SSP), sonorants – and particularly, approximants – are favoured in word-final position, indicating that consonantal (and feature) acquisition is impacted by syllabic structure.

We conclude this section by discussing two bilingual acquisition studies previously mentioned involving French-speaking children: the case study of Almeida (2011) investigating the acquisition of syllabic structure in a simultaneous Portuguese-French bilingual toddler and the transversal study lead by Kehoe and Havy (2019) involving French-speaking toddlers exposed to different L1s. Almeida's results (2011) indicated that obstruents emerge and are acquired much earlier than sonorants in word-final position, a developmental trend similar to that of the child observed by Dos santos (2007). Kehoe and Havy (2019) found that bilingual children exposed to L1s characterized by high frequency/complexity of word-final consonants (see above) produced more consonants in that position and were segmentally more accurate in their productions than those exposed to L1s with low frequency/complexity of word-final consonants. Besides, bilinguals were globally more accurate than monolinguals in their word-final consonants' productions, suggesting both cross-linguistic effects and a more general bilingual advantage.

In summary, this review of developmental studies about the acquisition of word-final consonant in French has shown the following developmental trends: (1) voiceless (labial and coronal)

[36] Coronal sounds are those articulated using the front part of the tongue (i.e., the tongue tip, blade, and the forward part of the body). This includes dental, alveolar, retroflex, palato-alveolar, alveo-palatal and palatal places of articulation.

stops are the earliest-acquired consonants in that position, (2) voiceless fricatives are acquired before voiced fricatives and voiced post-alveolars would be the latest fricatives to be acquired in that position, (3) different developmental timelines are observed for the word-final liquid /l/, (4) the rhotic /ʁ/ is generally one of the last consonant to emerge and be acquired in that position and (5), the acquisition of word-final consonants might be impacted by word length, sonority constraints and distributional frequency of consonants in that position.

I.3.1.3.2 Word-initial branching onsets

In French, different types of consonant sequences can occur in word-initial onset and clusters of up to 3 consonants are attested in that position. Branching onsets consisting in an obstruent followed by a liquid (from now on, OL clusters) are the most frequent sequences (56%). Moreover, OL clusters involving stops and the rhotic /ʁ/ (such as in *bras*) are the less segmentally restricted sequences: all stops can occur, whereas only labial fricatives are allowed to occur in fricatives+rhotic sequence (such as in *fromage*). Then, OL clusters involving either stops or fricatives and the lateral /l/ are also more constrained. Indeed, word-initial sequences involving coronal stops (such as /tl/ or /dl/) are not permitted (Dell, 1995) and only the sequence /fl/ is to be found in French (such as in *fleur*). French also includes word-initial branching onsets involving a semi-consonant in dependent position, either preceded by an obstruent, whether a stop or fricative (CG from now on, such as in *poisson* and *chien*) or by a sonorant (such as in *luire* and *nier*). Besides, sequences involving /s/ followed by one or more consonants (/s/C or /s/CC clusters) are also permitted in word-initial position. Less frequent than word-initial OL clusters, such sequences are mainly /s/+stops clusters (such as in *spatule*) or, even more rare, /s/+OL clusters comprising three consonantal elements (such as in *strident*). Besides, word-initial /s/C(C) and OL clusters are subjected to different syllabifications. While OL clusters are represented as branching onsets, the initial /s/ of /s/C(C) clusters is considered as a left-edge adjunct (Goad and Rose, 2004) or extrasyllabic segment (Clements & Keyser, 1983) followed by the onset. Finally, syllables involving branching onsets (CCV) would make up approximately 11% of all syllable types (Adda-Decker et al., 2002; Rousset, 2004) found to occur in French. However, both word-initial and word-medial branching onsets are merged into this percentage and there are, to our knowledge, no source documenting, on the one hand, frequencies of branching onsets in different positions within the word and, on the other hand, frequencies of the different consonant sequences just described.

A limited number of studies have focused on the acquisition of word-initial clusters in French and they have often been restricted to OL sequences. A recurrent finding of these studies is that OL sequences consisting in an obstruent followed by the lateral /l/ (Cl, from now on) are generally acquired before those involving an obstruent followed by the rhotic /ʁ/ (from now on, Cr). Indeed, results from the cross-sectional study conducted by Kehoe and collaborators with French-speaking children aged between 1;10 and 2;10 have shown significantly better accuracy scores for word-initial Cl sequences than for Cr ones (Kehoe, Hilaire-Debove, Demuth & Lleó, 2008). The authors proposed that the slower acquisition of Cr sequences might result from the variable phonetic realization of the rhotic. The earlier acquisition of Cl sequences has also been detected in the above-mentioned longitudinal case studies (Dos Santos, 2007; Almeida, 2011). More specifically, data from Dos Santos' dissertation (2007) indicated a later acquisition of Cr branching onsets (around 2;07) than Cl sequences already produced before 1;10. Moreover, the rhotic remains globally absent from the repertoire of the child. Finally, Almeida (2011) reported the same order of acquisition. Indeed, Cl sequences emerged in the child's productions between 2;5 and 2;09, whereas Cr started only to be produced at 2;10.

The types of phonological processes affecting branching onsets have also been studied. Globally, the most frequent phonological process is cluster reduction by which the first consonant is generally preserved and the following liquid is elided (Rose, 2000; Almeida 2011). This production strategy can be interpreted in terms of sonority constraints, as the most sonorant element would be deleted in order to maintain a greater sonority contrast between the consonant and the vowel (Bernhardt & Stemberger, 1998). Reversed cases in which the liquid is maintained while the first consonant is deleted or, even more radically, total cluster reduction in which both consonants are elided have also been noticed, however much less frequently (Dos Santos, 2007). Interestingly, Almeida noted that before starting to produce words containing branching onsets, the child seems to avoid produce those words, possibly because she has not yet developed phonological representations for branching onsets. Going back to Kehoe et al.'s study (2008), similar error patterns were found for both OL and CG sequences, such as liquid substitution (like [blos] for [bʁɔs] and [plɑ̃] for [viɑ̃d]) and vowel epenthesis (like [piˈjano] for [pjano]). These patterns were assumed to suggest no structural differences between the two types of sequences, both analysed as branching onsets.

A couple of studies have compared the acquisition of word-initial *vs.* word-final clusters in French-speaking children. Demuth and Mccullough (2009) longitudinally studied the acquisition of clusters in two French-speaking children aged from 1;5 to 3;0 and more specifically examined word-initial and word-final obstruent-/ʁ/ (OR) clusters as well as word-final /ʁ/-obstruent (RO) clusters. Their results have shown that word-initial clusters are acquired before word-final clusters, contrary to studies about German- and English-speaking children who tend to acquire word-final clusters before word-initial clusters (Lleó & Prinz, 1996; Kirk & Demuth, 2005). Moreover, word-initial clusters reached higher levels of accuracy earlier than word-final clusters. Their results confirmed the cross-sectional findings from Demuth and Kehoe's study (2006). In contrast, word-initial clusters were not found to be acquired earlier than word-final clusters in a study involving French-speaking monolinguals and French-dominant children (slightly exposed to English) aged from 18 to 36 months (Bishop & Minor-Corriveau, 2015). Furthermore, word-initial clusters were as much affected by phonological processes of reduction than word-final clusters. Consonantal clusters were acquired earlier and less subjected to truncations in French-dominant children, which was attributed to a positive influence of English leading to an accelerated cluster acquisition in French. In line with this, results from Kehoe and Havy (2019) have shown that bilingual children exposed to L1s characterized by high complexity of word-initial clusters were segmentally more accurate in their productions of word-initial OL clusters than those exposed to L1s with low complexity of word-initial clusters. Besides, bilinguals were also globally more accurate than monolinguals in their clusters' productions, possibly due to both cross-linguistic interaction and a general bilingual effect.

This review of developmental studies about the acquisition of word-initial clusters in French has shown the following developmental trends: (1) Cl sequences are acquired before Cr sequences, (2) the most frequent phonological process affecting word-initial branching onset is cluster reduction by which the first consonant is preserved and the following liquid is elided, (3) word-initial clusters tend to be acquired before word-final clusters and (5), bilinguals seem to be advantaged in their acquisition of word-initial clusters.

I.3.1.3.3 Word-final complex codas

As noted above, different types of consonant's sequences can be found in word-final position in French. The most frequent sequences are OL and LO clusters. OL clusters involve similar sequences than in word-initial position; that is, stops/fricatives followed by the rhotic /ʁ/ (such as in *zèbre* and *livre*) or by the lateral /l/ (such as in *peuple* and *souffle*). Moreover, the same segmental restrictions as those in word-initial onsets (see above) can be observed in that position. LO clusters include sequences made of the rhotic/ʁ/ or lateral /l/ followed by either a stop (such as in *porte* and *algue*) or a fricative (such as in *larve* and *marche*). French also allows for three-consonants clusters beginning with a liquid in word-final position (L+OL sequences, such as in *arbre* or L+OO sequences such as in *sculpte*). /s/C sequences are also attested in word-final position. These sequences are restricted to /s/+stops clusters (such as in *casque*) and can also comprise up to three elements in /s/+OL clusters (such as in *cadastre*). As already noted, word-final OL, LO and /s/C(C) sequences raise syllabation issues for being subjected to different syllabifications. There is, to our knowledge, no source documenting frequencies of word-final clusters in French.

There have been even fewer studies focusing on the acquisition of word-final clusters than on word-initial clusters in French. Also, they have already been mentioned in the previous section about word-initial clusters and therefore, we recap the key findings that pertain to consonant sequences occurring at the end of the word. First, word-final French clusters have been shown to be acquired later than word-initial sequences (Demuth & Kehoe, 2006; Demuth and Mccullough, 2009). Then, word-final clusters are most often subjected to phonological processes of reduction. Indeed, Demuth and Mccullough (2009) have observed that both OR and RO word-final clusters tend to be truncated to the obstruent; i.e., the rhotic undergoes reduction. They attributed this late acquisition of French word-final consonant sequences to the syllabic markedness and/or articulatory challenges that characterize these structures. By contrast, Bishop and Minor-Corriveau (2015) observed no difference in the rate of acquisition and truncations of word-initial and word-final French consonantal clusters.

In this section, we have provided a phonetic and phonological description of French, including its segmental characteristics and syllabic structure, focusing on specific syllabic constituents. Moreover, we have depicted the system in its fully developed, adult-like state. In addition, we have discussed segmental and syllabic acquisition through a review of the developmental studies. We will now proceed to the description of the three other languages to which our study's participants have been exposed; namely Italian, Arabic and Mandarin. As the toddlers involved in our study are simultaneous bilinguals, language acquisition occurs in both their languages. The two languages can thus be considered as their mother tongues or first languages, therefore both labelled as L1.

I.3.2 Comparative phonetic and phonological description of L1s

As mentioned above, we will describe the three different L1s from a comparative perspective; i.e., focusing on what properties they share or do not share with French. The description follows the same order as the description of French: (1) vowels, (2) consonants and (3), targeted syllabic constituents (word-final singleton codas, word-initial branching onsets and word-final complex codas). More specifically, each of these sub-sections will comprise two points: the description of phonemic (vowels/consonants) inventories and the description of the syllabic structure focused on the targeted syllabic constituents. Similarities and differences between the L1s and French will be presented in summary tables.

I.3.2.1 Segments

I.3.2.1.1 Vowels

I.3.2.1.1.1 Italian

As shown in Figure 15, standard Italian is reported to have seven oral monophthongual vowels /i, e, ɛ, a, u, ɔ, o/ (Agard & Di Pietro, 1964).

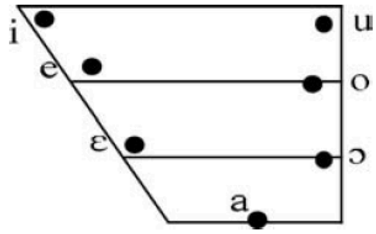

Figure 15: Italian vocalic system, extracted from Bertinetto and Loporcaro (2005).

It thus includes the contrast between front vowels (/i, e, ɛ/) and back vowels (/u, ɔ, o/) as well as between high (/i, u/), mid-high (/e, o/), mi-low (/ɛ, ɔ/) and low (/a/) vowels. It also includes rounded vowels (/u, ɔ, o/) but does not have nasal vowels nor a rounded anterior series. However, differences in number and/or phonetic quality can be found in the vowel systems of the various dialectal varieties of Italian (Romito and Trumper, 1989). Average formant values of standard Italian vowels can be found in Table 9.

	i	e	ɛ	a	ɔ	o	u
F1	290 ± 35	350 ± 45	490 ± 50	780 ± 45	550 ± 40	390 ± 60	320 ± 40
F2	2310 ± 140	2050 ± 110	1950 ± 100	1430 ± 80	970 ± 40	870 ± 80	800 ± 100
F3	2960 ± 165	2590 ± 100	2600 ± 80	2490 ± 110	2650 ± 160	2430 ± 160	2270 ± 140

Table 9: Average formant values of standard Italian vowels, extracted from Ferrero (1972), in Bertinetto and Loporcaro (2005:136).

The contrast between /e/ and /ɛ/ and between /o/ and /ɔ/ occurs only in stressed syllables. Vowels in unstressed syllables tend to be centralised. Furthermore, stressed vowels are lengthened in word-internal open syllables when occurring at the end of intentional phrase or under emphasis but not in word-final position (Bertinetto & Loporcaro, 2005). However, vowel duration is not contrastive in Italian, for vowel duration is conditioned by phonological context.

I.3.2.1.1.2 Arabic

It is generally attested that the stable core of the Arabic vocalic system is limited to the three cardinal vowels /i, a, u/ (Heath, 1997). Nevertheless, other vocalic segments are attested in studies about dialectal varieties of Arabic. Moreover, vowels can be either short (/i, a, u/) or long (/i:, a:, u:/). Indeed, vocalic duration is phonologically contrastive, at least in standard Arabic. However, the existence of such a contrast is discussed in the case of Maghrebian dialects in which short vowels have tended to disappear. Interestingly, short vowels have essentially a morphophonemic function in the root structure of Arabic words (Ali, 2013). Besides, speakers of Maghrebian dialects would also be prone to centralize short vowels in closed syllables while speakers of other dialects exhibit a more peripheral distribution (Pellegrino & Barkat, 1999). The vowel /a/ would be the less stable phoneme of the Arabic vocalic system. Moreover, its variable realization would depend on its contextual environment. as well as on regional varieties. For example, vowels following emphatic consonants (see next point) become pharyngealized and show a degree of F2 lowering, a phenomenon referred to as "pharyngealization spread" (Shar & Ingram, 2010). Figure 16 shows the basic triangular Arabic vocalic system.

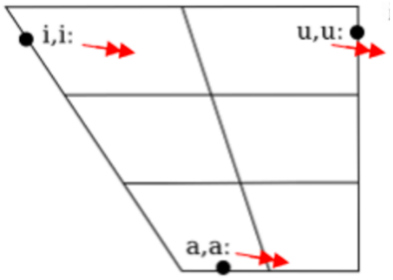

Figure 16: Arabic vowel system, with red arrows showing the direction of the vowels when they follow an emphatic consonant, extracted from Binasfour, Setter & Aslan (2017).

Given the variability characterizing the Arabic vowel system, it is probable that different vocalic sounds would be found in spoken Arabic (e.g., surface realizations) without being phonological. Besides, formants values of Arabic vowels / i, a, u/ would differ from those of the corresponding French vowels, particularly for the vowels /i/ and /u/ which would be phonetically closer to, respectively, the French vowels /e/ and /o/ (Nawafleh, 2012).

I.3.2.1.1.3 Mandarin

Different descriptions of the Mandarin vowel system are proposed in the literature. Following Duanmu (2007), Mandarin would include 5 basic monophthongal oral vowels /i, y, a, ɤ, u/. However, Mandarin is reported by other sources as having from 7 to 9 monophthongal oral vowels /i, y, (e), (ɛ), ə, ɚ, a, (o), ɤ, u/ (Bernhardt & Zhao, 2010; Hua & Dodd, 2000). Figure 17 shows the vowel chart with the five basic monophthongual vowels proposed by Duanmu (2007).

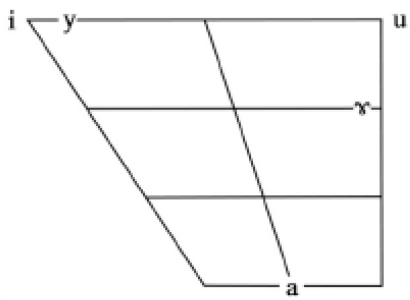

Figure 17: Mandarin monophthongual vowels, extracted from Yang and Fox (2017).

The [ɚ] is a central retroflex vowel, also called rhotic (Duanmu, 2007) and the /ɤ/ is a mid-close back unrounded vowel. In addition to these monophthongal vowels, there are also diphthongs and triphthongs in Mandarin. More precisely, there are 9 diphthongs, 4 with rising sonority /ai, ei, oʊ, ɑo/ and 5 with falling sonority /ia, uɑ, uo, ie, ye/, and 4 triphthongs (/iɑo, ioʊ, uae, uei/) (Hua & Dodd, 2000). Table 10 displays average F1-F2-F3 values and standard deviations for the vowels [i, y, ɤ, u, a, ə, ɚ].

Vowel /s.a.	F_1 mean	F_1 s.d.	F_2 mean	F_2 s.d.	F_3 mean	F_3 s.d.
[i]	300.42	56.33	2443.08	206.60	3384.78	254.92
[y]	310.10	52.83	2030.64	127.64	2418.58	185.00
[ɤ]	441.40	27.15	1059.34	92.41	2861.22	194.70
[u]	345.16	46.86	661.32	108.11	2783.00	225.76
[a]	956.98	157.23	1328.26	125.47	2813.06	233.33
[ə]	654.10	53.19	1220.38	101.17	2258.26	210.00
[ɚ]	428.34	53.37	1434.62	125.93	1810.82	100.22

Table 10: Average formant values and standard deviations for the vowels [i, y, ɤ, u, a, ə, ɚ] in male speakers, extracted from Zee & Lee (2001).

I.3.2.1.2 Consonants

I.3.2.1.2.1 Italian

As shown in Table 11, Italian includes 21 consonants (/p, t, k, b, d, g, m, n, ɲ, f, v, s, z, ʃ, l, ʎ, r, ts, dz, tʃ, dʒ/) and 2 glides /w, j/. The voiced sibilant post-alveolar fricative /ʒ/ is in brackets for it appears only marginally in loanwords.

PoA / MoA	Bilabial	Labio-dental	Inter-dental	Dento-alveolar	Retroflex	Post-alveolar	Alveolo-palatal	Palatal	Velar	Uvular	Pharyngeal	Glottal
Stop	p b			t d					k g			
Nasal	m			n				ɲ				
Trill				r								
Tap or Flap												
Affricate				ʦ ʣ		ʧ ʤ						
Fricative		f v		s z		ʃ (ʒ)						
Lateral approximant				l				ʎ				

PoA / MoA	Palatal	Labio-palatal	Labio-velar
Approximant	j		w

Table 11: Italian consonants, extracted from Bertinetto and Loporcaro (2005).

Italian includes similar places of articulation as French and involves an additional mode of articulation; that is, affricate consonants (/ts, dz, tʃ, dʒ/) which start like a stop and release as a fricative. The consonant /ʎ/ is a voiced lateral palatal. Part of the consonants can be geminated – i.e., doubled or lengthened – and gemination is contrastive, expanding the consonantal repertoire (Vieru-Dimulescu, 2008). The alveolar trill [r] is the unmarked allophone of the rhotic phoneme /R/ which can also be realised either as a uvular trill [ʀ] (in North Italy) or as uvular/alveolar/labio-dental approximant (Bertinetto & Loporcar, 2005). Typical of Tuscan Italian, a process of spirantization – i.e., consonant weakening – can affect voiceless, and to a lesser degree, voiced stops. Stop sounds become fricativised (e.g., /p, t, k/ > /ɸ, θ, h, ɦ/) under the effect of this phonological process which occurs in postvocalic context (Sorianello, Solé, Recasens & Romero, 2003).

Besides, all Italian fricatives are comprised in the French consonantal system, except for /ʒ/. It is worth noting that the occurrence of the phoneme /z/ is contextually restricted: it contrasts with /s/ only in intervocalic position within or at the right edge of lexical morphemes and does not occur in word/morpheme-initial position where only /s/ appears before vowels.

I.3.2.1.2.2 Arabic

Several descriptions of the Standard Arabic consonantal system may be found in the literature. As shown in Table 12, standard Arabic includes between 25 and 27 consonants (/b, t, d, k, q, ʔ, m, n, f, θ, ð, s, z, ʃ, (ʒ) χ, ħ, ʕ, h, dʒ, l, r, (ʁ), t̪ˤ, ðˤ, s̪ˤ, d̪ˤ/), and 2 glides (/w, j/).

PoA / MoA	Bilabial	Labio-dental	Inter-dental	Dento-alveolar	Retroflex	Post-alveolar	Alveolo-palatal	Palatal	Velar	Uvular	Pharyngeal	Glottal
Stop emphatic	b			t d tˤ dˤ					k	q		ʔ
Nasal	m			n								
Trill				r								
Tap or Flap												
Affricate						ʤ						
Fricative emphatic		f	θ ð ðˤ	s z sˤ		ʃ (ʒ)				χ (ʁ)	ħ ʕ	h
Lateral approximant				l								

PoA / MoA	Palatal	Labio-palatal	Labio-velar
Approximant	j		w

Table 12: Standard Arabic consonants, based on Benamrane (2013) and Anis et al. (2019).

Arabic includes modes and places of articulation not present in French. The additional MoA are: (1) affricate (/dʒ/) and (2), emphatic (/t̪ˤ, ðˤ, s̪ˤ, d̪ˤ/). Then, the additional PoA are: (1) inter-dental (/θ, ð, ðˤ/), (2) pharyngeal (/ħ, ʕ/) and (2), glottal (/ʔ, h/). The Arabic consonantal system is thus more extended in the posterior places of articulation than French. Specific to Semitic languages, the emphatic consonants /t̪ˤ, ðˤ, s̪ˤ, d̪ˤ/ involve a particular articulation. More precisely, they are characterized by two places of articulation for they entail a shift from the main articulatory zone to the soft palate (Benamrane, 2013). This specific articulation of emphatics proves to be really challenging for L2 learners (Binasfour, Setter & Aslan, 2017). Also, and as mentioned above, the presence of such a consonant in a word propagates this particular articulatory feature to its environment, either vocalic or consonantal. All Arabic consonants can be geminated and gemination has a contrastive function.

Besides, Standard Arabic includes a much larger number of fricatives than French. More precisely, it has 12/13 fricatives, amongst which the sibilant /s, z, ʃ/ on which the subsequent analyses will focus. The existence of the voiced sibilant post-alveolar /ʒ/ is debated. Indeed, depending on the regional Arabic variety, either /dʒ/ or /ʒ/ can be the realizations of the same phoneme. Acoustically, the sibilant /s, z, ʃ, ʒ/ appear to have a compact spectrum whose main zone of energy is located at a high frequency than the other fricatives and the alveolar /s/ present the highest spectral mean or centre of gravity. Moreover, they are characterized by a high intensity (Benamrane, 2014).

I.3.2.1.2.3 Mandarin

Mandarin is reported to have 20 or 21 consonants (/p, pʰ, t, tʰ, k, kʰ, f, s, ʂ, ɕ, x, ts, tsʰ, tʂ, tʂʰ, tɕ, tɕʰ, m, n, (ŋ), l/) and a retroflex approximant /ɻ/ (Hua & Dodd, 2000). Table 13 presenting the consonantal system of Mandarin integrates the two glides /j, w/ which can also be noted as vowels [i] and [u] in diph/triphthongues (Bernhardt & Zhao, 2010).

MoA \ PoA	Bilabial	Labio-dental	Inter-dental	Dento-alveolar	Retroflex	Post-alveolar	Alveolo-palatal	Palatal	Velar	Uvular	Pharyngeal	Glottal
Stop aspirated	p pʰ			t tʰ					k kʰ			
Nasal	m			n					(ŋ)			
Trill												
Tap or Flap												
Affricate aspirated				ʦ ʦʰ	tʂ tʂʰ		tɕ tɕʰ					
Fricative		f		s	ʂ		ɕ		x			
Central approximant					ɻ							
Lateral approximant				l								

MoA \ PoA	Palatal	Labio-palatal	Labio-velar
Approximant	j		w

Table 13: Mandarin consonants, extracted from Bernhardt & Zhao (2010).

Mandarin includes one mode and one place of articulation no present in French: (1) affricates (/ts, tsʰ, tʂ, tʂʰ, tɕ, tɕʰ /) and (2), retroflex (/tʂ, tʂʰ, ʂ/). Voiced obstruents (stops and fricatives) are absent from the Mandarin consonant inventory. However, it does include voiceless aspirated stops (/pʰ, tʰ, kʰ/) and affricates (/tsʰ, tʂʰ, tɕʰ/). The phonemes /ɕ, tɕ, tɕʰ/ are voiceless alveo-palatal consonants.

Besides, Mandarin includes slightly less fricatives (/f, s, ʂ, ɕ, x/) than French and only two of them are also found in French, the non-sibilant labial /f/ and the sibilant alveolar /s/. Moreover, two Mandarin fricatives involve PoA not existing at all (the retroflex /ʂ/) or not for that specific manner class (the velar /x/) in French and as just noted, there are no voiced fricatives in Mandarin. Also, the Mandarin sibilant alveo-palatal /ɕ/ is phonetically close to the French sibilant /ʃ/.

Table 14 (on the next page) summarizes the similarities and differences between the vowel and consonant inventories of the three L1s (i.e., Italian, Arabic and Mandarin) and the vowel and consonant inventories of French. Globally, vowel inventories of Italian and Arabic are less rich than that of French, whereas the vowel inventory of Mandarin is rather different than poorer than the French vowel inventory. Arabic has a richer consonant inventory than French and Italian has a slightly richer and rather similar consonant inventory than that of French. Finally, the Mandarin consonant inventory presents more differences with that of French in comparison with the two other L1s.

I.3.2.1.3 Similarities vs. differences with French vowels and consonants

		Italian	Arabic	Mandarin
Vowels	**Similarities Properties shared with French**	Common vocalic phonemes: /i, e, ɛ, a, ɔ, o, u/	Common vocalic phonemes: /i, a, u/	Common vocalic phonemes: /i, y, (e), (ɛ), (ə), a, (o), u/
	Differences Properties not shared with French	The Italian vocalic inventory is less rich: 7 vowels Several French vowels are absent in Italian, such as the rounded anterior /y, ø, œ/ and nasal /ɑ̃, ɛ̃, ɔ̃/ series	The Arabic vocalic inventory is much poorer: 3 vowels Presence of a duration contrast: /i, a, u/ *vs.* /iː, aː, uː/ All French vowels are absent in the Arabic inventory except /i, a, u/	The Mandarin vocalic inventory is very different: Presence of retroflex/rhotic vowels /ɚ, ɤ/ Presence of diphthongs and triphthongs Several French vowels are absent in Mandarin: such as rounded front vowels /ø, œ/ and nasal vowels /ɑ̃, ɛ̃, ɔ̃/
Consonants	**Similarities Properties shared with French**	Common consonant phonemes: /p, b, t, d, k, g, m, n, ɲ, f, v, s, z, ʃ, l/ and /j, w/	Common consonant phonemes: /b, t, d, k, m, n f, s, z, ʃ, l, (ʁ)/ and /j, w/	Common consonant phonemes: /p, t, k, l, m, n, (ŋ), f, s/ and /j, w/
	Differences Properties not shared with French	The Italian consonantal system is slightly richer: 21 consonants Presence of affricates /ts, ʧ, dz, dʒ/, lateral /ʎ/ and gemination A couple of French phonemes are not present in Italian: /ʒ/ - /ɥ/ (/ʁ/)	The Arabic consonantal system is richer: between 25 and 27 consonants Presence of posterior stops /q, ʔ/, affricates /dʒ/, emphatic /t̪ˤ, d̪ˤ, ð̪ˤ, s̪ˤ/ and gemination Presence of other fricatives: /θ, ð, χ, ʕ, ħ, h/ and emphatic /ð̪ˤ, s̪ˤ/ Several French consonants are absent in the Arabic inventory: /p, g, v, ɲ, (ʒ), (ʁ)/ and /ɥ/	The Mandarin consonantal system is very different: Presence of aspirated /pʰ, tʰ, kʰ, tsʰ, tʂʰ, tɕʰ/, affricates /ts, tsʰ, tʂ, tʂʰ, tɕ, tɕʰ/ and retroflex /ʂ, tʂ, tʂʰ/ Presence of other fricatives: the sibilant retroflex coronal /ʂ/ and palatal /ɕ/ and non-sibilant velar /x/ Several French consonants are absent in Mandarin: /b, d, g, v, z, ʃ, ʒ, ʁ, ɲ/ and /ɥ/

Table 14: Similarities *vs.* differences with the French vowels and consonants.

I.3.2.2 Syllabic structure

I.3.2.2.1 Description of the targeted syllabic constituents

I.3.2.2.1.1 Italian

Italian includes both open and closed syllables. As in French, the CV type is predominant as it represents 60% of all syllable types (Bortolini 1976). However, there is a wide range of possible syllables and Italian involves a high proportion of multisyllabic words (Carrissimo-Bertola, Vallée & Chitoran, 2012). Consonantal clusters can occur both in onset and coda, in word-initial/media/final position. In Italian, the segmental inventory occurring in coda is restricted, as it normally includes only the following consonants /n, s, l, r/. Word-medial codas can be occupied by the first consonant of a geminate and biconsonantal codas are quite rare (Bertinetto & Loporcar, 2005). While word-internal singleton codas are quite frequent, words ending in consonant(s) are much less frequent and are typically loanwords (Kramer, 2009). In contrast, word-initial position is far less restricted and branching onsets can be made of up to three elements. Word-initial clusters generally consist in OS sequences consisting in the combination of obstruents and the liquids /l, r/ or glides /j, w/. Like in French, sequences of consonants sharing coronal PoA are not permitted (such as /tl/). Word-initial /s/C(C) clusters are also attested in Italian and are more frequent and more complex than in French where they are mainly restricted to /s/+stops sequences. Like in French, such sequences are generally treated as heterosyllabic, the initial /s/ being analysed as a left-edge adjunct (see above) followed by an onset, whether simple or branching in the case of triconsonantal sequences. Besides, syllables with complex onsets would represent 10% of all syllable types (Kehoe and Havy, 2019; based on Goslin, Galuzzi, & Romani, 2014). Finally, word-final consonant sequences are segmentally more restricted and much less frequent than word-initial sequences (Kramer, 2009).

I.3.2.2.1.2 Arabic

In Standard Arabic, onsets are compulsory and vocalic onsets are not permitted, unlike in French. Therefore, syllables always start with a single consonant and syllables can be open (CV type) or closed (CVC type) (Vieru-Dimulescu, 2008). Similar to French, the CV type is predominant but there is a wide variety of possible syllable types. Different places of articulation are tolerated in word-final position: labials, coronals and dorsals (Amayreh & Dyson, 1998). Furthermore, complex codas are allowed (Kiparsky, 2003). Word-final codas are relatively frequent in Arabic, in comparison to French, since closed syllables represent approximately 45-50% of all syllable types (Hamdi, Barkat-Defradas, Ferragne & Pellegrino, 2004). Consonantal clusters can occur in coda and therefore, the syllable type CVCC is permitted. Subject to debate, the occurrence of consonant sequences at onset is said to be forbidden in Arabic, at least in the underlying phonological representation. Indeed, a process of deletion of short vowels in open syllables can be observed – notably in Maghreb dialects – resulting in numerous consonantal clusters and complex syllabic structures in surface realizations (Hamdi et al., 2004). Furthermore, Moroccan Arabic is particularly subjected to this process of vowel deletion and therefore, presents a tendency to complex surface syllables (such as CCVC, CCVCC) whether in onset or in coda position. In addition, both Moroccan Arabic and Berber would be characterized by long consonantal sequences that have been analysed both as complex onsets and syllables with consonantal nuclei (Kiparsky, 2003). Branching onsets in those Arabic varieties can be made of up to three consonants and allow for numerous combinations of places of articulation. Sequences of two or three consonants are also permitted in word-final position.

I.3.2.2.1.3 Mandarin

In Mandarin, onset and coda are optional in the syllabic structure, whereas nucleus and tone are compulsory (Duanmu, 2007). All consonants, except /ŋ/, can occur in the onset of a syllable. In contrast, codas are highly restricted in Mandarin, as only /n/ and /ŋ/ can occur in that position (Duanmu, 2007), and moreover, Mandarin is characterized by a very low frequency of word-final codas. Mandarin totally excludes the presence of consonantal clusters (Jacques, 2006) and consequently, complex syllabic structures, such as CVCC, are not permitted. Besides, there is only one morpheme per word and almost all roots are monosyllabic. Mandarin Chinese involves thus a very limited range of syllabic structures in comparison to French.

Table 15 (on the next page) summarizes the similarities and differences between the syllabic structure of the three L1s (i.e., Italian, Arabic and Mandarin) and the syllabic structure of French. In Italian, word-final singleton and complex codas are segmentally more restricted and less frequent, whereas word-initial branching onsets are less restricted and more frequent than in French. Arabic presents a higher frequency of word-final singleton codas and Mandarin presents the most restricted syllabic structure not permitting any consonantal clusters.

I.3.2.2.2 Similarities vs. differences in comparison with French syllabic structure

		Italian	Arabic	Mandarin
Word-final singleton codas	**Similarities Properties shared with French**	Presence of /n, s, l, r / in word-final coda position	Presence of different PoA in word-final coda position: labials, coronals and dorsals	Presence of /n, ɲ/ in word-final coda position
	Differences Properties not shared with French	Segmentally more restricted: only /n, s, l, r/ Lower frequency of word-final singleton consonants	Higher frequency of word-final singleton consonants (between 45 and 50% of closed syllables)	Segmentally more restricted: only /n, ɲ/ Much lower frequency of word-final singleton consonants
Word-initial branching onsets	**Similarities Properties shared with French**	Similar consonant sequences: Obstruents+Liquids, Obstruents+Glides and /s/C(C) clusters	Similar consonant sequences: Obstruents+Liquids and /s/C(C) clusters	Word-initial consonantal clusters are NOT permitted in Mandarin
	Differences Properties not shared with French	/s/C(C) sequences more frequent and more complex than in French	/	
Word-final complex codas	**Similarities Properties shared with French**	Similar consonant sequences: Obstruents+Liquids and Liquids+Obstruents clusters	Similar consonant sequences: Obstruents+Liquids and /s/C(C) clusters	Word-final consonantal clusters are NOT permitted in Mandarin
	Differences Properties not shared with French	Segmentally more restricted Less frequent	/	

Table 15: Similarities vs. differences in comparison with French syllabic structure

I.3.3 Conclusion

Based on the phonetic and phonological description of each language involved in this dissertation, it appears that each language pair is characterized by specific common and distinct aspects, either at a segmental or syllabic level. The French-Italian pair might be thought to present the lowest degree of inter-linguistic distance and the greatest similarity between both phonological systems. Still, despite their closeness, phonological systems of these two languages also bear dissimilarities. Then, the degree of distance and structural similarity can be less straightforwardly characterised for the two other combinations, French-Arabic and French-Mandarin. Based on the existing literature, a working hypothesis of the present study is that this varying degree of distance and similarity characterizing each language pair would result in different types of cross-linguistic effects and have a differential impact on phonetic and phonological development in French. We develop this point in full details in the next section about our research problematic and working hypotheses.

I.4 THE CURRENT STUDY

I.4.1 RESEARCH PROBLEMATIC AND STRATEGY

From the existing literature, one can conclude that bilingual toddlers follow a complex developmental path sharing both similarities and dissimilarities with that of monolingual children (see details in section I. 2.). Moreover, differences between bilingual and monolingual children have been reported for different levels of phonological organization, either at segmental and supra-segmental levels. These discrepancies have been said to arise from a mutual influence between the two phonological systems, potentially resulting in cross-linguistic effects which frequency and directionality would in turn depend on a variety of interlinked factors. More specifically, factors most often invoked to account for cross-linguistic interaction phenomena – either in the form of acceleration, deceleration or transfer – include linguistic dominance (referred to as one among other "language-external" factors) as well as frequency and complexity of the phonological properties of each language (referred to as "language-internal" factors). Thus, even if typical bilingual development is globally similar to monolingual development, bilingual children obviously have specific developmental trajectories and strategies. Besides, bilingual production studies present certain limitations including: (1) the reduced size of the participant sample, (2) the longitudinal approach not systematically adopted, (3) the almost exclusive focus on consonants, (4) the rare use of acoustic analyses and (5), the lack of diversification in the languages involved. Indeed, nearly all studies have focused on a single language pair involving either English and/or Spanish. There is thus an important lack of knowledge about bilingual speech acquisition in other language contact situations.

In light of this, the present study aims at longitudinally assessing French phonetic and phonological development in preschool bilingual children exposed to different language pairs and more precisely to: French and Italian, French and Arabic and French and Mandarin. These language pairs have been chosen based on methodological and theoretical premises. First, French has rarely been included in bilingual production studies and even more in combination with Italian, Arabic or Mandarin. Then, the three other languages selected (i.e., Italian, Arabic or Mandarin) differ by their degree of similarity/distance with French and each language pair involves specific inter-linguistic differences lying at both segmental and syllabic levels, as emphasized by the previous description of the targeted languages. These inter-linguistic differences are susceptible to give rise to different cross-linguistic interaction effects. More specifically, the languages involved differ by their degree of complexity with regard to the richness of their phonemic inventories and to the structural and segmental constraints they impose on syllabic structure. Besides, they are also characterized by different frequencies of certain phonological structures. Our objective is thus to assess the specific impact that each linguistic combination could have on the phonetic and phonological development in French, and to assess how similar or different French development is in simultaneous bilinguals who differ in terms of their other mother tongue.

One specificity of our study lies in the fact that we are focusing on one language of the bilingual children only, with the perspective to assess potential cross-linguistic effects through a comparative analysis of children exposed to different language pairs. Therefore, the key issue is not to relate the performances of bilingual children to those of monolinguals but rather to apprehend their performances in a contrastive approach; that is, to compare bilinguals with bilinguals, in relation to one another. Besides, individual trajectories will be carefully considered. Indeed, bilingualism is a multi-faceted experience, from which one could expect even more inter- and intra-variability than what is already observed in monolingual children. Therefore, assessing the linguistic performances of bilingual children exclusively with respect to monolingual norms and without considering individual variability might lead to a misinterpretation of certain observed phenomena.

More specifically, our research seeks to study the evolution of bilingual children's speech production skills over time as well as to observe the progressive emergence and organization of the French phonological system, by investigating the realization of individual segments, syllabic structure and whole-word forms. To that purpose, children involved in the study have been observed over a one-year period and speech productions have been collected in naturalistic conditions (i.e., close to the children's usual environment) by means of an adapted self-developed experimental protocol. Practically, speech productions have been gathered through an original word-naming task allowing targeting specific structures in the productions as well as to ensure similar data collection conditions for all children.

To fill some previously identified gaps, both vowels and consonants are included in our analyses. As highlighted by the previous literature review (section I.2. and I.3.), vowel systems have rather rarely been examined in monolingual and bilingual speech acquisition studies. Consonants are apprehended globally and in specific positions in the syllable and the word: targeted syllabic constituents include word-final codas, word-initial branching onsets and word-final complex codas. A typically understudied subset of fricatives receives particular attention given their reported later acquisition. Vowels and fricatives (especially /z, ʃ, ʒ/) are interesting to focus on at once for they are expected to be at opposite ends of the developmental path. In addition, their development has rarely been studied concomitantly with an examination of the syllabic structure. The speech sounds under investigation are subjected to complementary analyses involving several acoustic measures and a variety of analyses based on phonetic transcriptions. Acoustic analyses are focused on vowels (involving both standard and new measures, see section II.4.) and fricatives (spectral moment analysis, see section II.4.), whereas transcription-based analyses encompass all types of segments (i.e., all vowels and consonants), considered individually as well as part of whole-word forms. Combining these two types of analyses permits to focus on different aspects of speech production as well as to bring out different phenomena into light. As acoustic analyses enable to observe speech sounds in a more objective way, they also give an insight that transcription-based measures do not (easily) provide.

In addition to observing the impact of the linguistic combination on French phonetic and phonological development, we are attempting to control and assess the effect of a number of other factors on the evolution of the children's speech productions. Potential similarities and differences observed in the three types of bilinguals might not only be due to the properties of the two languages in contact. As our research involves a longitudinal perspective, the developmental variable is the second most important factor considered in our assessment of the children's performances. Indeed, the objective is to focus on the evolution of the children's developmental trajectories and to observe their phonetic-phonological development in time. Therefore, two developmental variables are included in the analyses: the recording session and the chronological age. Considering both developmental variables allows capturing different phenomena; however, the session receives a greater structural importance in the analyse (see section II. 4.).

Then, given that the nature and degree of exposure to both languages definitely affect bilingual development, the children's linguistic dominance is also taken into account. For that purpose, the children's daily linguistic environment has been documented in details to characterize each participant's bilingual profile. The lexical development in French, as well as in both languages combined, has also been assessed in order to investigate the link between phonological and lexical development, which is typically insufficiently addressed in the existing literature. Besides, variables of "gender" [37] and "(presence of) siblings" are included in our analyses, as these two factors are also susceptible to impact speech production development. Indeed, better performances have been found for girls (Dodd, Holm, Hua & Crosbie, 2003; Kehoe and Havy, 2019) and moreover, boys are more prone to develop a language/speech disorder than girls (Weindrich, Jennen-Steinmetz, Laucht, Esser & Schmidt, 2000). Besides, older siblings have been shown to provide an important source of linguistic input and to promote language development in their younger siblings (Bridges and Hoff, 2014).

The impact of variables related to the items of our word-naming task are also assessed, including elicitation technique, phonological complexity and lexical frequency. Elicitation technique refers to the method used to make the child produce the expected word; that is, whether the child is incited to name or repeat the word. Obviously, the ideal situation would be to have the same elicitation type for all speech productions collected from all children in order to compare them. In reality, however, younger children might still rely more on repetition than on spontaneous naming and/or alternate between the two (this issue will be returned to in section II.3.). Therefore, this variable should be controlled for, or failing that, should be documented and included in the subsequent analyses. Finally, phonological complexity and lexical frequency have been seldom considered in speech production studies. These two variables have been assessed based on specific criteria (this will also be developed in section II.4.).

I.4.2 WORKING HYPOTHESES

The definition of the research problematic naturally leads to the formulation of hypotheses about the impact of the different factors under investigation in the present study. Hypotheses for the different factors are presented below. Note that the use of the conditional below reflects the fact that these are reasonable, convergent with the literature, working hypotheses as to the direction in which we expect the main effects to go.

I.4.2.1 Effect of the linguistic group in interaction with developmental variables

We assume that different development patterns could emerge in the different linguistic groups resulting from potential cross-linguistic interaction between the two languages in contact. Moreover, and as mentioned earlier, we chose to rely on the concepts of acceleration and deceleration developed within the frame of comparisons between bilingual and monolingual children (see section I.2.). Indeed, it seems relevant to operationally use these concepts to compare bilingual children exposed to different language pairs. Given that each language pair involves specific similarities/differences

[37]We are aware that the term gender refers to a social construct, while the variable considered in our study is the sex category; that is, the biological and physiological characteristics defining men and women. However, we choose to use the more neutral appellation « gender » throughout this dissertation.

lying at different phonological levels, we presume different developmental paths for the different structures investigated and therefore, we present our hypotheses separately for each of them, including: (1) vowels, (2) consonants, (3) targeted syllabic constituents and (4) whole-word forms.

I.4.2.1.1 Vowels

We postulate that children exposed to French and Italian might be advantaged in French vowel acquisition and show a faster vocalic development in comparison to children exposed to French and Arabic and, to a lesser extent, to children exposed French and Mandarin. Indeed, vowel inventories of French and Italian are the most similar as the two languages share the largest number of vocalic phonemes.

In contrast, we assume that children exposed to French and Arabic might be disadvantaged in French vowel acquisition and show a slower vocalic development in comparison to children exposed to French and Italian and, to a lesser extent, to children exposed to French and Mandarin. Indeed, vowel inventories of French and Arabic are the most dissimilar and Arabic presents a much reduced vowel system.

We have no specific prediction regarding French vowel acquisition for the children exposed to French and Mandarin. The vowel systems of the two languages are very different with regard to their phoneme inventories, as Mandarin possesses both monophthongs and diph-/triphthongs.

Besides, we also expect a high individual variability in the evolution of vowel production and this, for children exposed to all three language pairs.

I.4.2.1.2 Consonants

We postulate that children exposed to French and Arabic might be advantaged in French consonant acquisition and show a faster consonant development in French, compared to children exposed to French and Italian and children exposed to French and Mandarin. Indeed, Arabic possesses the richest consonant inventory and involves more manners and (posterior) places of articulation than French. Besides, Arabic emphatic consonants present particular articulatory challenges. Regarding the targeted sub-set of fricatives, nearly all are present in Arabic (the existence of the voiced sibilant post-alveolar /ʒ/ is debated, see above) and Arabic also includes a much larger number of fricatives than French, which could benefit the acquisition of French fricatives. This complexity of the Arabic consonantal system, in terms of the richness of Arabic consonant inventory and the complexity of the articulatory content of several consonants, is thus expected to globally accelerate consonant acquisition in French in French-Arabic bilingual children when compared to French-Italian and French-Mandarin bilingual children.

We may also expect that children exposed to French and Italian might be slightly accelerated in French consonant acquisition in comparison with children exposed to French and Mandarin. Again, Italian shares the largest number of phonemes with French, whereas Mandarin presents a very different phonemic inventory. Besides, Mandarin possesses no voiced obstruents which could lead to more devoicing patterns in the children’s early productions.

I.4.2.1.3 Syllabic constituents

We assume that children exposed to French and Arabic might be accelerated in the acquisition of word-final codas in French in comparison to children exposed to French and Italian and children exposed to French and Mandarin. Indeed, Arabic presents the least segmental restrictions in that position as well as the highest frequency of closed syllable types.

In contrast, we postulate that children exposed to French and Mandarin might be slightly decelerated in their acquisition of word-final codas in comparison to children exposed to French and Italian and children exposed to French and Arabic. Indeed, Mandarin imposes the most segmental restrictions in that position and is furthermore characterized by a very low frequency of word-final codas.

We suppose that children exposed to French and Mandarin might be decelerated in the acquisition of word-initial branching onsets in French in comparison to children exposed to French and Italian and children exposed to French and Arabic. Indeed, Mandarin possesses the most restricted syllabic structure and totally excludes the presence of consonantal clusters.

We expect no differences between children exposed to French and Italian and children exposed to French and Arabic as complex consonant sequences in word-initial position can be found in both Italian and Arabic, albeit only in surface realizations for Arabic due to phenomena of short vowel deletion.

We assume that children exposed to French and Arabic might be accelerated in the acquisition of word-final complex codas in French in comparison to children exposed to French and Italian and children exposed to French and Mandarin. Indeed, Arabic presents the least segmental restrictions and allows for more varied combinations of places of articulation in word-final position.

For similar reasons as those mentioned above, we expect that children exposed to French and Mandarin might be decelerated in their acquisition of word-final complex codas in French in comparison to French-Italian and French-Arabic bilingual children.

I.4.2.1.4 Whole-word forms

Given our previous hypotheses about consonants and targeted syllabic constituents, we postulate that children exposed to French and Arabic might globally show better performances in their whole-word productions compared to French-Italian and French-Mandarin bilingual children.

I.4.2.2 Effect of the developmental variables

In addition to the different developmental patterns expected in the three linguistic groups, we also expect a global effect of both session and chronological age for all children and for all structures investigated and we more particularly expect better performances from one session to the other and as chronological age increases.

I.4.2.3 Effect of the linguistic dominance

As will be detailed in the next chapter, the children's linguistic environment will be documented in order to characterize their linguistic dominance. More precisely, children will be classified either as having a dominance in French or in the other language, or as being balanced bilinguals.

We assume that children who are more exposed to French should be advantaged in French phonetic and phonological development for all structures investigated, in comparison to children less exposed to French, either those having a dominance in the other language or those having a more balanced exposure to both languages.

I.4.2.4 Effect of lexical development

We suppose that phonetic and phonological development in French should benefit from a more advanced lexical development in French and in both languages or, more precisely, that children characterized by a greater lexical development in French and in both languages should be more advanced in their phonetic and phonological development in French and this, for all structures investigated.

We expect that French-Italian bilingual children might be more advantaged by a greater lexical development in both languages than French-Arabic and French-Mandarin bilingual children given that French and Italian share more phonological properties as well as more cognates.

I.4.2.5 Effect of gender

We postulate that, if there is an effect of gender on French phonetic and phonological development, girls could have an advantage over boys for all structures investigated.

I.4.2.6 Effect of the presence of older siblings

We expect that, if there is an effect of siblings on French phonetic and phonological development, children with siblings could have an advantage over children without siblings for all structures investigated.

I.4.2.7 Effect of item-related variables

We have no hypotheses regarding the elicitation technique, given the mixed results present in the literature (this issue will be returned to in section II.3.).

We assume that children's speech productions should be more accurate for less complex and more frequent items than for more complex and less frequent items in French. We do not predict a difference between the children exposed to different language pairs in this aspect.

Chapter II:

Method

II METHOD

The first chapter of this dissertation was devoted to the presentation of the literature review about phonological acquisition and bilingual development as well as to the exposition of our research problematic and working hypotheses. In the second chapter, we will describe the longitudinal study that we have conducted in order to examine French phonetic and phonological development in contrasted bilingual contexts. This chapter devoted to the description of our method is divided into the four following sections: (1) the description of the participant sample, (2) the description of the experimental paradigm for data collection, (3) the data processing and (4), the description of the conducted analyses.

II.1 PARTICIPANT SAMPLE

Our participant sample consists of a group of 18 preschool simultaneous bilingual children (8 girls and 10 boys) initially aged between 21 and 36 months (global mean age=34 months, SD=7 months). Children had been exposed to different language pairs, all including French plus one of the following languages: Italian, (Moroccan and Sudanese) Arabic and Mandarin Chinese. Data and recordings have been anonymised: each child is designated by a code of the form BNN, where B stands for "bilingual", and N for a number referring to the order of recruitment. This number has been assigned according to the order of recording.

II.1.1 RECRUITMENT OF THE PARTICIPANTS

Children have been recruited through numerous initiatives: (1) word of mouth, (2) social networks, (3) day-care centres/nurseries, (4) communal associations/services and (5), political and/or cultural official structures such as embassies, consulates and cultural centres. Families have been contacted through e-mails, phone calls or via flyers and posters. Once we had been ensured that the children would correspond to our inclusion criteria (see section II.1.2.), a consent form (see Appendix 1.) has been given to the parents to inform them clearly about the research objectives and their rights in regard to the participation to the study. Indeed, families took part in the study on a voluntary basis and were free to withdraw at any time and without giving any reasons for their decision. For each participant, one of the parents had to sign the form to give his/her agreement and each family received a duplicata. As a compensation for their participation, each family has been offered a one-year subscription to children's books (from the publishing house *Ecole des Loisirs*).

II.1.2 SELECTION CRITERIA

Participants have been recruited based on their chronological age (with both lower- and upper-age limits) and their type of bilingualism, in relation to the age of acquisition of the two languages and the language pairs involved. We explain in details each selection criterion.

II.1.2.1 Chronological age of participants

Age limits were set for the recruitment of children, with a lower age-limit of 18 months and upper age-limit of 50 months. Indeed, the age of 18 months marks the beginning of significant production (Hilaire et al., 2001) and of lexical expansion (Vihman, Ferguson & Elbert, 1986), while speech productions are still exhibiting systematic errors (Schelstraete & Maillart*,* 2004). Then, the upper limit of 50 months was fixed to ensure that children would not yet have been exposed to writing and reading. Furthermore, children's productions start becoming fairly intelligible around that age

(Sax & Weston, 2007) and most of phonological processes would have disappeared (Schelstraete & Maillart, 2004) by that age.

Accordingly, the 18 toddlers participating to our study were initially aged between 21 and 36 months when speech production data were first collected. As the longitudinal study expanded over a period of 1 year (data collection will be detailed in section II.2.), the total age range for the entire study goes from 21 months to 50 months.

II.1.2.2 Type(s) of bilingualism

II.1.2.2.1 Age of acquisition of both languages and family configuration

Children recruited for our study are simultaneous bilinguals, for they have been exposed to both languages since birth, or the very first months of their life, with more or less equivalent rates of exposure to each language. More precisely, our participants have been significantly and regularly exposed to their two languages; that is, at least three full days per week[38]. Actually, exactly equivalent exposure rates to both languages are quite rare in bilingual contexts since there is almost always one predominant language in the linguistic input received by the child. Moreover, the linguistic input fluctuates according to the changing environment of the bilingual individual.

Two types of family linguistic environment were included in our sample:

- families where each parent speaks a different language to their child, following the "One parent - one language" rule/principle (11 families)[39];
- families where both parents speak the same language (whether Italian, Arabic or Mandarin) and the child's exposure to French has occurred through siblings and peers and/or at the day-care centre (7 families).

Due to recruitment challenges, we decided to include bilingual children from these two types of environment in our sample. However, the specificities of each participant's linguistic environment and input have been thoroughly documented and taken into account.

II.1.2.2.2 Language pairs

As already explained in the section about our research problematic and hypotheses, children participating to our study are exposed to one of the three following language pairs: French-Italian, French-Arabic and French-Mandarin. Indeed, the interest is to compare the specific impact that the similarities/differences between the two linguistic systems of the child could have on phonetic-phonological development in French.

The share of participants per language pair is the following: 11 French-Italian bilinguals (5 girls and 6 boys, global mean age=34 months and SD=7 months), 5 French-Arabic bilinguals (2 girls and 3 boys, global mean age=34 months and SD=8 months) and 2 French-Mandarin bilinguals (1 girl and 1 boy, global mean age=37 months and SD=5 months). Figure 18 shows the repartition of the participants in the three linguistic groups as a function of their initial chronological age. Due to

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[38] This minimum amount of exposure time was chosen based on the Alberta Language Environment Questionnaire - ALEQ (Paradis, 2011).

[39] For 4 of these 11 families, it is the mother who is speaking French to the child.

significant recruitment challenges, the number of French-Mandarin participants is much more reduced than for the French-Italian and French-Arabic groups. Still, we decided to include them in the study but this asymmetry in the groups will be carefully considered in the subsequent analyses.

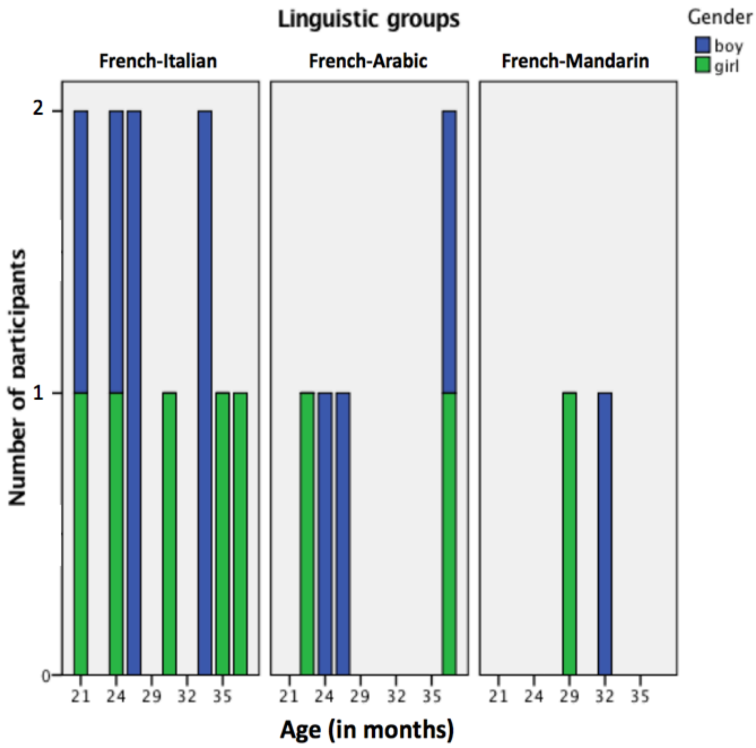

Figure 18: Repartition of children according to initial chronological age in the three linguistic groups.

Table 16 provides a summary of all the characteristics defining each participant, including information on Linguistic group, Initial chronological age, No-risk index, Linguistic dominance, Gender, Siblings and Vocabulary scores in French and in both languages. No-risk index, Linguistic dominance and vocabulary scores have been assessed based on parental questionnaires (this is explained in details in section II.2.1.).

Linguistic group	Subject	Initial chronological age (at S1)	No-risk index value	Linguistic dominance (1 = French 2 = other L1 3 = balanced)				Gender	Siblings	French vocabulary score (at S1)	Total vocabulary score (at S1)
French-Italian	B01	2;01;08	20	1	3	3	3	Boy	NO	161	260
	B02	2;01;04	19	3	3	3	3	Boy	NO	103	239
	B03	2;11;01	26	2	2	2	2	Girl	NO	236	444
	B07	2;09;18	17	2	2	2	2	Boy	NO	106	496
	B08	2;07;16	22	3	3	3	3	Girl	NO	178	336
	B09	1;09;13	25	1	1	1	1	Girl	NO	124	136
	B10	1;09;11	22	1	1	1	1	Boy	YES	198	218
	B12	2;00;27	26	1	1	1	1	Boy	YES	212	358
	B13	2;09;19	20	2	2	2	2	Boy	NO	84	287
	B17	3;00;16	20	1	3	3	2	Girl	NO	471	471
	B18	2;00;10	20	2	2	2	2	Girl	NO	59	302
French-Arabic	B04	3;00;21	26	3	3	1	1	Girl	YES	218	218
	B05	2;0;18	24	1	1	1	1	Boy	YES	64	64
	B06	2;01;15	22	2	2	2	2	Boy	YES	63	63
	B11	3;00;09	24	1	1	1	1	Boy	NO	644	744
	B14	1;10;15	19	1	1	1	1	Girl	YES	27	54
French-Mandarin	B15	2;08;17	22	1	1	1	1	Boy	YES	180	271
	B16	2;05.22	24	3	3	3	1	Girl	YES	109	436

Table 16: Description of the participants including information on Linguistic group, Initial chronological age, No-risk index, Linguistic dominance, Gender, Siblings and Vocabulary scores.

II.2 Paradigm for data collection: a multi-tool protocol for longitudinally collecting complementary data

In order to address our research objectives and questions, we have developed an experimental protocol involving the longitudinal collection of complementary data from our participants. More precisely, two kinds of data have been collected: *hetero-reported* data and *speech production* data in

French. Hetero-reported data collection is made through two parental questionnaires and include information about: (1) language emergence and linguistic daily environment and (2), lexical development in the two languages of each participant. Speech data collection consists in longitudinal recordings of a variety of speech samples, i.e., single words elicited via an original word-naming task (that will be described in section II.2.2.).

Chronologically, hetero-reported data were first gathered during the initial meeting ("Session 0") with the families and were subsequently updated on each speech data collection. The first meeting also gave us the opportunity to have a first contact with the child and get acquainted with the home environment before the first recording. Speech data collection thus started from the second meeting (called "Session1") and took place repeatedly on three subsequent meetings (Session 2, 3 and 4) scheduled at regular four-months intervals. To give a clear visual representation of the entire data collection process, Figure 19 shows a time line from Session 0 to Session 4.

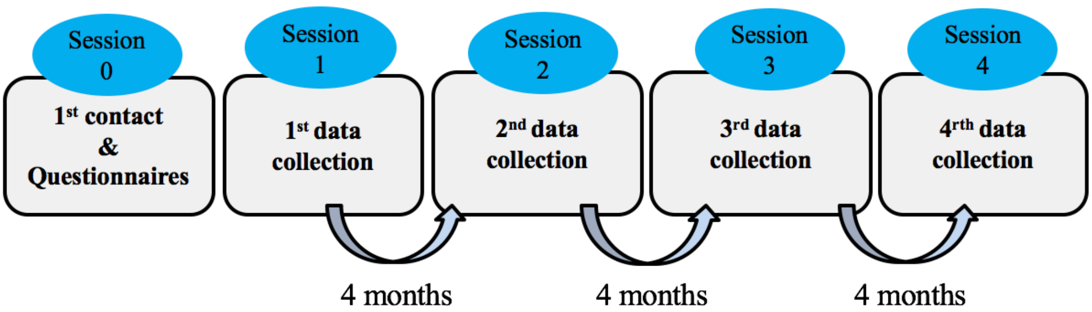

Figure 19: Time line of the data collection

Table 17 synthetises the different tools involved in our protocol for the collection of complementary data at each session, as well as the data collected. These tools and the data they provide will be extensively described in the present section.

Data collection tools	Type of data collected	Existing/original tool	Data collected
Parental questionnaire	Hetero-reported data documenting: - language emergence and development - language practices in the child's daily environment	Developed based on the PABIQ (2011)	- No-risk Index - Index of linguistic dominance
Parental reports	Hetero-reported data documenting lexical development in both languages	Existing adaptations of the MBCDI	- Total of words produced in French and in both languages
Word-naming task	Elicited single words in French	Original self-developed tool	-Acoustic and perceptual-phonological measures (see section II. 4.)

Table 17: Summary table of the different tools for data collection at each session.

II.2.1 PARENTAL QUESTIONNAIRES

We decided to use parental questionnaires in order to gather data about language emergence and linguistic daily environment, as well as lexical development, for they are an efficient tool to get a quick and reliable picture of the general linguistic profile of the child. Moreover, it has great ecological validity, given that information is provided by the parents who are in continuous contact with their children and therefore, are able to give very rich information reflecting what the child truly knows. It can be argued that parents could tend to overestimate or, on the contrary, underestimate their children's skills, out of pride or through a lack of knowledge or memory (Kern, 2004); still, they are good informants and the data gathered are more representative than observations collected in a formal/experimental setting.

More specifically, the collection of hetero-reported data includes two different tools:

- a parental questionnaire that we have elaborated on the basis of existing questionnaires (see point 2.1.1.1.), in order to collect *anamnestic data* about language emergence and daily linguistic environment and input of each participant;

- parental reports to document *lexical and communicative development* in both languages of each participant. More specifically, these reports are adaptations of the "MacArthur-Bates Communicative Development Inventories" (Fenson et al., 1993) in the different languages involved in the language pairs (Kern & Gayraud, 2010; Caselli & Casadio, 1995; Tardif, Fletcher, Zhang & Liang, 2008), (see point 2.1.2).

II.2.1.1 Parental questionnaire: language background

II.2.1.1.1 Development of the questionnaire

The parental questionnaire used for our study was built on the basis of the Questionnaire for Parents of Bilingual Children (from now on, PABIQ), adapted for toddlers, elaborated by Tuller and collaborators (Tuller, Messarra, Prévost & Zebib, 2011) in the frame of the IS0804 action of the COST Programme. This questionnaire is itself based on two existing tools, The Alberta Language and Development (Paradis, Emmerzael & Sorenson Duncan, 2010) and the Alberta language environment (Paradis, 2011).

We have drawn on this particular questionnaire for precise reasons. First, it has been specifically designed for use with parents of toddlers growing up in bilingual contexts. Indeed, The PABIQ aims at comprehensively documenting the specificities of each participant's bilingual experience; that is, first language developmental milestones and linguistic practices in the daily environment of the child. Therefore, it enables to precisely determine the degree of exposure to and use of both languages and, thereby, to establish a precise linguistic profile of each participant. Moreover, it allows for the computation of scores and indexes which makes it possible to turn qualitative information into quantitative data. More concretely, the different sub-scores are computed on the basis of the questionnaire's responses and, in turn, can be combined to generate two indexes: a *No-risk index* (Tuller et al., 2011; Tuller, 2015), taking account of risk factors for language delay/disorder, and an *Index of linguistic dominance* (developed by Almeida et al., 2016) concentrating information about language exposure and use.

Besides, the PABIQ was also built as a complementary tool to identify a potential language delay/disorder in bilingual children. As such, the use of its scores and indexes in combination with other language assessment tools developed specifically for bilingual children would permit to distinguish typically developing bilingual children and bilingual children with a language impairment (Tuller, 2015). Hence, the use of this questionnaire is totally adapted to our research objectives. However, we did make slight changes to the questionnaire and its scoring system. More concretely, certain questions were restated or refined in order to be more clear and/or adapted to our research issues. We will indicate the changes made in the subsequent description of the different sections of the questionnaire (the questionnaire can be found in Appendix 2).

II.2.1.1.2 Structure of the questionnaire

The questionnaire includes two mains parts: Part A on the child and Part B on parents. Then, Part A is divided in different sections: (1) General information about the child, (2) Early history and developmental milestones, (3) Current abilities, (4) Language use in the family and (5) Language use in other contexts. Part B involves three sections: (1) Information about the mother, (2) Information about the father and (3) Family history and language difficulties. It consists mainly of closed, yes-no questions or questions with predefined answers, such as frequency adjectives among which the parent(s) has/have to choose. Questions are formulated as clearly as possible so that the parents could fill it by themselves in writing, but also in order to collect raw information.

1 – General information about the child

This section gathers information about the child's date and place of birth, the actual place of residence, the presence of siblings and the child's place among siblings.

2 – Early history

This section comprises questions about: (1) first language developmental milestones such as the age of the first word(s) and word combinations, (2) the presence of parental concern about their child's language emergence, (3) the occurrence of ear infections, (4) global and specific exposure to both languages and (5), the beginning of significant exposition to each of their languages. We refined the question about the different exposure contexts, by adding different interlocutors and activities.

3 – Current abilities

In this section, parents have to assess their child's current language abilities in comparison to children of the same age. It includes expression and pronunciation abilities, lexical knowledge and the ability to form small phrases. We excluded questions inadequate for toddlers only starting to produce words and added one question requiring parents to give a global assessment of their child's level of comprehension and expression for his/her two languages.

4 – Language use at home

This section focuses on the language use at home: what language(s) is(are) used by the different members of the family to speak to the child, and conversely, what language(s) the child is using to speak to the different members of the family.

5 - Language use in other contexts

This section involves questions about the language use in other contexts, i.e., with different kinds of interlocutors, outside the home and during different activities, specifying the frequency of use as well. We added questions to document language use with a wider range of interlocutors (such as children at the nursery and friend's children).

6 – Information about the mother and 7– Information about the father

These two sections are focused on the child's parents. It allows gathering the following information: place of birth, number of years spent in Belgium, current occupation, education and level of proficiency for each language they speak.

8 – Family history and difficulties

This last section aims at documenting potential language difficulties in the family and more precisely, difficulties lying at different linguistic levels: reading and spelling, comprehension and oral expression. For difficulties in oral expression, we added a question requiring parents to specify the type of difficulties.

II.2.1.1.3 Scoring system of the questionnaire: calculation of indexes

We now describe in details the way the two indexes, the *No-risk index* (Tuller, 2015) and the *Index of linguistic dominance* (Almeida et al., 2016), are generated and precise the changes that we have made to their original method of calculation.

II.2.1.1.3.1 No- risk index

The *No-risk index* was developed by Tuller and colleagues in the questionnaire PABIQ (2011). It aims at identifying children that could potentially belong to a "high-risk" category; that is, children that would be more prone to a problematic language development. It gathers all factors that may increase the chances of being subject to language impairment, as it is generated based on questions about early development, parental concern and the existence of familial language difficulties. However, as pointed out by Tuller (2015), these are risk factors and not clinical markers. Indeed, a late emergence of language would be a hallmark characteristic of children with language impairments (Rice, 2007). Yet, all late talkers do not necessarily develop a language disorder and some of them eventually catch up and later performed within norms. Another risk factor is the presence of familial language difficulties, as it would increase the chances that a child will have a language disorder[40].

Table 18 extracted from our questionnaire shows the index calculation method. Practically, the *No-risk index* is generated by: (1) calculating a sub-score for early development by adding the points earned from answers to questions of the section 2, (2) subtracting the total of points for the question of the section 8 (about the presence of familial difficulties) from the maximal score that can be obtained and (3), summing up the results of the addition and the subtraction.

[40]Several studies focusing on children with familial difficulties did show important proportions of children with early language delay and persistent low language scores (Tuller, 2015), suggesting that children with a history of language impairment are themselves at high risk for language delay/impairment.

Questions		Response	Attributed points	Points
2.1	1sr word	15 months or younger	**6 points**	**/6**
		16-24 months	**4 points**	
		25 months or older	**0 point**	
2.2	1st word combinations	24 months or younger	**6 points**	**/6**
		24-30 months	**4 points**	
		31 months or older	**0 point**	
2.3	Parental concern	No	**2 points**	**/2**
		Yes	**0 point**	
2.5	Repeated ear infections	No	**3 points**	**/3**
		Yes	**0 point**	
Total for early development (*sum up obtained points*)				**/17**
8.1	Family difficulties	Subtraction: **9 – [total for family difficulties]**		**/9**
No-risk Index (sum up totals for early development /17 and family difficulties /9)				**/26**

Table 18: *No-risk index* quotation system (extracted from our questionnaire).

We have made few changes to the original calculation method of the index: we decided to include the question about the occurrence of recurrent ear infections in the calculation of the sub-score about early development. From our discussions with parents, we realised that repeated otitis in the first two years impacted early language development without children being diagnosed with hearing impairment. Indeed, even if the impact was always limited in time, parents reported that it did momentarily affect the quality of their child's speech productions. Therefore, it seemed pertinent to take this factor into account for the index, in link to our specific research issues. As a result of this change, the index maximum value increased from 23 to 26.

The *No-risk index* is calculated only once and thus, has a fixed value. Its maximum value is 26. Following the interpretation approach proposed by Tuller (2015)[41], an index value of 21-22 or more (corresponding to a score above 80%) can be interpreted as a probable indication of a typical development and an index value below 17 (corresponding to a score below 65%) as a probable indication of an atypical development. Then, as the index would be very sensitive, values between 18 and 20 would suggest a non-typical development requiring monitoring. As the PABIQ and the resulting *No-risk Index* are still in the process of validation, these threshold values are not yet standards. Still, the questionnaire has been used in bilingual research and appears to be an efficient tool to distinguish typical and atypical language development in bilingual contexts of acquisition, particularly for simultaneous bilinguals (Tuller et al., 2013; Almeida et al., 2016).

II.2.1.1.3.2 2 Index of linguistic dominance

The *Index of linguistic dominance* was developed by Almeida and colleagues (2016) based on the PABIQ questionnaire. It aims at characterizing the participants' bilingual profile in relation to their degree of exposure to and use of both their languages. Therefore, the index results from the ratio

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[41] We kept the same ratio to identify the different threshold values.

between the scores of exposure computed for the two languages. As such, it is generated based on questions about early exposure to both languages (section 2), the actual use of both languages at home (section 4) and in other contexts (section 5) and the number of months spent at nursery and at school[42].

Table 19 lists the different sub-scores and points assigned to each. Practically, the exposure score for each language is computed on the basis of different sub-scores: (1) a sub-score for the age of the beginning of exposure (/4), (2) a sub-score for the frequency early exposure contexts (/4), (3) a sub-score for the length of exposure (/4), (4) a sub-score for the diversity of early exposure contexts (/10), (5) and (6) sub-scores for the actual use of both languages at home (/16) and in other contexts (/16) and finally (7) and (8), sub-scores for the number of months spent at nursery (/2) and at school (/4). Exposure score for each language is calculated by adding all sub-scores (/60). Then, the Index of linguistic dominance is generated by subtracting the exposure score obtained for the second language from the exposure score obtained for French.

Sub-scores to compute the global exposure score for each language	**Quotation**
Age of the beginning of exposure (AoE)	**/4**
Frequency of early exposure (FoE)	**/4**
Length of exposure (LoE)	**/4**
Diversity of early exposure contexts (VoEC)	**/10**
Actual use of language at home (LUH)	**/16**
Actual use of language in other contexts (LUoC)	**/16**
Months spent in nursery (LoN)	**/2**
Months spent in school (LoS)	**/4**
Total exposure score	**/60**
Index of linguistic dominance (French exposure score – exposure score of the other language)	

Table 19: *Index of linguistic dominance* quotation system.

We made very slight adaptations to the original calculation method of the index. We increased the total of the sub-score for the diversity of early exposure contexts up to 10 (initially 8), as our parental questionnaire includes more exposure contexts (see the point about the questionnaire structure). We also added a sub-score for the number of months spent in the nursery and reduced the total of the sub-score for months spent at school to 4 (initially 5) in order to balance its weight in the total exposure score. Indeed, the original index was originally developed for school-aged and sequential bilinguals and only included a sub-score for time spent at school. As a result of these changes, the value of exposure score increased from 57 to 60.

Following Almeida et al. (2016), an index value comprised between -6 and 6 corresponds to a balanced bilingualism. An index value above 6 indicates a linguistic dominance in French and an index value below -6 to a linguistic dominance in the other language. The interval of -6 to 6 corresponds to a margin of 10% of the total score. Contrary to the *No-risk index*, the value of *Index of linguistic dominance* is not fixed as it is susceptible to fluctuate due to changes occurring in the linguistic environment of the child. Therefore, exposure scores to both languages and the resulting index value are updated at each collection of speech production data.

[42] As children were longitudinally followed, they eventually all entered school during the course of the study.

II.2.1.2 Parental reports: data about lexical development

As already explained in the section about our research problematic and hypotheses, we decided to gather data about lexical development in parallel to collecting speech productions of the participants. One objective was to assess the initial level of lexical development of the children to ensure that they would already produce words spontaneously in order to include them in our sample. Moreover, it enabled us to check whether they would have a total productive vocabulary of, at least, 50 words (combining words from both languages) and, at least, 25 words in French. Another objective is to make the link between children's phonetic-phonological and lexical development. Therefore, we longitudinally (from session 0 to session 4) collected those complementary data. As a matter of fact, the different levels of linguistic competence (phonology, lexicon, syntax, etc.) develop simultaneously in interdependence and not in isolation. Hence, those developing language skills would affect each another. Indeed, learning new words mobilise children's cognitive resources and, could, thereby, have an impact on the quality of their phonological representations and phonetic realizations. Consequently, data about lexical development could enlighten and refine our interpretation of the results of analyses conducted on speech productions and possibly, lead to better understanding of children's phonetic-phonological development.

II.2.1.2.1 Choice of the specific parental report

We chose to specifically use the MacArthur-Bates Communicative Developmental Inventories (from now on, MBCDI) in our research for several reasons. Originally created by Bates and colleagues, the MBCDI constitute a type of parental report aiming at assessing children's early linguistic abilities, including receptive and productive vocabulary, paralinguistic gestures and morphosyntax (Bates, Camaioni & Volterra, 1975). Standardised over a sample of more than 1800 American English-speaking children, this instrument has been adapted into many different languages, based on the original American version (Fenson et al., 1993). Its validity and reliability have been extensively and thoroughly studied and more precisely, the following psychometric qualities have been ascribed to it: internal and external test-retest reliability, convergent and concurrent as well as predictive validity (Kern, 2004). Besides, it appears to be a good tool to draw up the general indicators of a normal development and to detect a potential language delay/disorder if used in association to other observations in order to cover different aspects of language development (Kern, 2004; Kern & Gayraud, 2010). In sum, the use of the MBCDI allows gathering rapid and reliable information about the child's linguistic profile.

However, this tool presents some disadvantages and/or limits. Indeed, given that parents fill it, the data reflect their perception; hence, it is an instrument of indirect assessment, since it gives no access to language in real-world context and to natural speech production. Moreover, it does not provide information about the frequency and/or context of use of a specific word or utterance. Besides, it has been designed and standardised over populations of monolingual children which should be kept in mind when interpreting the results of bilingual toddlers.

The original American version (Fenson et al., 1993) consists of two questionnaires: (1) the questionnaire "Words and gestures" addressed to children aged from 8 to 16 months and focusing on receptive vocabulary and paralinguistic gestures and (2), the questionnaire "Words and sentences" addressed to children aged from 16 to 30 months and focusing on productive vocabulary[43] and emerging morphosyntax. Once the questionnaire(s) filled by the parents, the researcher can synthesise the linguistic development of the child and interpret the results by completing the encoding form and comparing the results with the norms. To do so, one has to refer to the charts with the percentiles and percentages.

In the frame of our study, we used the full versions[44] of the questionnaire "Words and sentences" in order to easily collect data about the children's productive vocabulary. Moreover, we decided to ask parents to fill the questionnaire for each language of the child. In order to observe the potential impact of the expanding lexicon on phonetic-phonological development, it appears important to consider the whole lexical repertoire of the child and therefore, to assess both languages. Conveniently, standardised adaptations of the questionnaire "Words and sentences" exist for French (Kern and Gayraud, 2010), Italian (Caselli and Casadio, 1995) and Mandarin (Tardif and Fletcher, 2008)[45] (French, Italian and Mandarin parental reports can be found in Appendix 3, 4 and 5). Regarding Arabic, the Plymouth Babylab team is currently working on adaptations for multiple Arabic dialects. Following our request, they kindly accepted to share their vocabulary checklists for Moroccan and Standard Arabic (the checklists can be found in Appendix 6). However, norms were not yet available. Besides, it must be pointed out that some children were already over 30 months of age when their parents first filled the questionnaire (during Session 0) and were thus exceeding the age limit for the norms. Therefore, we are considering the total number of words produced in French and in both languages rather than percentiles and percentages, whose application to bilingual children would furthermore be questionable or subject to cautious interpretation. For what we are interested in is the developmental/growth curve of the children's productive vocabulary, in order to link it to their phonetic-phonological development in French.

II.2.1.2.2 Structure of the MBCDI adaptations used in the study

Basically, all adaptations have the same structure, apart from the Arabic version which did not yet include a section about emerging morphosyntax. The questionnaire "Words and sentences" is divided into two parts. Its first part involves a productive vocabulary checklist split into different semantic categories[46]. Then, its second part is focused on emerging morphosyntax. Globally, it consists of questions about the children's ability to: refer to present *vs.* absent objects and past and future events, use morphemes and verbal tenses and combine words into sentences[47]. Regarding word combinations, all adaptations include a question about the longest utterances produced by the child.

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[43]As pointed out by Kern and Gayraud (2010), the second half of the second year is characterised by a great vocabulary expansion; hence, it would not be realistic to ask parents to assess lexical comprehension.
[44]Short versions of the MBCDI have been developed for some languages. However, they are less complete and do not exist for all languages involved in our study.
[45]Adaptations of the questionnaire "Words and sentences" for French and Mandarin are addressed to children aged from 16 to 30 months, just as the original American version. The Italian adaptation is addressed to children aged from 16 to 36 months.
[46]More precisely, French adaptation comprises 690 words split into 22 semantic categories, Italian adaptation: 670 words split into 23 semantic categories, Mandarin adaptation: 801 words split into 24 semantic categories and Arabic adaptation: 395 words split into 19 semantic categories.
[47]Regarding the part about morphosyntax, French and Italian adaptations are very similar. Due to its morpho-typological specificities, the Mandarin adaptation involves questions about ability the use of possessive and aspect markers.

II.2.1.3 Administration of parental questionnaire and reports

The language background questionnaire as well as the parental reports have been developed in such a way that parents could fill it by themselves in writing. Accordingly, parents were sent the language background questionnaire right before the first meeting by email and could already complete as much questions as they could. During session 0, we examined the whole document with them orally in the form of a semi-structured interview, in case some questions were considered as ambiguous or difficult to answer. After the questionnaire's verification, parents were asked to fill the parental report in each language of the child. They could always choose to do it in our presence or by themselves, at a more convenient time. In both cases, we went through the whole list with them and gave them precise instructions for properly filling it, following Kern and Gayraud (2010). The instructions are the following: (1) mark the words/morphemes/utterances that your child spontaneously produces, (2) if you hesitate about a word, do not mark it, (3) if your child says the word with an incorrect pronunciation, do mark the word. We also reminded them that the list includes words produced by many different children and that they should not worry if their child knows only a few at that time. When none of the parents would be a native speaker of French, siblings or child-care/nursery school worker were asked to complete the questionnaire.

Parental questionnaire and reports have been updated at each recording session (from S1 to S4) in order to take into account potential changes in the language exposure and use – and if necessary, recalculate the *Index of linguistic dominance* – and to document lexical development of each participant.

II.2.2 Speech production data collection

II.2.2.1 Choice of the data collection paradigm

Currently, there are still few instruments appropriate and/or available for the assessment of phonetic-phonological development (in speech production) in French for children under 3 years of age. Two types of data collection paradigm are generally used to analyse speech production in toddlers: paradigms consisting in the collection of spontaneous speech in interactive/play context generally involving the children's parents and paradigms consisting in the collection of elicited speech (more particularly elicited production of isolated words/non-words), possibly in presence of the children's parents.

These two types of paradigm present both advantages and drawbacks. The collection of spontaneous speech during parent-children interactions is ecological and adapted to toddlers. Additionally, it allows assessing language development with a dynamic approach and taking into account different linguistic levels, from phonetic to pragmatic competence (Le Normand, 2007). However, a considerable disadvantage is that it generates a very large amount of data resulting in extremely time-consuming transcription and analyses. This type of task also makes determination of the targets of distorted productions – very common in toddlers – more problematic[48]. In comparison, the collection of elicited speech allows targeting specific productions in children, depending on the particular research objectives. Therefore, it permits to make the child directly produce the needed language responses, which is time-saving and enables to know the productions' targets with more certainty. In addition, it makes data more comparable as it involves the same task, and thus the same

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[48]Consequently, the researcher could be more prone to "restore" children's productions (Le Normand, 2007).

items to be produced, for all children. Nonetheless, this task is less ecological and toddlers might not always spontaneously produce the expected output.

We chose to use a word-naming task in order to collect specific speech productions in a rapid and controlled way. We chose words rather than non/pseudo-words for not adding the cognitive process of word learning. Moreover, we decided to develop our own task so that it would be the most adapted to our research issues and participants. Besides, we also wanted to organise our corpus items in a specific order of presentation. Therefore, our corpus should be built based on specifically chosen criteria for both the selection and organization of the words (all criteria are described in details in section II.2.2.3.). In order to maintain naturalistic conditions and improve the likelihood of the child producing the words, we also decided to integrate the task in a playful context with a picture-book (see Figure 20 below).

Figure 20: Cover and page of the picture-book made for the task.

II.2.2.1.1 An adaptive protocol

Given the variability in age and linguistic level of our participants, our protocol for speech data collection had to be adaptive in several respects. Indeed, children were at different stages of linguistic and cognitive development and would certainly follow different developmental patterns. Moreover, some of them were very young, below 24 months of age, when they were first recorded. Consequently, we decided to build a single comprehensive corpus identical for all children with the possibility of going through the whole corpus or only part of it, according to the linguistic, cognitive and/or attentional abilities of our participants. Furthermore, we decided that the words constituting the corpus should not be presented randomly but rather, in a specific order, based on precise criteria. We describe this specific order of presentation in the next section about the protocol's operational development (see II.2.2.2.2.).

For the same reasons, administration procedure and instructions addressed to the child should also be adaptive. Indeed, not all children were initially able to directly and spontaneously name the pictures and they could also be differently affected by the experimenter's presence[49]. Hence, our protocol had to be dynamic. When necessary, the word-naming task evolved towards a word-repetition task and accordingly, different instructions were given to the child. Then, we chose to be responsible for administering the task to the children, possibly in presence of one (or both) parent(s).

[49]Indeed, children who just started to spontaneously produce words might do so with their parents but might not be willing or daring to speak in front of a person from outside their usual environment.

Indeed, we wanted to avoid cases where the child would repeat words uttered by a parent who is not a native speaker of French and reproduce a particular pronunciation, whether deliberately or not. Still, parents could always stand by their child during the speech recordings in order to encourage and put them at ease for the task. When the child would not respond at all to us, they were involved to a greater extent in the interaction. In sum, we chose to remain flexible regarding the modalities of task administration by adapting to the specific circumstances of each recording while ensuring consistency between the different sessions and participants in parallel. Administration procedure and instructions will also be explained in a subsequent point (II.2.2.3.1.).

II.2.2.2 Development of the word-naming task

As previously mentioned, we have created an original word-naming task in order to be able to choose specific criteria for both the selection and order of presentation of our corpus items. We will now describe in details the development of our task, starting with the criteria used for the selection of the items, followed by the elaboration of the specific order of presentation of the items.

II.2.2.2.1 Items for the task: selection criteria

II.2.2.2.1.1 Selection criteria of existing tools

In order to select the items for our word-naming task, we have reviewed different existing speech/language assessment instruments for French as well as protocols from studies about phonological development in bilingual preschool children involving French. Indeed, several authors did use word-naming task to assess particular segmental and supra-segmental structures in early speech productions. A specific criterion present in most tools is the presence of consonants and consonantal clusters in different positions in the word. MacLeod and colleagues have developed a tool for screening speech sounds disorders in French-speaking preschool-aged children, focusing on the assessment of consonant production (MacLeod, Sutton, Sylvestre, Thordardottir & Trudeau, 2014). Their screening tool involves 40 words including almost all Québec French consonants in word-initial, word-medial and word-final position, and targeting several consonantal clusters as well. Similarly, Rvachew and colleagues (2013) also developed a screening test to investigate speech production accuracy, the *Test de Dépistage Francophone de Phonologie,* and used 30 words reflecting the distribution of phonemes, syllabic structures and word lengths characteristic of Québec French. Moreover, consonants appear in at least four different positions in the syllables of their items: onset, branching onset, coda and glide in the nucleus[50]. While these authors have taken the age of acquisition into account by only including words acknowledged to be acquired between 2 and 8 years (Rvachew et al., 2013), MacLeod and colleagues paid attention to the fact that words used should be easily represented by a picture[51] (MacLeod et al., 2014).

In the frame of our research, we were interested to combine some of the selection criteria from the instruments just cited and therefore, it was necessary and appropriate to elaborate our own corpus of words to be produced by the children.

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[50]Other authors have devoted particular attention to the acquisition of word-initial and word-final consonantal clusters (Bishop and Minor-Corriveau, 2015), or on word-initial occlusive consonants (MacLeod, Laukys, Ravchew, 2011).

[51]Rvachew and colleagues (2013) also checked if the words were acceptable for both parents and children and based on this criteria, rejected words eliciting incorrect/no answer(s) or embarrassing participants.

II.2.2.2.1.2 Choice of specific selection criteria for the corpus

In order to constitute a thoroughly controlled corpus, we have chosen six criteria that we considered as being the most relevant for our study. These criteria are of a psycholinguistic, phonological and structural nature. They are hierarchically listed below, according to the order of importance attributed to them:

- the age of acquisition of the words,
- the imageability of the words,
- the presence of all French phonemes in the resulting corpus,
- the occurrence of all French consonants in different positions in the word,
- the presence of different consonantal clusters in different positions in the word,
- the presence of different word lengths and syllabic structures existing in French

We will now explain and justify the choice of these specific selection criteria and their hierarchical organization.

1. Age of acquisition (from now on, AoA) of the words

The age criterion takes precedence over other criteria because it was crucial that the corpus includes words known to be in the lexicon of a preschool child. Therefore, we have selected words identified as being acquired between 8 and 70 months. To this end, we referred to the lexical database of Chalard and collaborators (Chalard, Bonin, Méot, Boyer & Fayol, 2003) providing standardised psycholinguistic measures of objective AoA. When AoA norms were not available, we resorted to both questionnaires of the French adaptation of the MBCDI (or, from now on, IFDC for Inventaire Français du Développement Communicatif). Indeed, this tool provides a list of words supposedly understood and/or produced by children between 8 and 30 months[52]. Therefore, we chose to rely on parental report as well for the selection of the words to include in our corpus (see Appendix 7 for a lists of all items with their presence in either lexical database or parental reports).

2. Imageability of the words

Imageability of the words was our second priority concern. Indeed, we wanted words of our corpus to be easily named on the basis of visual stimuli; that is, words whose referents could be represented by a picture readily identified by toddlers. Based on this criterion, we decided not to include some words such as "viande" or "limonade", which explains the lack of word ending with the phoneme /d/ (see next point). As for the choice of the specific visual stimuli, we explain it in an upcoming sub-section (see II.2.2.2.3.).

.3. Inclusion of all French phonemes

As our research focuses on phonetic-phonological development in French, the words of our corpus had necessarily to involve at least one occurrence of each French phoneme in order to cover

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[52]Different studies have been conducted to guarantee the relevance of the items selected for both questionnaires (Kern & Gayraud, 2010); that is, to ensure that the chosen items are actually used by children aged between 8 and 30 months. Practically, mothers were asked to document the questionnaires and to add items that seem relevant to them or, on the contrary, to remove those inappropriate (Kern & Gayraud, 2010).

the whole French phonemic repertoire. Consequently, all phonemes excepting the vowels /ɑ/ and /œ̃/ appear at least once in our corpus. However, the phoneme /œ̃/ nowadays tends to disappear from Standard French and the phoneme /ɑ/ is quite rare.

4. <u>Inclusion of all French consonants in different positions</u>

As consonants would be more and less difficult to produce and master depending on their position in the word/syllable and whether they occur as singleton or in consonantal clusters (MacLeod et al., 2011), we also wanted our corpus to involve occurrence of all French consonants in different positions in the word (word-initial, word-medial and word-final) and in the syllable (onset and coda position) as well as in isolated and clustered contexts. Being more specific by distinguishing consonants in medial *vs.* final coda as well was not possible, as our corpus would have been much too long.

Practically, all French consonants appear in all three positions in the word, except:

- the phoneme /ɲ/ not occurring in word-initial position/initial onset,
- the phonemes /d/ and /v/ not occurring in word-final position/final coda,
- the glide /w/ not occurring in word-final position/final coda and the glide /ɥ/ not occurring in both word-initial/initial onset and word-final position/final coda.

Besides, the phonemes /p/, /b/, /t/, /k/, /g/, /f/, /v/, /s/, /l/, /r/ appear both in isolation and in clusters (see the upcoming criteria).

5. <u>Inclusion of consonantal clusters in different positions</u>

As consonantal clusters would also be acquired more and less early depending on their position in the word and are likely to trigger the emergence of phonological patterns, our corpus had to include consonantal clusters in different positions in the word. However, similarly to the previous criteria, it was not conceivable to represent all consonantal clusters existing in French (moreover in different positions in the word) in our corpus due to length constraints.

In total, 24 different clusters are involved, each of which occurs, at least, in one of the following position in the word: initial, medial or final. Only the cluster /bʁ/ appears in all three positions.

6. <u>Inclusion of different word lengths and syllabic structures</u>

Finally, length and syllabic criteria have been considered in combination and are, in a certain way, induced by the previous phonological and structural criteria. In order to observe the complexification of the children's productions, we wanted to include words of different lengths and with different syllabic structures. Moreover, the two variables affect the accuracy of early productions and are interlinked. Indeed, trisyllabic words would be acquired later than mono- and disyllabic ones[53]; however, trisyllabic words with a simple syllabic structure such as CVCVCV (as in *pantalon*), would be easier to produce than a mono-syllabic word with a syllabic structure such as VCCC (as in

[53]Indeed, according to Gayraud & Kern (2007), trisyllabic words would emerge around 30 months (and after) in the child's lexicon.

arbre). Then, the most frequent syllabic structure produced by French-speaking children around 24 months would be the structure CV but its frequency would start decrease around 30 months while that of structures such as CVC and CCV increase, as they start acquiring consonants in coda and consonantal clusters.

In total, our corpus involves 19 monosyllabic, 23 disyllabic and 6 trisyllabic words and includes a total of 29 different syllabic structures. Moreover, it consists of a total of 48 test-items, plus 3 training items and 2 leitmotiv items (see Table 21). Indeed, it includes three words (namely, *lit, bateau* and *bébé*) as training items to ensure children understand well the game before making them produce the test-items. Those training items involve the basic syllabic structure CV in order not to start with complex items. We also decided to add two leitmotiv items, *Maya* and *Oui-oui*, which are repeatedly presented to the child during the task and this, for several reasons. First, those two words involve the glides /j/ and /w/ in intervocalic position which allows for an easy identification of the first and second formants[54] of the vowels /a/, /i/ and /u/ for the subsequent acoustical analyses of the speech signal[55]. Second, both words also refer to cartoon characters generally known by the children, which enhances the playfulness of the task and permits drawing the child's attention back to the game.

II.2.2.2.2 Order of presentation of the items

II.2.2.2.2.1 Criteria for the order of presentation

As previously explained, our protocol is adaptive in several aspects. Indeed, we decided to adjust to the child's linguistic level and/or cognitive/attention skills. Consequently, we anticipated the fact that the youngest children (below 24 months) would be likely to produce only part of the corpus. Therefore, we decided that the words should be presented in a specific order, based on two criteria: the AoA of the words and their degree of phonological complexity. More precisely, the items should have gradually increasing AoA – going from the earliest-acquired items to the latest-acquired ones – and fluctuating levels of phonological complexity – alternating between words of less and greater phonological complexity. The purpose of this particular order of presentation was to start with words more likely to be known by the youngest children and to counterbalance the degree of difficulty throughout the whole corpus. Consequently, we would ensure that the child would utter items implying different degrees of phonological complexity in situations where it would not be possible to make them produce all the words. To our knowledge, this has not been done before in studies about phonological development or in any speech/language assessment instruments that we have reviewed.

II.2.2.2.2.2 Creation of an index of phonological complexity

1. Choice of the parameters for the index calculation

Phonological complexity is a multi-layered notion whose definition involves different aspects of speech production. We decided to compute an index in order to quantify the phonological complexity of the words of our corpus. Similar to the index of phonetic complexity developed by Jakielski and collaborators (2000) for English, we wanted to build an index specifically for our corpus

[54]A formant is a concentration of acoustic energy around a particular frequency in the speech wave.
[55] Indeed, given children's high but "normal" variability in production resulting from the development of still immature vocal apparatus, vowels' formants might not necessarily be located where one would generally expect them.

in French. In practical terms, we have chosen specific parameters lying at different phonological levels: (1) syllable level, i.e., the type of syllabic structure combined to the word length; (2) segmental level, i.e., the absence *vs.* the presence of specific phonemes (i.e., nasal vowel, word-initial vowel, fricatives /ʃ, z, ʒ/) possibly in a specific position in the syllable and/or the word; (3) inter-segmental, i.e., the absence *vs.* the presence of a consonantal cluster of two or more consonants, possibly in a specific position in the syllable and/or the word (see Table 20). It is the combination of these different levels that would make a word more difficult to produce for children still in the process of language acquisition. Segmental parameters have been chosen based on the following motives: nasal vowels are reported be acquired later than oral vowels (Rondal, 1999), words starting with vocalic onset would emerge after 36 months (Gayraud and Kern, 2007) and the fricatives /ʃ/, /z/ and /ʒ/ are reportedly the latest acquired phonemes in French (Rondal, 1997; Macleod et al., 2011), even more in coda position.

Levels	Parameters	Grades of each parameter	Complexity weight
Syllable	Syllabic structure and word-length	Monosyllabic and disyllabic duplicated	0
		Disyllabic variegated	1
		Trisyllabic	2
Segmental	Nasal vowel	Absence	0
		Presence	0,5
	Word-initial vowel	Absence	0
		Presence	1
	Fricatives /ʃ/, /z/, /ʒ/	Absence	0
		Presence in onset	1
		Presence in coda	2
Inter-segmental	2-consonants cluster	Absence	0
		Presence	1
		Presence in coda	2
	3-consonants cluster	Absence	0
		Presence	2
		Presence in coda	3

Table 20: Representation of the different grades of the parameters with the values assigned to each of them.

2. Calculation of the index of phonological complexity

Defined parameters were operationalized in order to calculate an index of global phonological complexity for each word. To do so, we assigned a specific value – or complexity weight – to each grade of the parameters (see Table 20). The value of 0,5 was chosen for the presence of nasal vowels as it was considered as a less complex feature than the presence of a word-initial vowel and/or of one of the specific fricatives (which were attributed a value of 1).

For each of the three levels of phonological complexity, we calculated a weighted sum, equal to the sum of the products obtained for each parameter's level divided by the maximum value obtained in our corpus for this specific level of phonological complexity. For each word *i,* we obtained a final score of phonological complexity, as shown in the following equation, with CI_i corresponding to the complexity index of the word i, SyC_i corresponding to the syllable complexity of the word i, Se_i corresponding to the segmental complexity of the word i, ISC_i corresponding to the inter-segmental complexity of the word i and max_j corresponding to the highest value of the index amongst all words j of the corpus:

$$CI_i = \left(\frac{SyC_i}{max_j SyC_i} + \frac{SeC_i}{max_j SeC_i} + \frac{ISC_i}{max_j ISC_i}\right)/3$$

The score obtained corresponds to the index of (global) phonological complexity calculated for each word of our corpus. Based on this index, we were able to generate a complexity ranking of the words (see Table 21).

II.2.2.2.2.3 Elaboration of the specific order of presentation

Both criteria, AoA and phonological complexity, have been combined to elaborate the particular order of presentation of the items of our corpus. In parallel to their complexity ranking, words were also classified based on their AoA. More precisely, they were organised in seven ranges of AoA from 8 to 70 months, rather than precise AoA values, based on the age brackets used in the MBCDI questionnaires[56]. Still, the AoA criterion outweighed the complexity criterion in the organization of the words, in order to maximise the chances that the child would produce the word. Thus, the 48 words of the corpus have been organised into 8 series of 6 items. The successive series were of globally increasing AoA[57], and the items within each series were of an increasing degree of phonological complexity. As the child progresses in the word-naming task, items to be produce are words acquired increasingly late. Moreover, their degree of phonological complexity rises in parallel within each series while dropping back to a low level of complexity at the beginning of each new series. The degree of complexity evolves identically within the different series but they do not necessarily start at the exact same level of complexity. The task starts with the presentation of the three training items and the two leitmotiv items (*Oui-Oui* and *Maya*) are inserted between each series of words (see Table 21).

[56]Indeed, no precise AoA value was available for items not present in the lexical database of Chalard and colleagues (2003) but found in one of the IFDC questionnaires (Kern & Gayraud, 2010). Therefore, the AoA bands were the following: (1) 8 to 16 months, (2) 16 to 30 months, (3) 30 to 38 months, (4) 38 to 46 months, (5) 46 to 54 months, (6) 54 to 62 months and (7), 62 to 70 months. All AoA bands cover a period of 8 months, corresponding to the age bracket used in the IFDC questionnaire "Words and Gestures" (8-16 months), except the second AoA band which covers a larger period of 14 months corresponding to the age bracket used in the IFDC questionnaire "Words and sentences" (16-30 months).

[57]The first series comprises words exclusively from the first AoA band and words from AoA bands 2 and 3 are reunited into the second series. From the third to the fifth series, only words from the AoA band 3 are included. The sixth series involves part of the words from AoA band 4. Then, the seventh series contains the rest of the words from AoA bands 4 and 5. Finally, the eight series consists of words from both AoA bands 6 and 7.

Order	**Items**	**AoA band**	**Index of complexity**	**Series**
Training item	*Lit*			
Training item	*Bébé*			
Training item	*Bateau*			
1	Coucou	1	0,00	1
2	Langue	1	0,06	1
3	Cheveux	1	0,28	1
4	Nombril	1	0,33	1
5	Pyjama	1	0,44	1
6	Echarpe	1	0,61	1
Leitmotiv items	**Oui-Oui - Maya**			
1	Pomme	3	0,00	2
2	Robe	3	0,00	2
3	Glace	2	0,11	2
4	Souris	3	0,17	2
5	Livre	3	0,22	2
6	Yaourt	2	0,39	2
Leitmotiv items	**Oui-Oui - Maya**			
1	Fleur	3	0,11	3
2	Cadeau	3	0,17	3
3	Porte	3	0,22	3
4	Tortue	3	0,28	3
5	Poisson	3	0,33	3
6	Etoile	3	0,39	3
Leitmotiv items	**Oui-Oui - Maya**			
1	Oiseau	3	0,28	4
2	Chaussure	3	0,28	4
3	Chaise	3	0,33	4
4	Crayon	3	0,33	4
5	Pantalon	3	0,44	4
6	Eléphant	3	0,50	4
Leitmotiv items	**Oui-Oui - Maya**			
1	Chien	3	0,28	5
2	Cuillère	3	0,28	5
3	Girafe	3	0,28	5
4	Téléphone	3	0,33	5
5	Parapluie	3	0,56	5
6	Escalier	3	0,67	5
Leitmotiv items	**Oui-Oui - Maya**			
1	Feuille	4	0,00	6
2	Doigt	4	0,11	6
3	Banane	4	0,17	6
4	Panier	4	0,28	6
5	Grenouille	4	0,28	6
6	Arbre	4	0,44	6
Leitmotiv items	**Oui-Oui - Maya**			
1	Train	5	0,17	7
2	Vache	5	0,22	7

Order	Items	AoA band	Index of complexity	Series
3	Carotte	4	0,28	7
4	Zèbre	5	0,33	7
5	Cloche	4	0,50	7
6	Champignon	4	0,56	7
Leitmotiv items	**Oui-Oui - Maya**			
1	Peigne	6	0,00	8
2	Bras	7	0,11	8
3	Parc	6	0,22	8
4	Fourmi	7	0,28	8
5	Pingouin	7	0,39	8
6	Fromage	7	0,50	8

Table 21: Items by presentation order based on AoA and the Complexity Index.

In Figure 21 below, the different series of words are plotted on a XY axis chart where the "X" axis corresponds to the order of presentation, and the "Y" corresponds to the degree of complexity. Each of the eight series appears in the same specific colour as in Table 21 and three items with different AoA and levels of phonological complexity are made visible.

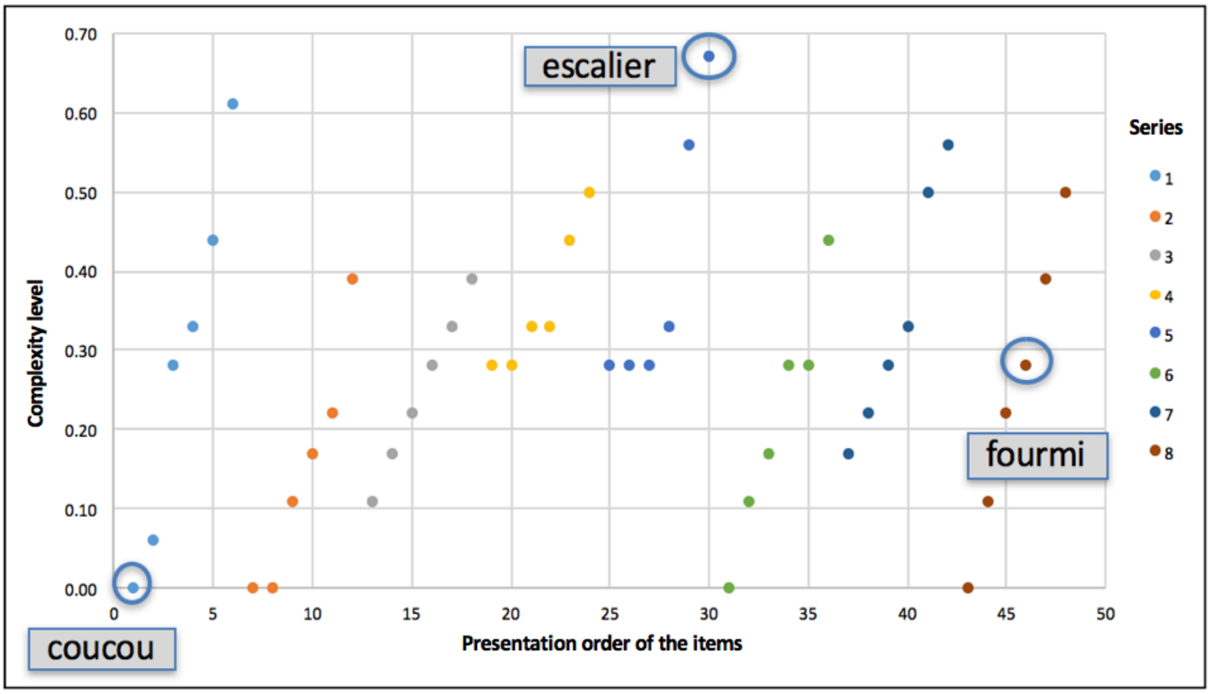

Figure 21: Graph representing the order of presentation based on AoA and CI.

II.2.2.2.3 Selection of visual stimuli

To found the pictures, we looked in two different databases of colour photos normalised[58] for different psycholinguistic variables. The databases are the following:

- the *Ecological alternative to Snodgrass and Vanderwart* (Moreno-Martinez & Montoro, 2012): a new set of 360 high quality colour images belonging to 23 semantic subcategories and normalised for seven psycholinguistic variables (age of acquisition, familiarity, manipulability, name agreement, typicality and visual complexity).
- the *Bank of Standardized stimuli* (Brodeur, Dionne-Dostie, Montreuil & Lepage, 2010): a new set of 480 photo stimuli normalized for seven psycholinguistic variables (name, category, familiarity, visual complexity, object agreement, viewpoint agreement, and manipulability).

Pictures not present in any database, or present in a database but considered as inappropriate[59] for our protocol, were searched on internet (pictures free of rights). In total, 24 photos came from the databases and 27 were found on internet (see Table in Appendix 7 for a list with each picture's specific source).

II.2.2.3 Experimental procedure

II.2.2.3.1 Task administration and instructions

Given that some children could not yet spontaneously speak in front of a person from outside the home environment, conditions of the interaction should remain flexible[60]. Then, another adaptive aspect of our protocol concerns the dynamic nature of the task. Our objective is to collect specific speech productions from very young children in the process of acquiring language – furthermore, in a process of bilingual language acquisition – and in this regard, the task could evolve towards word-repetition if needed.

Accordingly, the task could involve different potential stages and types of elicitation requiring precise and operational instructions aimed at the child. Therefore, and based on different language assessment tools (Chevrie-Muller & Plaza, 2001; Coquet, Ferrand & Roustit, 2009; Rvachew et al., 2013; MacLeod et al., 2014), we defined the potential elicitation stages and corresponding instructions that should be followed to administer the task. They are listed right below.

- Stages 1 and 2: "Spontaneous and direct naming on request"

First, we present the picture to the child without saying anything (*spontaneous naming*). Then, we ask him/her to name it by asking "What is it?" or "What is this called?" (*direct naming on request*).

[58]That is, standardised over large population samples.
[59]Pictures were intuitively judged as inappropriate based on different criteria: (1) pictures representing referents in a way not adapted to children; that is, not clearly or straightforwardly enough or too specifically, (2) pictures not attractive enough for children and (3), picture insufficiently bright.
[60]Indeed, parent(s) could be required to take part in the interaction in cases where the child would not cooperate at all.

- *Stage 3: "Naming with a hint"*

If the child does not name the picture or does not produce the expected word, we help the child by giving him/her a semantic clue and, as a last resort, a phonological hint (first phoneme/syllable of the word) but in that case, we make him/her repeat the item if the first phoneme/syllable is elided.

- *Stage 4: "Induced repetition"*

If the child still does not name the picture at stage 2, we try to make the child repeat the word in a spontaneous way, by using a formula such as: "Oh look, what is it, is that an apple? ... Yes, it is an apple!"[61].

- *Stage 5: "Direct repetition"*

If the word is still not produced at stage 4, we try to make the child repeat in a more direct/explicit way, by saying: "Could you repeat the word after me (…)".

It should be underlined that we have tried to go through all the steps just described while keeping an intuitive approach. Besides, when the child's production was very distant from the target, we asked him/her to repeat the word once, while being careful not to correct the error in order to ensure that it is his/her usual pronunciation. However, the elicitation type, whether naming or repetition, will be considered as an independent variable in the subsequent analyses (this issue is returned to below in section II.3.2.4.).

II.2.2.3.2 Recording equipment

Children have been audio recorded at their home during the task. We used an audio-recorder with one additional external microphone, in order to have different sources for sound recording. This appeared to be the best relationship between the degree of invasiveness and the quality of the equipments. We used the following devices: (1) a Zoom H5 handy recorder which is a compact, portable handheld digital recorder capable of four-track recording with two integrated directional microphones, (2) a Sennheiser e912 BK Condenser Boundary Microphone, generally used for capturing theatre productions and whose acoustic properties have been optimized for instruments, vocals and speech. The Sennheiser microphone was placed alongside the audio-recorder and both instruments were positioned at a maximum distance of 40 cm from the child.

II.3 DATA PROCESSING

II.3.1 PROCESSING OF HETERO-REPORTED DATA

The parental questionnaires have been processed in order to compute two indexes: the *No-risk index* (from now on, NRI), calculated once, and the *Index of linguistic dominance* (from now on, ILD), actualised at each session. The obtained NRI and ILD values enabled us to respectively identify children with a potentially delayed language development and to classify participants into three sub-

[61]Indeed, this procedure has already been successfully used by Harmegnies and colleagues in their study about bilingual Castillan-Catalan children, in which mothers interact with their child to make them repeat words (Harmegnies, Huet, Piccaluga, Delvaux & Lopez, 2016).

groups: children characterized by a linguistic dominance in French (FLD for French Linguistic Dominance), children characterized by a linguistic dominance in their other language (NFLD for Non-French Linguistic Dominance) and children characterized by no linguistic dominance or by an equivalent degree of exposure to both languages (BBil for Balanced Bilingualism). Linguistic dominance of the participants will be considered as an independent variable in the subsequent statistical analyses (to be detailed in the next chapter).

Data from adaptations of MBCDI were processed in order to calculate two vocabulary scores: the total number of words produced in French and the total number of words produced in both languages combined. Vocabulary score(s) will also be considered as an independent variable in the subsequent statistical analyses. Besides, as most words (all except three: *parapluie, champignon* and *peigne*) involved in our naming task are comprised in the vocabulary checklist of the IFDC, we checked at what point every word was reportedly spontaneously produced for all participants, which allowed us to distinguish between two types of repetitions (we explain this in section II.3.2.4).

II.3.2 PROCESSING OF RECORDED SPEECH DATA

In order to start analysing speech data collected from the participants, we had to: (1) choose the best audio track on which to base the analyses, (2) organise the corpus and (3), segment and annotate the data using different softwares. We detail these different steps in the following sub-sections.

II.3.2.1 Choice of the audio track

Each collection of speech data via the word-naming task has been registered via three different sources: the two microphones from the Zoom H5 handy recorder and the external boundary microphone (see point II.2.2.3.2.). This was done in order to have a back-up solution (the external microphone) when children were not standing still during the recording and/or when the audio file resulting from the recording via the handy recorder was damaged or of poor quality. However, it was possible to use the audio track registered via the handy recorder for all recordings. We still had to extract both channels of the stereo audio file from the recorder and chose the one of the highest quality; that is the audio track with the greatest amplitude and on which the child could best be heard. Once the audio track was selected, it was saved as a new audio file in WAV format.

II.3.2.2 Organization of the corpus of recordings

To organise our corpus of recordings, we renamed each new WAV file with the following nomenclature: **AAAA_MM_JJ_BNN_SN**, where **AAAA_MM_JJ** corresponds the date of recording expressed as year/month/day (for example: 2017_10_06), **BNN** corresponds to the linguistic status of the participant (with B for bilinguals) and **NN** to the number of the participant (from 01 to 18, corresponding to the order of registering), **SN** corresponds to the session number (from S1 to S4). To give a specific example, the file named 2017_10_06_B02_S2 corresponds to the second recording session of the second bilingual participant made on the 6th of October 2017. In total, the corpus consists in 72 recordings (18 participants * 4 sessions) of approximately 20 minutes each.

II.3.2.3 Segmentation and annotations of the recordings

II.3.2.3.1 Annotations and automatic alignment with software programs PRAAT and SPPAS

All recordings have been manually and automatically annotated via PRAAT (Boersma & Weenink, 2015) and SPPAS (Bigi, 2015) in the Textgrid format. We have chosen to create 6 levels of annotation, each on a different tier of the Textgrid. The annotation levels and their coding were the following: (1) the speaker in the associated conversational exchange (1: target child, 2: investigator, 3: caregiver, 4: overlapping voices), (2) the target item, (3) the phonetic transcription of the child's production in IPA, (4) the technique of elicitation used to make the child produce the word (1: spontaneous naming, 2: direct naming on request, 3: naming with a hint, 4: induced repetition and 5: direct repetition), (5) the time-aligned sequence of segments forming the word produced by the child and (6), potential comments about the child's productions.

Annotations for speaker (tier 1), target item (tier 2), phonetic transcription (tier 3), elicitation (tier 4) and comments (tier 6) have been done manually on PRAAT. Annotations for tier 5 (segments/phones of the item) have been done automatically, using SPPAS. Automatic segmentation and alignment at the phone level were performed on the basis of the transcriptions in the third annotation tier. Practically, the automatic alignment in phones results from a phonetization, itself resulting from a tokenization which requires a phonetic transcription in orthographic code. Segments/phones are transcribed with the SAMPA phonetic alphabet (Wells, 1997). The frontiers as wells as the SAMPA symbols for the segments of the fifth tier have been checked manually and readjusted if necessary. Figure 21 presents an example of annotation for an item of the corpus.

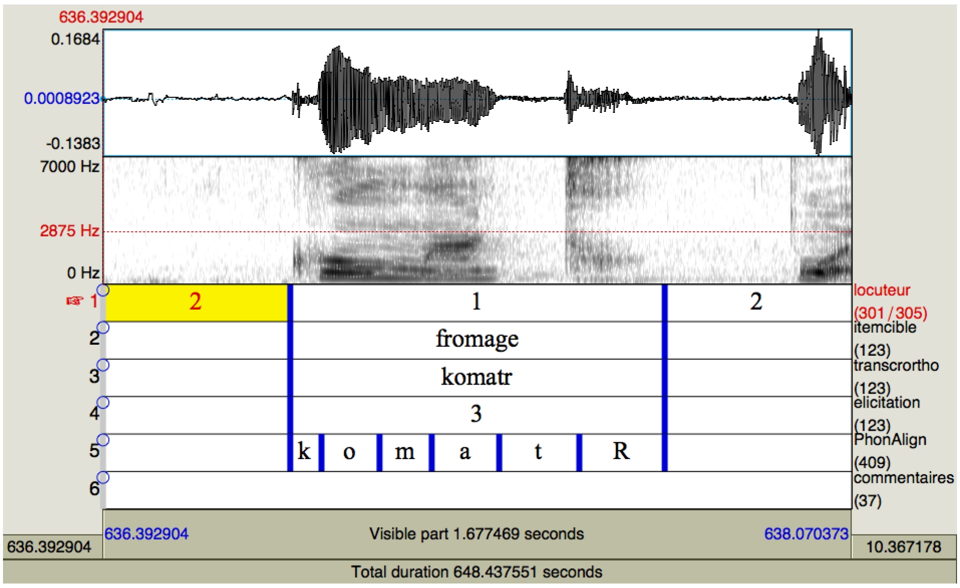

Figure 22: Annotation extract of the 2018_02_15_B03_S3.wav file.

Practically, the 5th annotation tier involving the segmented phones produced by the child served as the basis for subsequent acoustic measures and analyses (see section II. 4.).

II.3.2.3.2 Annotations with PHON

All recordings have also been processed and annotated using PHON (in its version 3.0.4), a software program specifically designed for the management, analysis and sharing of phonological data. It has been developed by Rose and collaborators (Rose et al., 2006) in order to constitute PhonBank, an international corpora of acquisition data publicly available. PhonBank is the phonology component of the CHILDES (Child Language Data Exchange System) project, itself part of a greater initiative, the TalkBank system which aims at stimulating fundamental research in the study of human spoken communication.

In order to annotate recordings on PHON, it is necessary to link each recording session to its audio WAV file and segment it in order to identify the speech utterances produced by the child. The program allows automatically segmenting the file and generating entries for each speech utterance of the child, based on an existing Textgrid. Using the option "Create records from Textgrid data", children's records were automatically generated. Then, the session editor window comprises, amongst others, a section "Session Information", where we have entered information about the child as well as a section for transcriptions. The transcription section involves different tiers to be filled: (1) the orthographic transcription of the target utterance ("Orthography"), (2) the phonetic transcription, in IPA characters, of the adult-like target ("IPA Target") and (3), the phonetic transcription of the child's actual output as perceived by the transcriber ("IPA Actual"). We have used the IPA Lookup function to automatically generate the "IPA Target" based on the orthographic record. The "IPA Actual" was filled based on the transcriptions previously generated with SPPAS. At this occasion, each transcription has been verified and readjusted if necessary. Figure 23 shows the section editor window with the different sections and tiers.

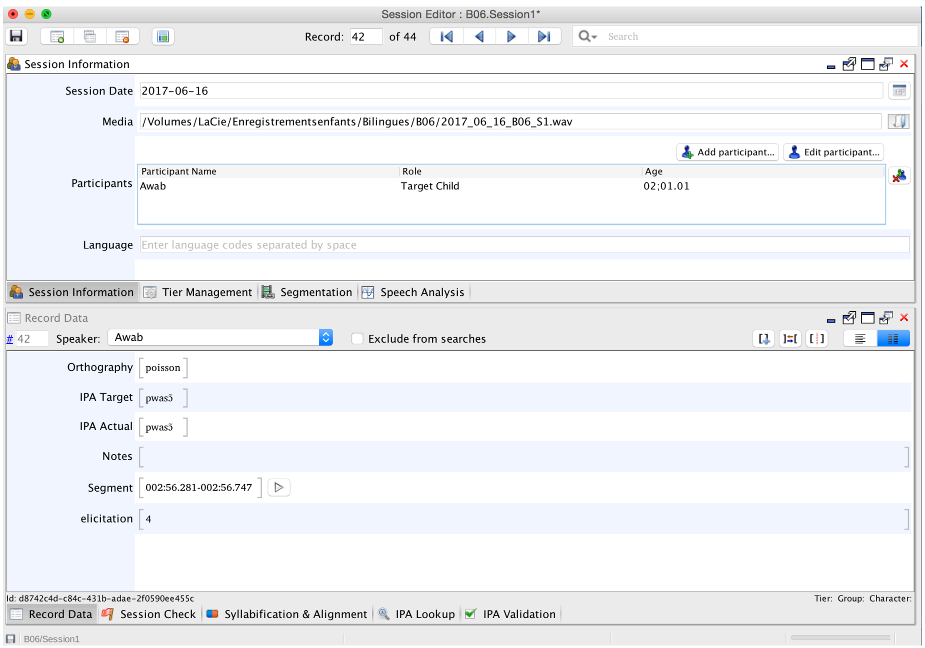

Figure 23: The session editor window in PHON.

In addition, the software PHON enables automatic syllabification of the words and attributes a syllabic status to each segment produced by the child (such as onset, nucleus, coda, onset of an empty-headed syllable, etc.). The syllabifier settings depend on the specific language[62]; besides, a complementary alignment function allows automatically aligning target and actual segments and syllables. Phonetic transcriptions in PHON have served as the basis for various relational phonological analyses focusing on comparisons between the child's productions and their corresponding target forms. As will also be explained in details in the next section, phonological analyses have been focused on both vowels and consonants, syllabic structure and phonological processes.

II.3.2.4 Selection of data

While processing the speech data, we also had to decide which data should be selected for the subsequent analyses, whether acoustic or phonological. For all analyses, we decided to select the first attempted production for every word, in order to reflect the usual pronunciation and degree of accuracy of the child. Accordingly, we did not consider ensuing attempts in which the child would try to correct him/herself. We also decided to exclude unintelligible items of which the target was unidentifiable. Then, we decided to include the three test items (i.e., *lit*, *bébé* and *bateau*) in the two types of analyses (acoustic and phonological) in order to increase the number of items to be analysed.

In the frame of (relational) analyses with PHON, we decided to exclude words elicited with a hint, the 1st phoneme or syllable of which had consequently been elided. Resulting from the specific elicitation technique, such elisions should not be considered as phonological processes. However, these words elicited with a hint, the 1st phoneme or syllable of which had consequently been elided, were actually considered in acoustic analyses, in order to maximize the corpus of sounds to analyse. Therefore, and only for those cases, we did include second attempts to produce the word. Besides, children generally responded with a single-word, possibly in combination with an article, but as they grew older, they could produce the word within a phrase/sentence. We included only the target item in the analyses, whether uttered in isolation or in a phrase. In addition, we did include all the vowels involved in the leitmotiv items (*Maya* and *Oui-Oui*) in the acoustic analyses, in order to have as much corner vowels /a, i, u/ as possible for the acoustic analyses. However, we did not include those items in the phonological analyses considering they are proper names. Indeed, proper names are particularly vulnerable to retrieval deficits because the set of acceptable phonological representations for proper names would be indefinitely broad (Cohen & Burke, 1993).

Finally, we decided to consider repeated items in all types of analyses. Indeed, it turned out that most of the younger toddlers from the participant sample were producing only a few words spontaneously during the first, and possibly the second, recording session, whether due to their developmental stage or because they were not willing to utter words in presence of an outsider. Figure 24 displays the rates of spontaneous production/naming *vs.* repetition for different age ranges based on the data collected for our study.

[62]Indeed, there is a syllabification algorithm designed on the basis of the target language. However, it can be changed manually.

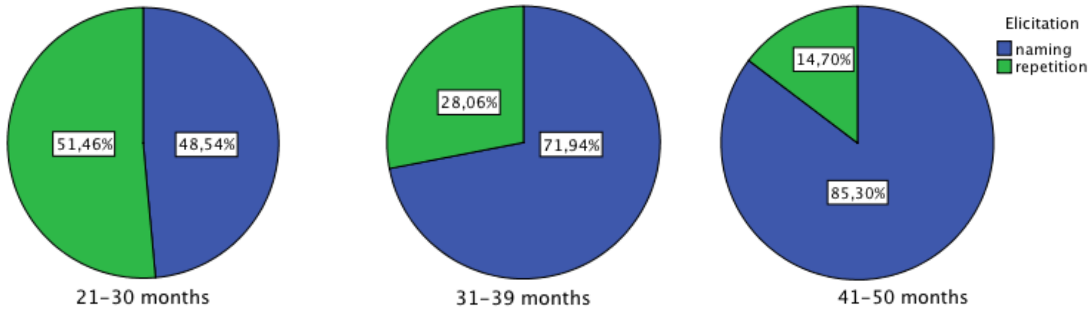

Figure 24: rates of naming *vs.* repetition for different age ranges based on collected data for all subjects.

We have chosen to have an adaptive protocol allowing for repetitions and to include repeated items in order to maximize the data set to be analysed. It might be argued that including repetitions/imitations would lead to an over-estimation of the children's phonetic-phonological skills and accuracy because productions with a model would be more stable and precise than spontaneous ones. However, several studies showed no significant difference between spontaneous *vs* repeated productions, whether for acoustic measures (Grandon, 2016) or consonantal accuracy measures (Goldstein, Fabiano-Smith & Iglesias, 2004), therefore not confirming the argument of a supposedly qualitative difference between the two in favour of repetitions. Still, elicitation should be considered as an independent variable in the subsequent statistical analyses. Moreover, based on data gathered via the IFDC (see above), we streamlined and refined our initial coding of this variable by distinguishing three different categories of elicitation: (1) naming, whether spontaneous, direct or with a hint, (2) repetition of reportedly known words, involving the reactivation of familiar material, and (3), repetition of reportedly unknown words, corresponding to verbal imitation without comprehension.

II.4 ANALYSES OF SPEECH PRODUCTIONS

Different types of analyses have been carried out on the children's speech productions in French, focusing on different levels of phonological organization, from segments to whole-word forms. Moreover, we have chosen to conduct analyses based on both acoustic measures and phonetic transcriptions. These different types of analyses are complementary. Indeed, while transcription-based analyses aim at apprehending speech sounds and whole-word forms in relation to their targets and are inherently subjective, analyses based on acoustic measures allow assessing speech sounds more objectively from a phonetic perspective. We detail all types of measures and analyses in the next sub-sections. We begin with the description of the acoustic measures taken on both vocalic and consonantal segments, followed by analyses of the vocalic space's organization. We then describe the different measures generated on the basis of transcriptions in the frame of perceptual-phonological analyses.

II.4.1 ACOUSTIC MEASURES

As just mentioned, acoustic analyses have been carried out on vowel and consonant sounds. These analyses have been based on acoustic measures of: (1) the vowels' first three formants and (2) the targeted fricatives' spectral moments. Values of both formants and spectral moments have been measured via a customized script written in PRAAT (Boersma & Weenink, 2015).

II.4.1.1 Vowels

Via our word-naming task, we have collected a variety of productions of the 11 French oral vowels /i, e, ɛ, y, ø, œ, ə, a, u, o, ɔ/ and the 3 French nasal vowels /ɛ̃, ɑ̃, ɔ̃/ (thus, all French vowels, except the oral /ɑ/ and nasal /œ̃/), longitudinally recorded during the four sessions of each participant. As already explained, the corpus of our word-naming task include at least one occurrence of each French vowel and moreover, the three peripheral oral vowels /a, i, u/ are deliberately more frequent in our corpus given the repeated occurrence of the two leitmotiv items *Maya* and *Oui-Oui* involving the vowels /a, i/ and glides /j, w/). Consequently, most analyses will be based on these particular vowels.

The vowels' first three formants have been measured at 50% of the segment duration. Values of the first three formants (F1-F2-F3) have been automatically extracted using the Burg Method (3 formants, 5500 Hz) via a PRAAT script and subsequently manually verified. Based on formants measures, analyses of the vocalic system organization have been conducted, focusing on: (1) the total area of the vocalic space in a F1-F2 plan and (2), the degree of organization of the vocalic system based on F1-F2-F3 values. We explain these analyses in the subsequent section II.4.2.

II.4.1.2 Fricative consonants

We have selected a subset of French fricative consonants for our analyses, including the voiced and voiceless sibilant alveolars /s, z/ and post-alveolars /ʃ, ʒ/, as the fricatives /z, ʃ, ʒ/ are reportedly amongst the latest acquired phonemes in French. We have longitudinally collected productions of the targeted fricative consonants in word-initial/medial/final position (see Table 22) during four recording sessions for each participant. Due to length constraints of the corpus, we could not control for the vocalic environment of the fricatives.

	Word-initial	Word-medial	Word-final
/s/	*souris*	*poisson, chaussure*	*glace*
/z/	*zèbre*	*oiseau*	*chaise*
/ʃ/	*cheveux, chaussure, chaise, chien, champignon*	*écharpe*	*cloche*
/ʒ/	*girafe*	*pyjama*	*fromage*

Table 22: Targeted fricative consonants in the word-naming task corpus.

The targeted fricatives are subjected to both acoustic and phonological analyses (see point II.4.3.1). However, we have decided to more specifically focus on the acquisition of the place-of-articulation contrast between the voiced alveolar /s/ and postalveolar /ʃ/ for spectral moments' analysis. Indeed, these particular fricatives have been studied in most developmental studies involving spectral moment analysis, and furthermore, our data clearly suggested that this specific contrast was particularly challenging for the children to acquire. While the corpus involves more occurrences of the postalveolar /ʃ/ (7 in total when /s/ appears only in four items), no particular vocalic context has been favoured neither for the alveolar /s/, nor the postalveolar /ʃ/.

Measures of the first four spectral moments (centre of gravity, standard deviation, skewness, and kurtosis) of the fricatives have been automatically extracted via a customized PRAAT script elaborated on the basis of the *Time averaging for fricatives.praat* script made available by Christian Di Canio (2013, Haskins Laboratories). This latter script is itself based on time-averaging procedure (Shadle, 2012) consisting in taking six spectra across a fricative duration, averaging these spectra and computing the first four spectral moments based on this averaged spectrum.

II.4.2 Analyses of vocalic system organization

Based on the formant values of the three corner vowels /a, i, u/, we have conducted analyses focused on the vocalic system organization. To that end, two measures have been used: a standard measure widely used in the literature, the Vocalic Space Area (VSA), and a more modern and refined one, the PHI Index, developed by Huet and Harmegnies (2000).

II.4.2.1 Vocalic Space Area (VSA)

The Vocalic Space Area (from now on, VSA) is a traditional measure used to study vowel distinctiveness. It has been used in a number of studies involving both typical and atypical populations of adults and children. Indeed, developmental studies previously mentioned (see section I.3.) have used the VSA with infants aged between 10 and 18 months (Rvachew et al., 2006) or for comparing school-aged normally-hearing and hearing-impaired children (Ryalls et al., 2003). It refers to the two-dimensional area bounded by lines connecting vowels' coordinates of first and second formant frequency ($F1/F2$). The area of the triangular vocalic space formed by the three cardinal vowels (/a, i, u/) in a F1-F2 plan is calculated with Heron's formula:

$$VSA = \sqrt{p(p-a)(p-b)(p-c)} \quad \text{with} \quad p = \frac{a+b+c}{2}$$

where *a, b* and *c* represent the length of the three triangle's edges, each corresponding to the Euclidean distance between each vowel pair (e.g., /i/ to /a/) in a F1-F2 space, and *p* is the semi-perimeter of the triangle corresponding to the sum of the three edges divided by two.

Albeit this classic measure has been predominantly used in the literature, it presents certain limitations. Indeed, changes in the size of the triangle's area might result either from a cognitive (i.e., structuration of the vocalic categories) or a physiological (i.e., lengthening of the vocal tract) evolution, or from a combination of both. Using the VSA does not allow distinguishing between the two aspects. Formant values are thus generally normalized in order to remove the physiological information (that is, non-pertinent individual information) and be able to compare subjects of different ages and/or gender. Yet, the focus of this study is precisely the developmental dimension as the objective is to observe how the children are progressively structuring their cognitive space by building their vocalic categories. By normalizing, we could lose the information about the cognitive development that is of particular interest to us. Therefore, if the standard VSA is interesting for comparative purposes, we decided to also use the PHI index which allows overcoming this normalization issue.

II.4.2.2 PHI Index

Developed by Huet & Harmegnies (2000), the PHI Index is a quantification measure calculated with the following formula:

$$\phi = \frac{CM_{inter}}{CM_{intra}}$$

with CM_{inter} = Mean square between vocalic clouds in the vocalic space
CM_{intra} = Mean square within vocalic clouds in the vocalic space

Inspired by variance analysis, this index is based on the analogy between the *deviation* of a value – either a given or mean value – from the reference mean and the *Euclidian distance* between a point in F1-F2(-F3) plan – either a vowel (d_{intra}) or the centre of gravity of the vocalic cloud (d_{inter}) – and the mean gravity centre of reference (see Figure 25).

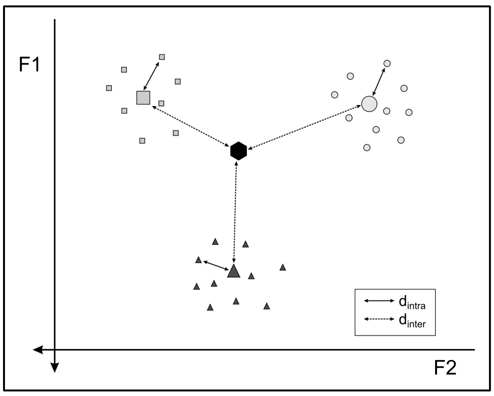

Figure 25: PHI Index construction principle based on three vocalic clouds in F1-F2 plan.

This PHI index is aimed at quantifying the dispersion of the vowels' formant values within the vocalic space, by comparison of the inter-vocalic categories variability and intra-vocalic category variability. A higher PHI Index value indicates a higher degree of organization of the vocalic system: CM_{inter} increases with more distinct vocalic categories and CM_{intra} decreases with less dispersed vocalic categories.

It is the first time that this measure is used with child populations and its use in its specific context is particularly relevant as it enables to capture relative variability and to avoid confusion between the cognitive and physiological development without data normalization.

Given that children did not necessarily produce all French vowels at each session (whether because they did not produce an item or elided a syllable), we decided to compute the PHI index based on the first three formant values of the three cardinal vowels /a, i, u/.

II.4.3 Perceptual-phonological analyses

Based on phonetic transcriptions, perceptual-phonological analyses involve different measures: (1) segmental accuracy measures taken on vowels and consonants (both global and nuanced for consonants), (2) rates of deletion and substitution processes affecting vowels and consonants and (3), measures of whole-word forms' proximity/distance to the target. Table 23 summarizes the different perceptual-phonological measures.

Vowels	Consonants	Whole-word forms
- Accuracy measure: *PVC* - Rates of deletion-substitution	- Accuracy measure: *PCC* - Rates of deletion-substitution	- Proximity to target: *PWP* - Distance to target: *PDAP-IS*

Table 23: Perceptual-phonological measures focused on vowels, consonants and whole-word forms.

II.4.3.1 Segmental accuracy measures

Accuracy measures consisted in the calculation of the percentage of correct segments for each item (i.e., word) produced by the children for all four recording sessions. The Percentage of Consonants Correct or PCC (Shriberg & Kiatowski, 1982) and, to a lesser extent, the Percentage of Vowels Correct or PVC (Shriberg, 1993) have been used in a large number of studies investigating phonological skills in both bilingual and monolingual children (see section I.2.). First proposed in the context of speech pathology, the PCC metric was initially validated on conversational samples in order to derive profiles on an ordinal severity scale of speech disorders (Shriberg & Kiatowski, 1982). However, it has since been widely used for productions derived from single-word samples as well. Even if segmental accuracy measures have been often used in phonological acquisition studies, several limitations pointed out by some researchers (Ingram, 2002; MacLeod et al., 2011) should be mentioned. First, they are based on individual segments while it is acknowledged that phonological organization includes multiple levels of information below and beyond the segmental level. Indeed, toddlers' developing phonological systems might not necessarily be built solely on segmental units but also at the whole-word level. For this reason, they should be complemented by other measurements, which is why we decided to include measures based on whole-word forms in our analyses (see section II. 4.3.2.). The two accuracy measures result from dividing the number of correct segments (either vowels or consonants) produced by the child by the sum of all attempted and elided segments, multiplying the result by 100. Here is an example of PCC/PVC calculation for the item *tortue* [tɔʁty] realized as [taty]:

PCC = 2/2 + 1 * 100 = 66,67% and PVC = 1/2 * 100 = 50 %

Global PVC and PCC have been automatically computed for each of the 51 items of the word-naming task using the PHON software for all participant's four sessions. In parallel, nuanced PCC measures were also automatically generated with PHON, first for a group of consonants of interests, namely the selected sub-set of fricatives /s, z, ʃ, ʒ/, second for all consonants as a function of their position in the targeted syllabic constituents; i.e., word-final singleton codas, word-initial branching onsets and word-final complex codas. Nuanced PCC measures have been calculated on a total of 17 items for fricatives, 20 items for word-final singleton codas, 12 items for word-initial branching onsets and 7 items for word-final complex codas. Stimulus items for the different nuanced PCC measures are presented in Table 24. We are aware that the number of items involved for the calculation of these nuanced PCC measures is too reduced to draw any generalizable conclusions but, as for the assessment of children's lexical development, what we are primarily interested in is the developmental curve of the children's segmental accuracy. Word-initial branching onsets and word-final complex codas include two types of consonant sequences: Obstruent+/Liquid (OL) and Obstruent+Glide (OG) clusters for word-initial position and Obstruent+/Liquid (OL) and Liquid+Obstruent (LO) clusters for word-final position. PCC is calculated in the same way for consonant clusters.

Items	Fricatives consonants	Word-final codas	Word-initial clusters	Word-final clusters
Coucou				
Langue		g		
Cheveux	ʃ			
Nombril		l		
Pyjama	ʒ			
Echarpe	ʃ			ʁp
Pomme		m		
Robe		b		
Glace	s	s	gl	
Souris	s			
Livre				vʁ
Yaourt				ʁt
Fleur		ʁ	fl	
Cadeau				
Porte				ʁt
Tortue				
Poisson	s		pw	
Etoile		l		
Oiseau	z			
Chaussure	s, ʃ	ʁ		
Chaise	ʃ, z	z		
Crayon			kʁ	
Pantalon				
Eléphant				
Chien	ʃ		ʃj	
Cuillère		ʁ	kɥ	
Girafe	ʒ	f		
Téléphone		n		
Parapluie				
Escalier	s			
Feuille		j		
Doigt			dw	

Items	Fricatives consonants	Word-final codas	Word-initial clusters	Word-final clusters
Banane		n		
Panier				
Grenouille		j	gʁ	
Arbre				ʁbʁ
Train			tʁ	
Vache	ʃ	ʃ		
Carotte		t		
Zèbre	z			bʁ
Cloche	ʃ	ʃ	kl	
Champignon	ʃ			
Peigne		ɲ		
Bras			bʁ	
Parc				ʁk
Fourmi				
Pingouin				
Fromage	ʒ	ʒ	fʁ	
TOTAL	*17 items*	*20 items*	*12 items*	*7 items*

Table 24: List of stimulus items containing targeted fricatives and syllabic constituents.

II.4.3.2 Measures of whole-word forms' proximity/distance to targets

We first assessed the accuracy of the children's whole-word forms or, in other words, their proximity to target word forms using the Proportion of Whole-word Proximity (PWP) measure. Proposed by Ingram (2002), the calculation of PWP is based on another whole-word measure; namely the phonological mean length of utterance (PMLU). Developed in analogy to the morphosyntactic MLU (which measures the child's mean length of utterance in morphemes), PMLU is calculated by counting the number of segments produced by the child, adding an extra point for each correct consonant (as in *tortue* [tɔʁty] realized as [taty], PMLU = 6). PMLU thus rewards the production of consonants and vowels even if they are not correctly produced or, in other words, it gives credit to both segmental presence and consonant accuracy. PWP is the result of the ratio between the PMLU of the child's production and the PMLU of the target adult-like production, as in the same example of *tortue* [tɔʁty] realized as [taty]:

Child PMLU = 6, target PMLU = 8 and PWP = 6/8 = 0.75

Like for global PCC and PVC, PWP was automatically computed for each of the 51 items of the word-naming task using the PHON software, for all participant's four sessions.

Since PWP accounts only for consonantal accuracy and is still based on a binary correct *vs.* incorrect assessment, we were willing to find a more refined measure to assess the productions' distance to the target. Therefore, we decided to use the intelligibility score based on an acoustic-phonetic decoding task elaborated by Ghio and collaborators for use in clinical context (Ghio et al., 2018) which has been the subject of several communications in international conferences (Ghio et al., 2018; Fredouille et al. 2019).

Referred to as PDAP-IS (for Perceptual DAP-based intelligibility score, with DAP for *Décodage acoustico-phonétique*), this measure consists in computing the Levensthein distance[63] between the perceived form (i.e., the phonetic transcription of the child's production) and the targeted item using a Wagner-Fisher algorithm that integrates deletion, substitution and epenthesis phenomena (see Figure 26). The distance between a given realization and the associated target is represented as the shortest path between two sequences (strings) of phonemic units. A local distance is established between each pair of phonemes based on their content in terms of phonetic features (Ghio, 1997). More precisely, this local distance corresponds to the number of features that differ between the target *vs.* produced phoneme so that a substitution of a vowel by another vowel or by a voiceless consonant would not have the same weight. A decomposition of all phonemes into distinctive features allows to build a cost matrix which consists in a double-entry table containing all the phonemes and their degree of (dis-)similarity. Based on calculated local distances between phonemic units, a cumulative distance between target and perceived whole-word forms is then generated and expressed as a function of the number of phonemes in the target. The final score obtained thus corresponds to the average difference of features by phoneme for the target *vs.* perceived/transcribed word form.

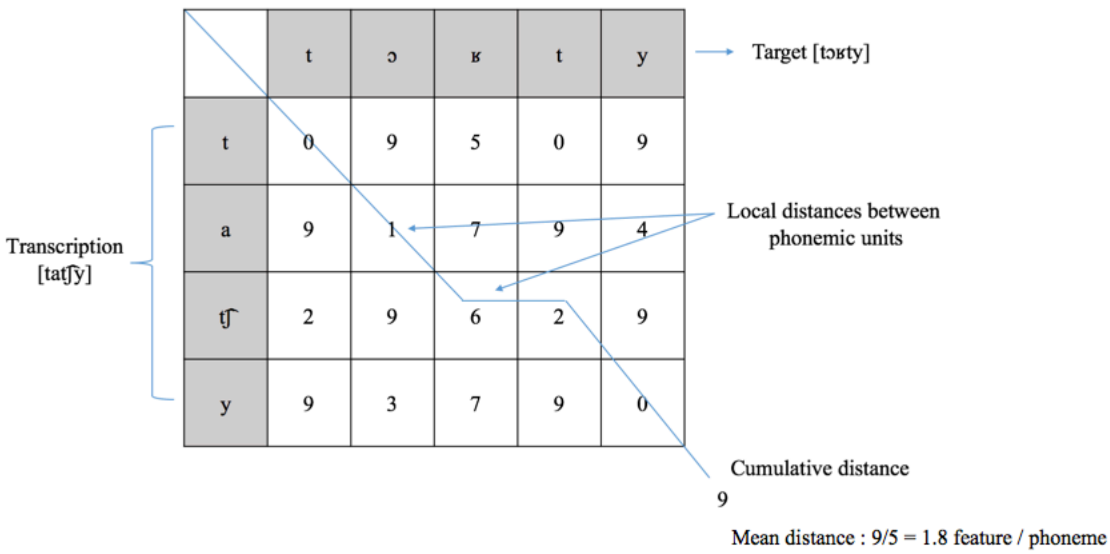

Figure 26: Comparison of two phonemic strings by the Wagner-Fischer algorithm.

The original cost matrix includes 35 phonemes /a, i, u, o, ɔ, e, ɛ, y, œ, ø, ɔ̃, ã, ɛ̃, œ̃, p, t, k, b, d, g, f, s, ʃ, v, z, ʒ, m, n, l, R, j, w, ɥ, ñ, ŋ/ and several archiphonemes: Ô (for /o/ or /ɔ/), Û (for /ø/ or /œ/) and Ê (for /e/ or /ɛ/) for which the opening feature is neutralized and µ (for /ɛ̃/ou /œ̃/) and & (for

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[63]The Levenshtein distance is a metric that measures how distant are two strings of characters. The Levenshtein distance between two words is the minimum number of single-character edits (i.e., deletions/elisions, substitutions or epenthesis/insertions) required to change one word into the other.

Û and Ê) for which the rounding feature is neutralized. In order to compute this intelligibility score on our data, we had to adapt the original matrix of between-phonemes cost in order to include some phonetic variants which were frequent in our data but not present in the initial, phoneme-based method. More precisely, we added three features to the original decomposition into features – namely affricate, sibilant and open-glottis – in order to integrate the affricates [t͡s, t͡ʃ, d͡z, d͡ʒ] and the fricatives [ç, x, h] into the cost matrix (the adapted decomposition into distinctive features and resulting cost matrix can be found in Appendix 9).

Like other accuracy measures, the Perceptual DAP-based intelligibility score was generated for each of the 51 items of the word-naming task, for all participant's four sessions. Even if this measure assesses the proximity/distance to the target word with a greater degree of precision and nuance, we decided to still include the PWP measure in our analyses as PWPs for French-speaking monolingual children are available in the literature. Indeed, Macleod and collaborators (MacLeod et al., 2011) investigated French consonantal acquisition in a large cohort (n=156) of Canadian children aged 20-53 months based on a word-naming task and PWP measures were involved in their analyses. Made available in their results, mean PWPs and standard deviations for six age ranges (from 23 to 53 months) can be used as reference monolingual values to which we will compare the performances of the bilingual pre-schooled children involved in our study.

II.4.3.3 Phonological processes

To complement segmental accuracy measures (global PVC and PCC), we examined phonological processes affecting vowels and consonants. More precisely, rates of substitution and deletion processes have been calculated based on automatically extracted occurrence number of the two processes by PHON. Substitution types have also been investigated for both vowels and consonants.

II.4.4 Statistical processing of data

The type of statistical procedures that can be carried out on data have to be chosen carefully according to some constraints:

- Heterogeneity of the number of participants in the three linguistic groups: 11 French-Italian, 5 French-Arabic and 2 French-Mandarin bilinguals;
- No age-match across the linguistic groups (initially aged between 21 and 36 months at S1, children from the three linguistic groups were recruited at different ages);
- Heterogeneity of the linguistic dominance profiles between the three groups (see the *Index of linguistic dominance* described in section II.2 and Table 16 for the description of all participants).

Given the pre-cited disparities between the linguistic groups, we conducted non-parametrical tests within each group to observe the impact of different independent variables. Tables 25 and 26 summarize the different independent and dependent variables taken into consideration.

Independent variables	
Subject-related	Session Chronological age Linguistic group Linguistic dominance Vocabulary score (in French and in both languages) Gender Siblings
Item-related	Elicitation Phonological complexity Lexical frequency

Table 25: Independent variables

Dependent variables	
One measure/session	Vocalic space area (VSA) values PHI index values
One measure/ item	Global PCC and PVC Nuanced PCC for: - word-final codas - word-initial branching onsets - word-final complex codas - targeted fricatives PWP Perceptual DAP-based intelligibility score
One measure/segment	F1-F2-F3 values for vowels Spectral moments for /s/ and /ʃ/

Table 26: Dependent variables

As noted above, both the recording session and the children's chronological age have been included as developmental variables in the analyses but the session was preponderantly used to observe the effect of chronological development. We chose to give a greater importance to session given the fact that all children went through the four sessions; there was thus the same number of participants for each session. Still, it must be said that a single session includes children of different chronological ages. Besides, if an effect of the session very likely indicates a developmental effect, we are not immune of a learning effect in children. In parallel to these non-parametrical tests, we also conducted correlation tests between different variables, both globally and inside each linguistic group. Based on these non-parametrical and correlation tests, we will propose a comparative analysis of the three linguistic groups. In addition, it seems important to focus on particular individual developmental profiles/trajectories. Independent subject-related and item-related variables have been coded in order to create categorical variables.

II.4.4.1 Subject-related Independent Variables

Subject-related independent variables have been coded in the following manner:

- Chronological age:

Children have been split into six groups: (1) 21-23 months, (2) 24-29 months, (3) 30-35 months, (4) 36-41 months, (5) 42-47 months and (6), 48-53 months, based on the age ranges used by MacLeod et al. (2011). This will permit the comparison of our participants' PCC and PWPs to those they obtained for monolingual French-speaking toddlers.

- Linguistic dominance:

Three profiles result from the calculation of the *Index of linguistic dominance*: FLD (French Linguistic Dominance), NFLD (Non-French Linguistic Dominance) and BBil (Balanced Bilingualism).

- Vocabulary score in French (total of words produced by the child in French, as measured by the MBCDI questionnaires):

The score was transformed into a 5 levels independent variable: (1) 27-155 words, (2) 156-284 words, (3) 285-413 words, (4) 414-542 words, (5) 543-670 words.

- Vocabulary score in both languages combined (sum of the words marked by the parents in the two questionnaires):

The score was transformed into a 5 levels independent variable: (1) 54-272 words, (2) 273-491 words, (3) 492-710 words, (4) 711-929 words, (5) 930-1150 words.

II.4.4.2 Item-related Independent Variables

Item-related independent variables have been coded in the following manner:

- Elicitation:

The elicitation variable includes three levels: (1) naming (whether spontaneously or with a hint), (2) repetition of reportedly known words and (3), repetition of reportedly unknown words.

- Complexity:

Complexity refers to the phonological complexity of the item, as measured by our Complexity Index. Words have been classified in three categories: (1) word of little complexity (such as *coucou* or *bateau*), (2) moderate complexity (such as *fourmi* or *carotte*) and (3) high complexity (such as *escalier* or *parapluie*). Complexity values can be found in Table in Appendix 8.

- Lexical frequency:

Lexical frequency values were drawn from the Manulex database (Lété, Sprenger-Charolles & Colé, 2004) based on a corpus of 54 primary school textbooks. We chose more particularly the *Standard Frequency Index* (SFI) value corresponding to an estimated frequency per million of words and we selected the "CP" or 1st grade database (i.e., the first year of primary school during which children are aged between 5 and 6 years) to get as close as possible to our participants' age. Words have been classified into two categories: not frequent (such as *nombril* or *crayon*) and frequent (such as *lit* or *pomme).* Frequency values can be found in Table in Appendix 8.

Depending on the specific dependent variables (whether measures by session/item/segment), we will select different independent variables in our analyses. For example, we will not include item-related independent variables (i.e., elicitation, complexity and lexical frequency) for the dependent variables consisting in one measure by session (i.e., PHI and VSA values).

Chapter III:

Results

III RESULTS

The results section is organised in three sections, as followed:

- a section about vowels, in which we focus on the compared evolution of: (1) the organization of the vocalic system as measured by VSA and PHI index values, (2), the global vocalic accuracy as measured by PVC and (3), the phonological processes affecting vowels.
- a section about consonants, in which we focus on the compared evolution of: (1) the global and nuanced (for targeted syllabic constituents and fricatives) consonantal accuracy as measured by PCC, (2) the acquisition of the place-of-articulation contrast between the two voiceless fricatives /s/ and /ʃ/ through spectral moment analysis and (3), the phonological processes affecting consonants.
- a section about whole-word forms, in which we focus on the proximity/distance of whole-word forms to the target word forms measured by PWP and PDAP-IS.

III.1 VOWELS

III.1.1 ORGANIZATION OF THE VOCALIC SYSTEM

The vocalic system organization (based on formant values of the cardinal vowels /a, i, u/) has been assessed through the calculation of two measures: the VSA and the PHI index (one measure per participant per session). Devoiced vowels or those occurring in unintelligible words have been excluded from our analyses. In total, VSA and PHI values have thus been generated based on a total of 4016 vowel productions including 1779 productions of /a/, 1456 productions of /i/ and 781 productions of /u/. Table 27 presents the vowels' mean formant values in Hz for each linguistic group.

Linguistic group	Vowels	Total number of vowels	Mean number of vowels per child per session	Mean F1 value in Hz	Mean F2 value in Hz	Mean F3 value in Hz
French-Italian	a	1072	15	998 (243)	2183 (329)	4375 (343)
	i	873	12	542 (106)	3224 (327)	4579 (502)
	u	470	7	605 (114)	1663 (516)	4280 (454)
French-Arabic	a	489	24	999 (231)	2234 (337)	4376 (383)
	i	430	22	511 (112)	3101 (387)	4569 (366)
	u	235	12	565 (129)	1681 (467)	4326 (394)
French-Mandarin	a	218	27	956 (200)	2240 (280)	4480 (254)
	i	153	19	555 (133)	3118 (360)	4606 (329)
	u	76	10	634 (117)	1720 (379)	4429 (327)

Table 27: Mean F1-F2-F3 values of the vowels /a, i, u/ (with standard deviations) for the three linguistic groups.

One value for each measure (VSA and PHI) has thus been obtained per session per participant. Correlation studies between these two measures and other variables of interest have been performed.

III.1.1.1 Vocalic space area

The VSA (vocalic space area) measure aims at summarizing the various vowel productions made by a given child in one particular recording session (one measure per participant per session). Figure 27 presents the evolution of the VSA values for all participants over the four sessions (expressed as S1, S2, S3 and S4). The "Y" axis represents the VSA values and the colour bars correspond to the VSA values for the four sessions of each participant. Each bar corresponds to a particular measure for a given child at a specific session, given that there is one VSA value computed per session for each participant. The participants are clustered according to their linguistic group with French-Italian (blue frame), French-Arabic (green frame) and French-Mandarin (orange frame). Within each group, participants are organized by increasing age based on their initial age at the first recording session (S1) expressed in years, months and days.

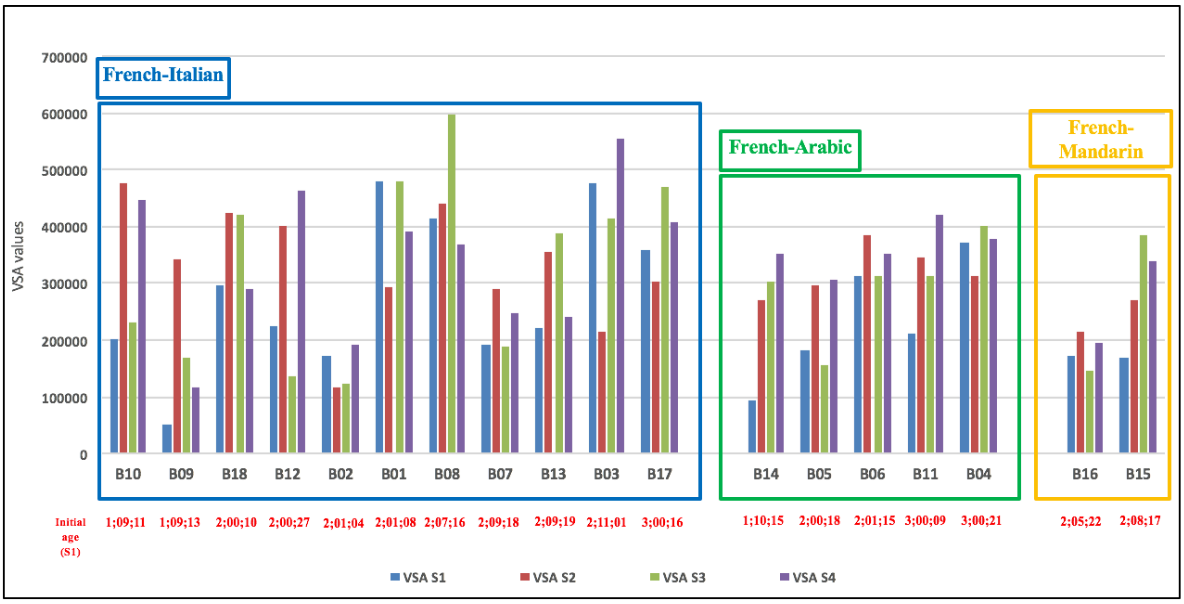

Figure 27: VSA values for each session of all participants.

Again, several observations can be drawn from this graph. First, VSA values increase from S1 to S4 for 15 of the 18 participants. Still, it seems that the evolution of the vocalic space area is non-linear and involves a large amount of individual variability. Indeed, the values fluctuates between the first and the last session for all participants except one, the French-Arabic participant B14. Thus, the evolution of VSA values is fluctuating at all ages. However, the lowest VSA values are observed in the youngest children – namely, the French-Italian participant B09 and the French-Arabic participant B14 initially under 24 months of age – and the highest VSA values are found in two French-Italian bilingual children aged above 36 months (i.e., the participants B08 and B03).

Then, comparing the different linguistic groups, the tendency for VSA values to rise with age is not as obvious for the three types of bilinguals. More precisely, it is most clearly observed for the French-Arabic participants, whereas the French-Italian and French-Mandarin groups displays more contrasted profiles. Furthermore, if fluctuating VSA values can be seen in participants from all groups, the within-subject variability appears stronger in the French-Italian group. Given these seemingly different developmental patterns in the evolution of the vocalic space area, we conducted

Bravais-Pearson correlation tests between VSA values and age for all linguistic groups pooled together and for each linguistic group separately in order to investigate whether there is a correlation between the two variables and whether the degree of correlation is similar or differ for the different bilinguals (see Table 28). The scatter plots of VSA values (tagged with the session number) as a function of age are shown together with the associated regression line in Figure 28 (one graph per linguistic group).

VSA	All participants	French-Italian	French-Arabic	French-Mandarin
versus	r = 0.338	r = 0.290	r = 0.647	r = 0.682
Age	p = 0.004	p = 0.056	p = 0.002	p = 0.063

Table 28: Correlation coefficients r_{BP} between VSA values and chronological age in each linguistic group.

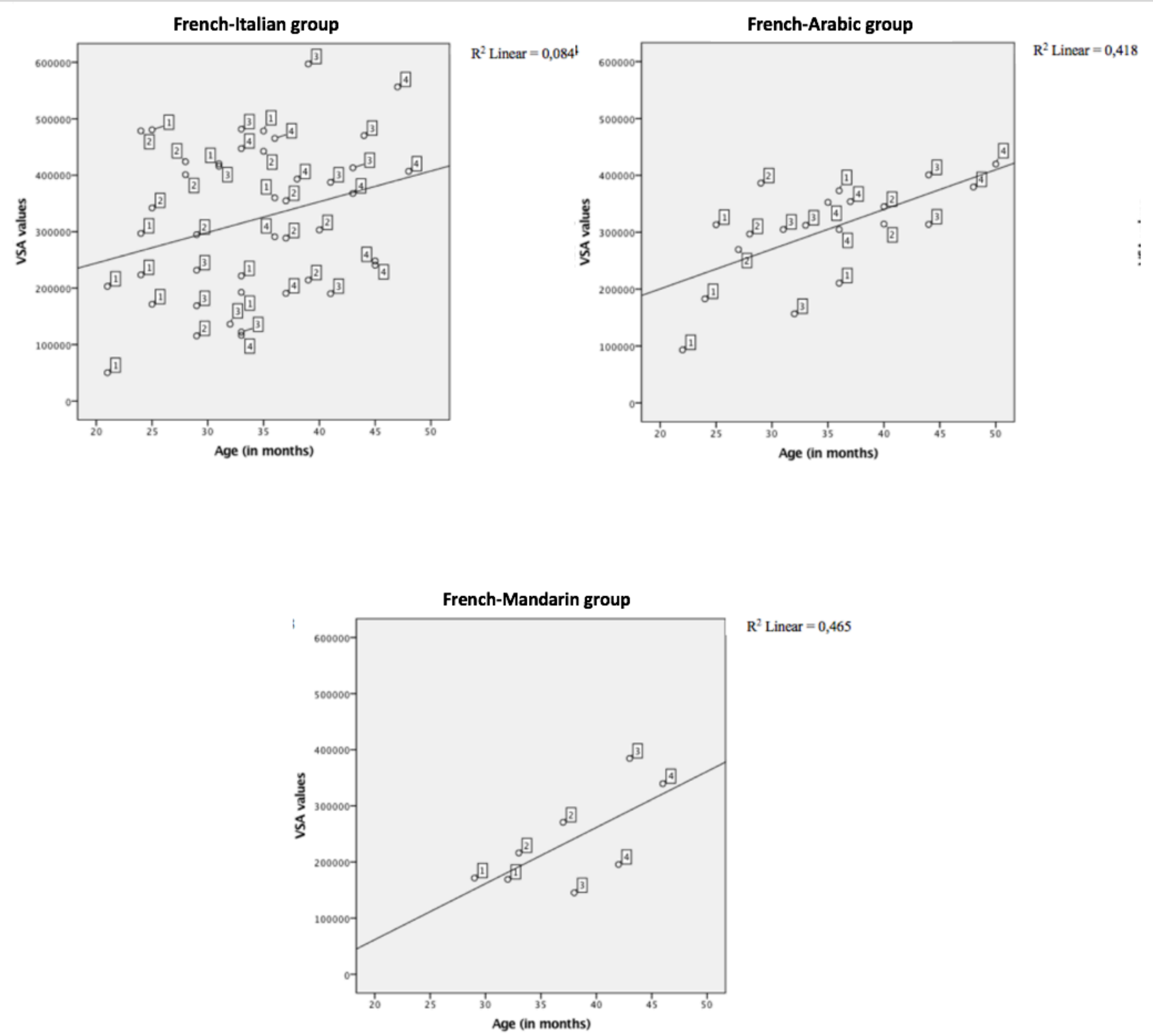

Figure 28: Correlation between VSA values and chronological age (in months) for each linguistic group.

These results indicate that there exists a moderate-to-high positive correlation between the VSA values and age only for the French-Arabic group. In other words, VSA values increase with age for children from that group. This corroborates what could already be seen on the VSA values graph; namely, highly variable and poorly age-correlated VSA values in French-Italian and French-Mandarin bilingual children in contrast to French-Arabic bilinguals.

In line with the VSA values graphs and the correlation results, the vocalic triangles (see Figure 29) allow visualizing these different developmental patterns in the evolution of the vocalic space area for the three different linguistic groups over the four sessions. The three corners of the triangles represent the mean F1 and F2 values of the three cardinal vowels /a, i, u/. The different colours of the triangles correspond to the different sessions and for ease of comprehension, we used the same colours as in the VSA values graphs (see Figure 26). The different triangles tend to overlap for the French-Italian participants. Based on the VSA values graphs, it can be said that the increase in the vocalic space area at S3 might be mainly attributable to three participants of different ages (B01, B08 and B17). For the French-Arabic group, an expansion of the vocalic space area can be observed for the second and fourth sessions. It is worth noting that, for both the S3 of French-Italian and the S4 of French-Arabic, the VSA expansion seems to be related to the production of the vowel /u/, as this category becomes more distinct from the two other ones. Finally, the vocalic space area of the French-Mandarin participants appears to be globally more restricted, especially at S1, than those of the two other groups. Their VSA slightly increases at S2 and does not evolve much after until the fourth session.

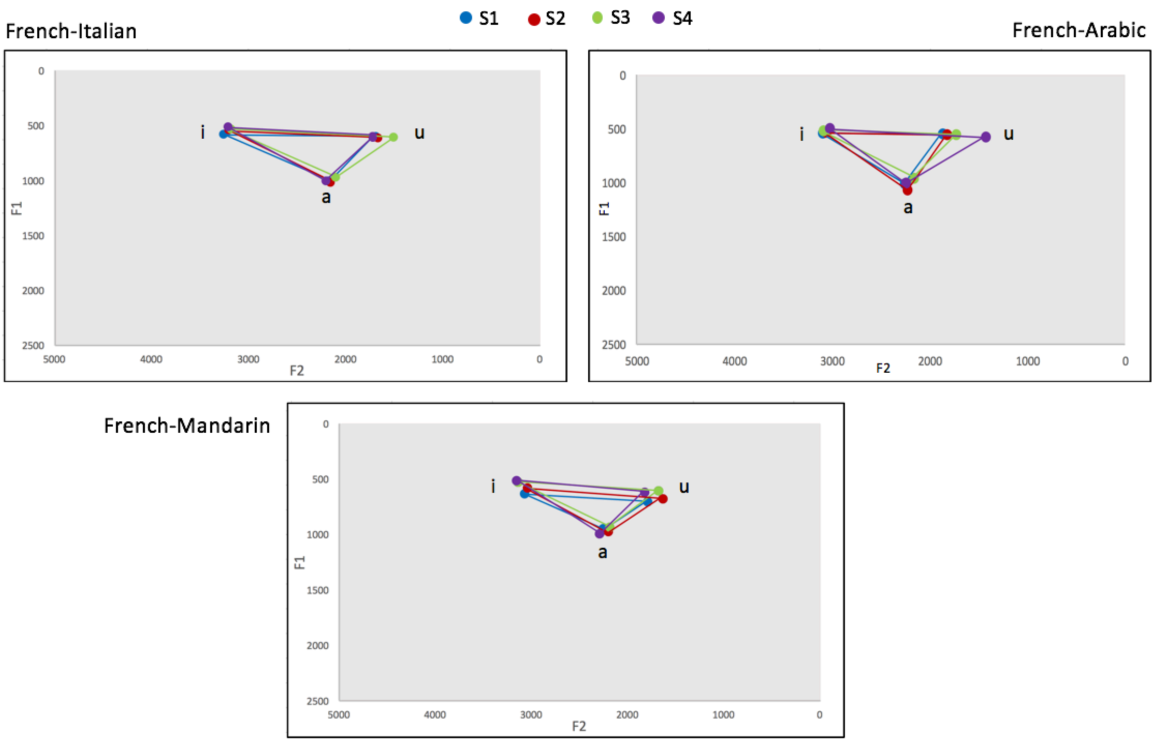

Figure 29: Vocalic triangles over the four sessions for each linguistic group.

We also examined whether there would be a correlation between VSA values and the children's linguistic dominance and vocabulary scores (French and total vocabulary scores). No relation was found, neither between VSA values and linguistic dominance, nor between VSA values and lexical competence (whether in French or in both languages).

III.1.1.2 PHI index

Similar to the previous VSA values graph (see Figure 27), Figure 30 presents the evolution of the PHI values for all participants over the four session. Several observations can be drawn from this graph. The general trend seems to show that the PHI values increase more obviously with age than VSA values and this, for all three linguistic groups. Indeed, the lowest PHI values are globally found in the children initially aged less than 26 months – such as for the S1 of French-Italian participants B09, B18 and B02 and the French-Arabic participant B14 – and the highest PHI values are mostly observed in children aged above 36 months such as the French-Italian participants B03 and B17.

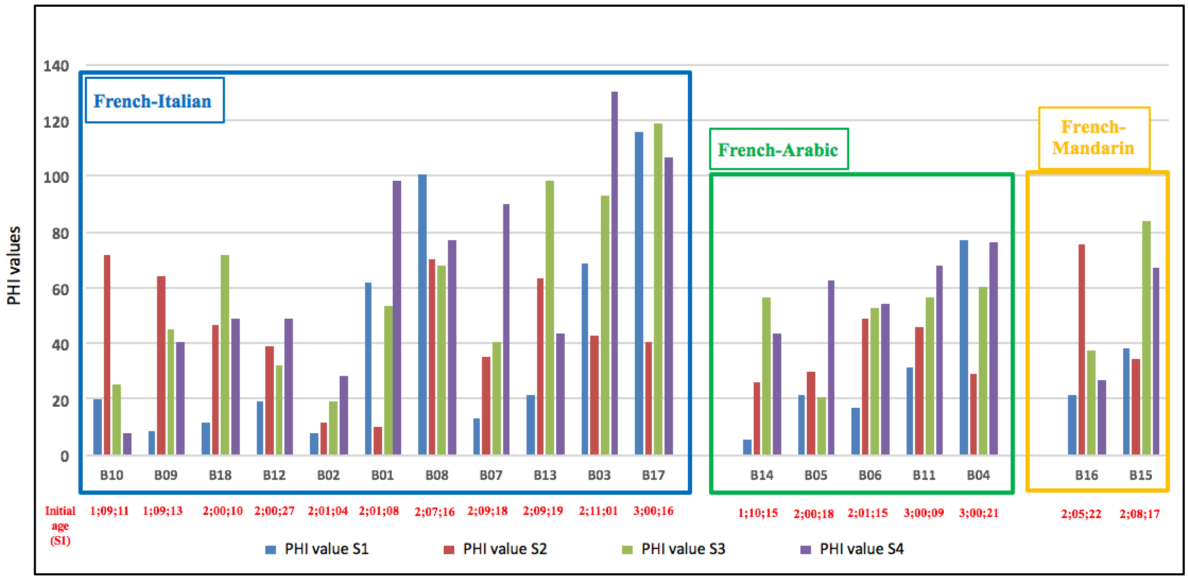

Figure 30: PHI values for each session of all participants.

However, the highest PHI values do not necessarily correspond to the third and fourth sessions, as several children already display high PHI values at S1 and/or S2 such as the French-Italian participants B08, B10 and B17, the French-Arabic participant B04 and the French-Mandarin B16 (see Figure 30). Still, the PHI values subsequently fall back during the following session to eventually increase again. In line with the fluctuating VSA values previously observed, this suggests that the development of the vocalic system's organization does not follow a linear path. A closer look within each subject on the PHI values graph (Figure 30) indicates a certain variability for most participants. Indeed, PHI values tend to fluctuate between the first and the last session, especially in younger children (such as B10, B09, B18, B12, B14 and B05) which could indicate that the organization of their vocalic system has not yet reached a stable state. Oscillating PHI values can also be observed in the performances of older children (such as B08, B03, B17 or B04); however, they display already higher values and more stability across the four sessions.

To examine more closely this different developmental patterns in younger *vs.* older children, let us look at the vowel dispersion graphs (see Figure 31) of two French-Italian participants, namely

B03 and B12, over the four sessions. These graphs show all occurrences of the vowels /a, i, u/ per participant per session, based on which the PHI indexes have been computed. Participant B03 is a girl initially aged 35 months and B12 is a boy initially aged 24 months. What strikes first from these graphs is that, at S1, the vocalic categories are less well distinguished in the subject B12 than in the subject B03, especially for the vowels /a/ and /u/ whose productions are more dispersed or less clustered around the centre of the category. Then, if the vocalic system of the participant B12 begins to show some organization at S4, the evolution is less linear than in the participant B03. Indeed, a slight improvement is seen at S2 followed by a decrease in organization at S3 where the system appears much more constricted with much less distinction between the vocalic categories. In contrast, participant B03 displays a more organized vocalic system already at S1 and, apart from more dispersed occurrences of the vowel /u/ at S2, the evolution of the organization appears to be more stable with vocalic categories /a/ and /i/ being more clearly established form the start.

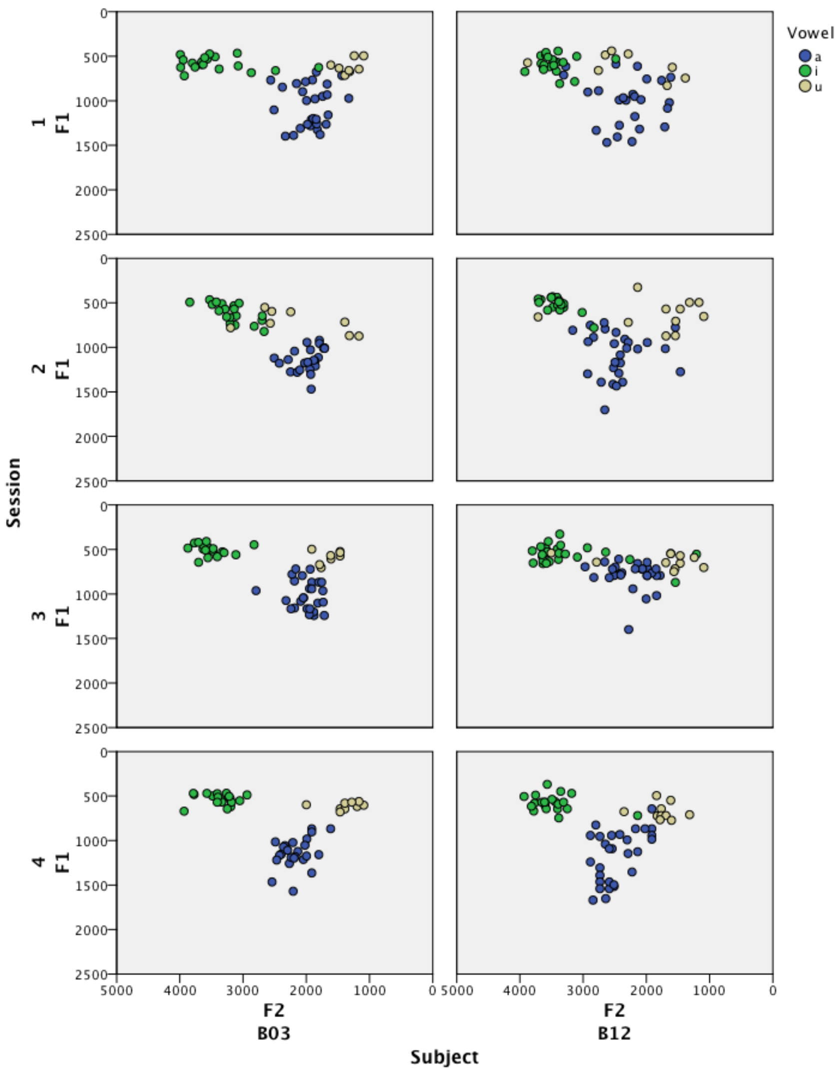

Figure 31: Vowel dispersion graphs (for /i/, /a/ and /u/) for each session of participants B03 and B12.

Going back to the PHI values graphs and considering the three linguistic groups separately, it appears that the highest PHI values are to be found in the French-Italian bilingual children, suggesting that they better distinguish the three vocalic categories (/a, i, u/) and produce them with less variability. An examination of the vowel dispersion graphs (/i/, /a/ and /u/ only) (see Figure 32) of the three linguistic groups (all participants combined) from S1 to S4 allows observing this from a more global comparative perspective.

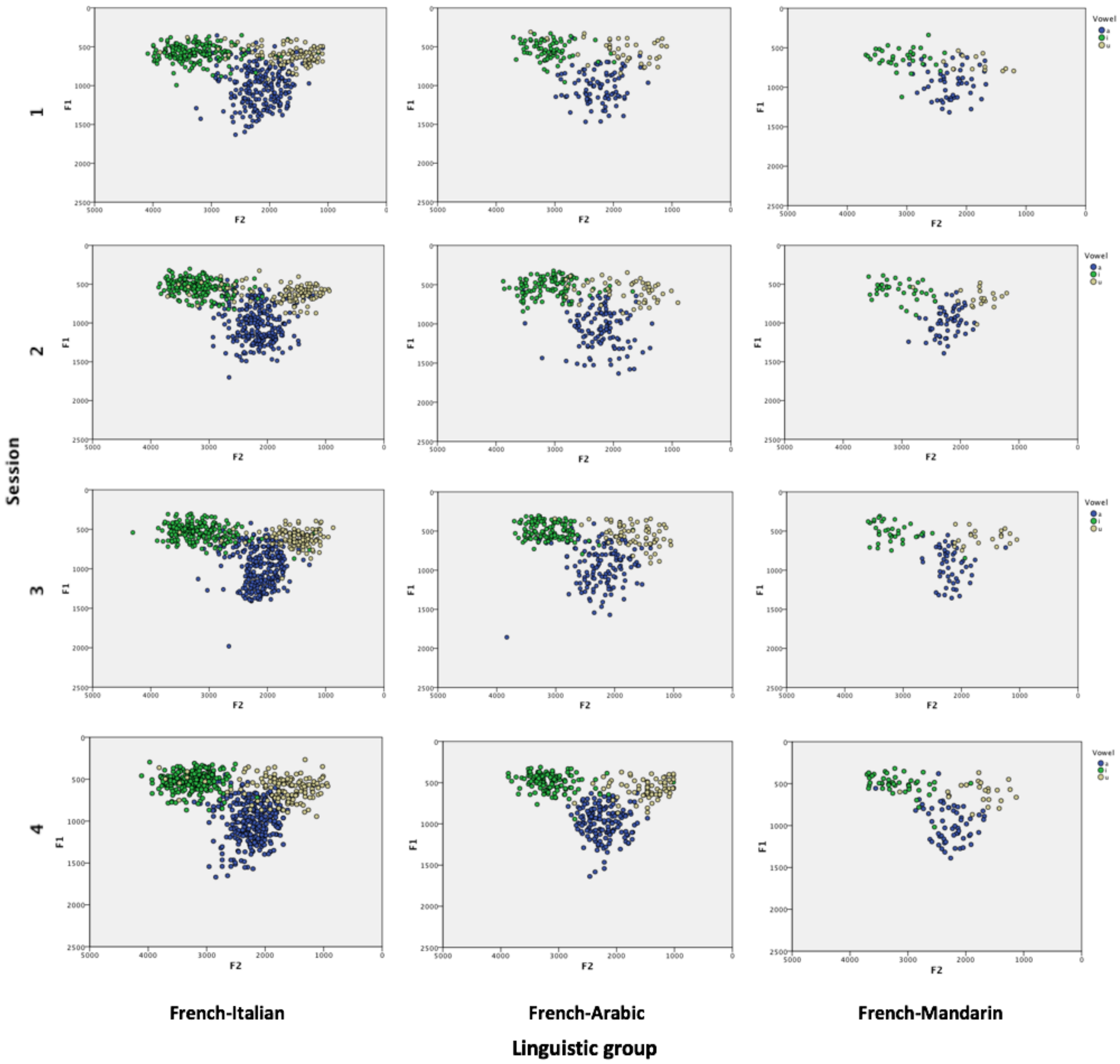

Figure 32: Vowel dispersion graphs (for /i/, /a/ and /u/) for each linguistic group and each session.

Comparison of the vowel dispersion graphs of the three groups over the different sessions indicates an evolution of the vocalic system organization from S1 to S4 in all three groups, as vowels productions become gradually less dispersed and vocalic categories more and more distinct. The French-Italian bilinguals show the more linear development and already display a certain organization at S1. In contrast, the vowels productions of the French-Mandarin participants are very scattered and concentrated in a more restricted area of the F1-F2 plan, in line with the restricted vocalic space areas previously observed (see Figure 29). French-Arabic seem to fall between the two other groups but exhibit not much improvement at S2. Rather, their vowels become more dispersed or less clustered within the categories, especially for /a/. Their productions become more and more organized from S3 to S4. In particular, at S3, the vowel /i/ appears to be better categorised than /a/ and /u/ whose realizations still remain more dispersed. Still, at S4, their productions of the vowel /u/ become more clustered and begin to form a category distancing itself from the others. French-Mandarin bilinguals progressively achieve a better vocalic system organization from S1 to S3. However, they regress at S4, during which they show more disorganization as their vowels productions become again scattered, especially for /a/ and /u/.

These dispersion graphs corroborate the fact that the vocalic system (based on the three corner vowels) gets more rapidly and steadily organized in French-Italian bilinguals than in French-Arabic and French-Mandarin bilinguals. As both PHI values and dispersion graphs suggest different developmental patterns in the evolution of the vocalic system organization for the three linguistic groups, we conducted Bravais-Pearson correlations between PHI values and age for all linguistic groups pooled together and for each linguistic group separately to examine whether there is a correlation between the two variables and whether the degree of correlation differs from one group to the other (see Table 29). The scatter plots of PHI values (tagged with the session number) as a function of age are shown together with the associated regression line in Figure 33 (one graph per linguistic group).

PHI versus Age	All participants	French-Italian	French-Arabic	French-Mandarin
	r = 0.577 p <.001	r = 0.599 p <.001	r = 0.739 p <.001	r = 0.433 p = 0.283

Table 29: Correlation coefficients r_{BP} between PHI values and chronological age in each linguistic group.

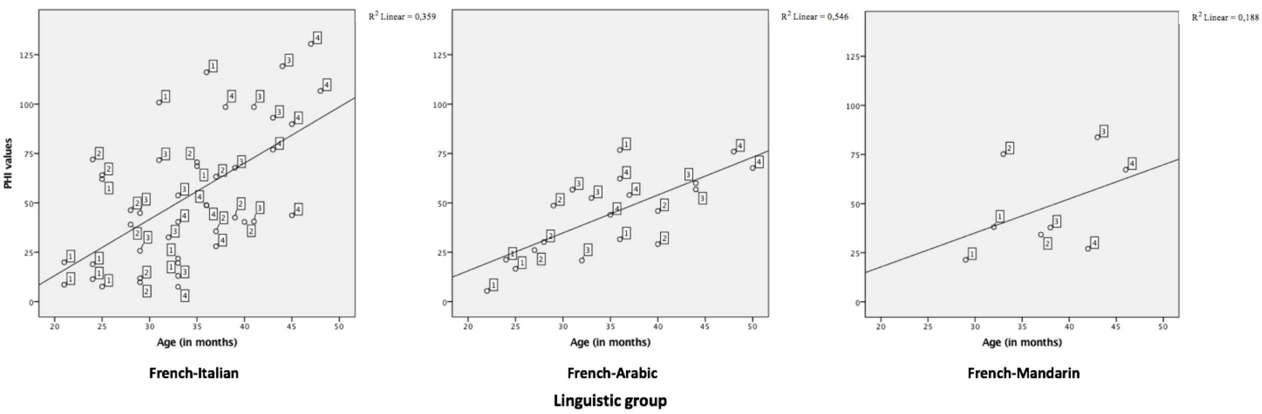

Figure 33: Correlation between PHI values and chronological age (in months) for each linguistic group.

Results show that there exists a high positive correlation between the PHI values and age for the French-Arabic and French-Italian groups (but not significant in the French-Mandarin group). In other words, PHI values increase with age for French-Italian and French-Arabic bilingual children. However, this correlation is stronger for the French-Arabic group.

As with VSA values, we also examined whether there would be a correlation between: (1) the PHI values and the children's linguistic dominance and (2), the PHI values and the two vocabulary scores (in French and combined for both languages). No relation was found between the PHI values and the linguistic dominance. Table 30 presents the results for correlations between PHI values and each vocabulary score calculated for all linguistic groups pooled together and for each linguistic group separately.

	All participants	French-Italian	French-Arabic	French-Mandarin
PHI vs French vocabulary scores	$r = 0.360$ $p = 0.002$	$r = 0.323$ $p = 0.032$	$r = 0.498$ $p = 0.025$	$r = 0.310$ $p = 0.454$
PHI vs Total vocabulary scores	$r = 0.384$ $p = 0.001$	$r = 0.351$ $p = 0.019$	$r = 0.537$ $p = 0.015$	$r = 0.119$ $p = 0.779$

Table 30: Correlation coefficients r_{BP} between PHI values and French Vocabulary score/Total Vocabulary score in each linguistic group.

We notice that it is for the French-Arabic group that the correlation coefficients are the highest, indicating that the vocalic system gains in organization as their lexical competence increase.

Following this, the issue of whether the three groups would differ or resemble each other in the way in which the vocalic system gets organized, in relation to both inter- and intra-categorical variability, seemed worth addressing. To investigate this, we calculated correlations between PHI, CM_{inter} and CM_{intra} values for each group. We present the correlation results in Table 31.

	Correlation between PHI and CM_{inter}	Correlation between PHI and CM_{intra}
French-Italian	$r = 0.820$ - $p < .001$	$r = -0.605$ - $p < .001$
French-Arabic	$r = 0.919$ - $p < .001$	$r = -0.491$ - $p = .028$
French-Mandarin	$r = 0.793$ - $p = .019$	$r = -0.516$ - $p = .191$

Table 31: Correlation coefficients r_{BP} between PHI, CM_{inter} and CM_{intra} values for each linguistic group.

Interestingly, the relation between the different variables differ among the different groups. For the French-Italian and French-Arabic bilinguals, the PHI values are highly correlated to the CM_{inter} and moderately to the CM_{intra}. However, the PHI values are less correlated to the CM_{intra} for the French-Arabic bilinguals.

These results mean that the evolution of the PHI results more from the evolution of the CM_{inter} in all three groups, meaning that the increase on their vocalic system organization has more to do with the increase of the inter-categorical distance than with the diminution of the intra-categorical distance. Furthermore, the increasing organization is even less explained by the decrease in intra-categorical variability for the French-Arabic participants. As for the French-Mandarin bilinguals, the PHI are not correlated with the CM_{intra}. Figure 34 presents the evolution of the CM_{inter}, CM_{intra} and PHI values over the four sessions in the three linguistic groups.

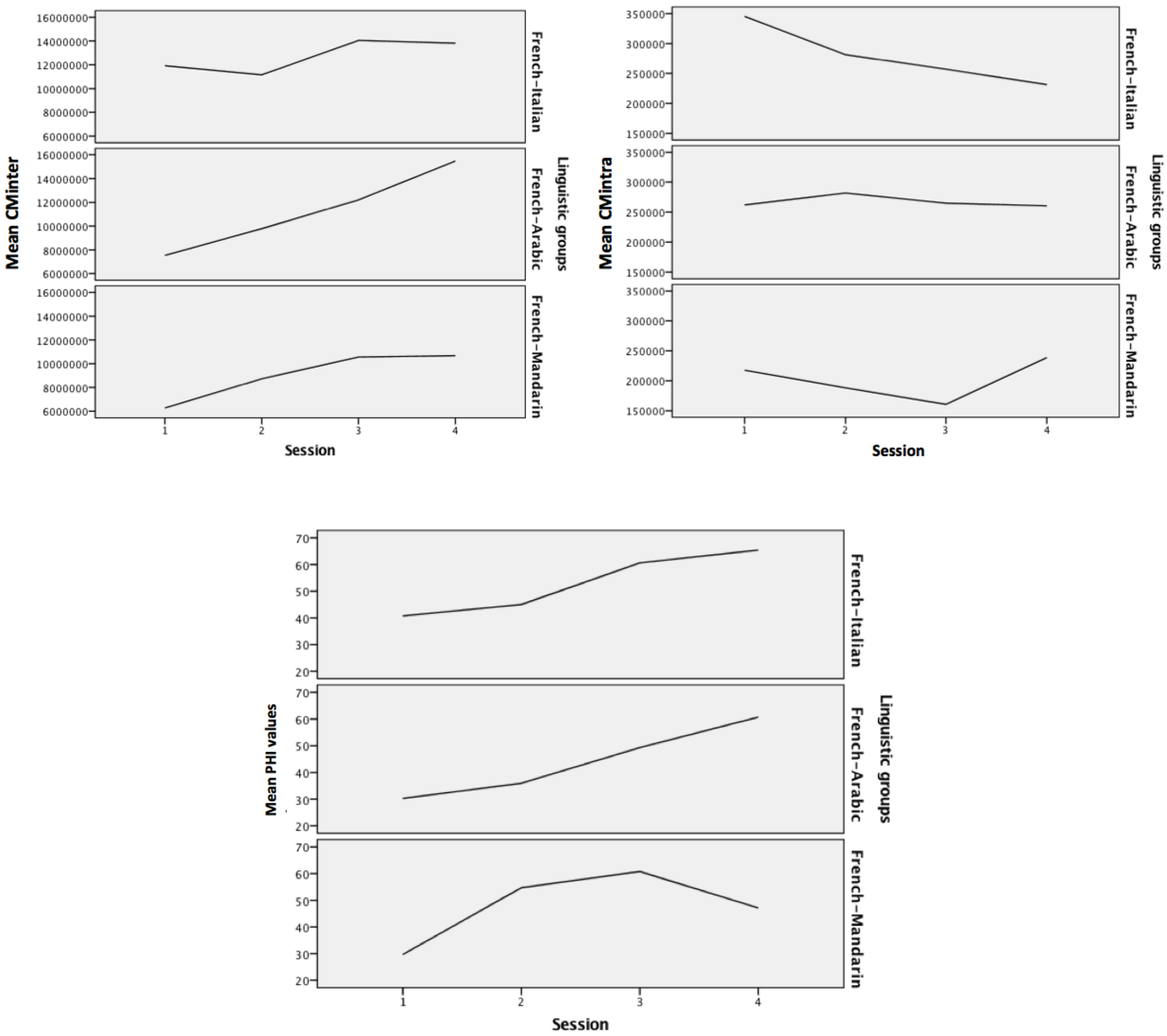

Figure 34: Evolution of CM_{inter}, CM_{intra} and PHI values for each linguistic group over the four sessions.

A number of remarks can be made based on these graphs as it clearly appears that the two mean squares evolve differently in the three linguistic groups. First, the French-Italian participants have initially higher CM_{inter} values than the two other groups and this remains the case until the third session. After a slight decrease at S2, the values increase until S3 and show almost no evolution at S4. This suggests that, from the start, their vocalic categories are more distinct from each other, compared to the two other groups, as was already shown by the vowels dispersion graphs (see Figure 32). In contrast, they begin with higher CM_{intra} values than the two other groups, which indicates that their vowel productions are initially characterized by a greater intra-categorical variability. Their CM_{intra} values subsequently decrease on each session. Still, given the high positive correlation between CM_{inter} and PHI values, they end up with PHI values relatively higher than the two other groups.

Then, French-Arabic bilinguals initially display much lower CM_{inter} values, indicating less distinct vocalic categories, which then continuously rise until the last session. Initially lower than those of French-Italian, their CM_{intra} values slightly rises at S2 and then only minimally decrease, as shown by the almost flat line on the graph. In other words, their vowels productions would initially present less intra-categorical variability than French-Italian. However, instead of declining, the variability inside the categories slightly increases at S2 (as could also be observed in the dispersion graphs) and remains almost constant across the subsequent sessions. Again, this is reflected in their increasing PHI values much more correlated to the CM_{inter} than to the CM_{intra} values.

Finally, the French-Mandarin participants initially exhibit the lowest CM_{inter} and CM_{intra} values at S1, which suggest little distinction between the vocalic categories and low variability inside the categories. This may seem contradictory but in fact, it is in line with the above dispersion graphs showing scattered vowels productions confined in a restricted F1-F2 area. Their productions are less dispersed inside the categories but at the same time, they use a smaller area. Then, both CM_{inter} and CM_{intra} values respectively rise and decrease until the third session, resulting in increasing PHI values and thus, increasing organization. Still, no evolution is seen for CM_{inter} values at S4, whereas CM_{intra} values increase, indicating a greater disorganization than in the beginning, reflected by their declining PHI values. Also observed in the dispersion graphs (Figure 32), this regression is also reflected in the fact that their PHI values marginally correlate with age.

Following this, it seemed worthwhile investigating the relation between the two measures focused on the vocalic system organization; that is, the PHI and VSA values. The two variables appear to be correlated to age to a different extent for the three linguistic groups. Besides, as both measures are characterized by a large amount of individual variability, we were interested to examine whether a higher PHI value would necessarily be associated with a higher VSA value and whether the relation between the two variables would be similar or different for the different bilinguals. Therefore, we conducted correlation tests globally for all participants and separately for each of the three groups. Figure 35 shows the scatter plot of PHI values (tagged with the session number) as a function of VSA values as well as the associated regression line for all participants pooled together. The subsequent Table 32 presents the results obtained for all correlation tests.

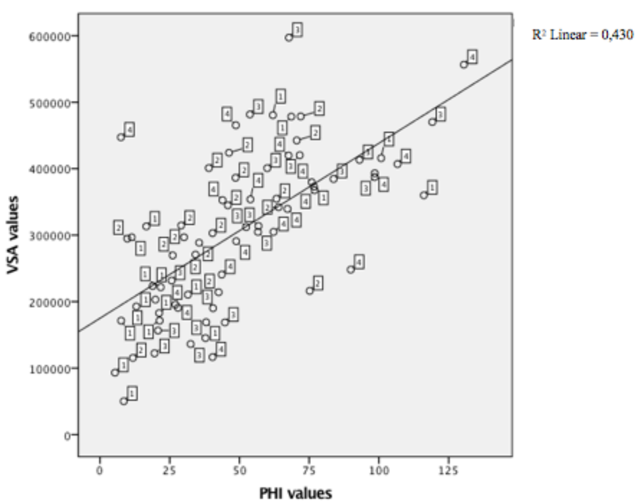

Figure 35: Correlation between VSA and PHI values for all participants.

	Correlation between PHI and VSA values
All participants	r = 0.656 - p <.001
French-Italian	r = 0.641 - p <.001
French-Arabic	r = 0.783 - p <.001
French-Mandarin	r = 0.724 - p = .042

Table 32: Correlation coefficients r_{BP} between PHI values and age both globally and for each group.

These results suggest that, globally, there is a moderate-to-strong positive correlation between the two variables, meaning that the VSA values increase alongside the PHI values. Looking at each group separately, the correlation between the two variables is higher for the French-Arabic bilinguals than for the French-Italian group and is just significant for the French-Mandarin participants, as their PHI values decrease at S4 (see Figure 34) while their VSA does not evolve.

Thus, for all linguistic groups, VSA and PHI values are concomitantly increasing over time. In other words, the vocalic space area grows as the vocalic system gets more organized. Still, from an individualised perspective, one can notice different developmental patterns, as shown by the two line graphs below. Indeed, for several children – such as the French-Italian B03 (represented on Figure 36), B09, B12, B17 and the French-Arabic B05 – the VSA and PHI values are positively correlated over the four sessions. Then, the opposite tendency can sometimes be observed, such as in one French-Italian participant B08 (represented on Figure 36) for whom the two variables are negatively correlated across all sessions. It should be specified that B03 and B08 are both aged above 30 months at S1.

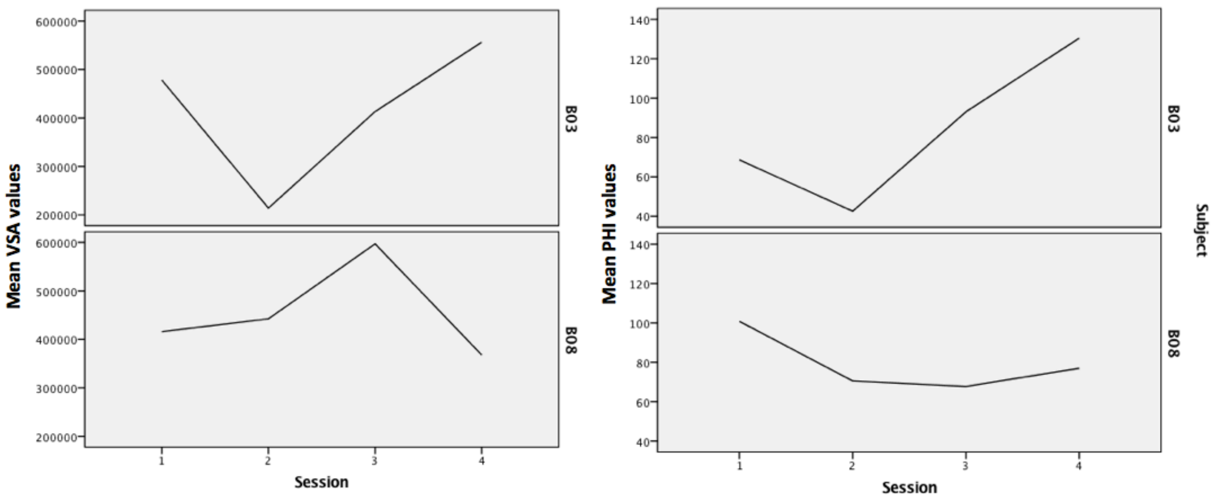

Figure 36: Evolution of VSA and PHI values for the participants B03 and B08.

In conclusion to this section, results show that the French-Italian participants initially display a more expanded VSA as well as higher PHI values. They present a greater degree of organization of the system since their vocalic categories are initially more distinct from one another than those of the two other groups. This discrepancy in inter-categorical variability between the groups can be observed until the third session, following which the French-Italian participants are being caught up by the French-Arabic bilinguals. In line with this, these latter show the more increasing VSA and CM_{inter} values but no decline of intra-categorical variability. French-Mandarin bilinguals display the more reduced VSA and seem the least linear in their evolution showing a regression in PHI values at S4.

While these results are interesting, we must remain careful with our interpretations, especially with regard to the French-Mandarin participants. Therefore, our findings do not allow us to draw generalizable conclusions. That said, given that the French-Italian are the most numerous, they can be considered as being the most representative of our sub-samples. Besides, these analyses of the vocalic system organization are based on the three corner vowels /a, i, u/ and as such, may be considered as providing a partial representation only of all the information available. Therefore, we conducted complementary transcription-based analyses focusing on the evolution of global vowel accuracy.

III.1.2 VOWEL ACCURACY

In order to assess the evolution of global vowel accuracy in the children's productions, we have calculated the global Percentage of Vowels Correct (PVC) per session, based on all vowels included in all items produced by session. PVC is a measure automatically computed by PHON based the comparison between the phonetic transcriptions of the actual productions *vs.* the intended targets. In total, 2857 items have been analysed. Table 33 presents the mean PVC values for each linguistic group, both globally and for each session. We see that global mean PVC and standard deviation values are quite similar in each linguistic group. We conducted a non-parametrical Kruskal-Wallis test that revealed no significant difference between the linguistic groups, all sessions combined.

Linguistic group	Total number of items (all participants, all sessions)	Mean number of items per child per session	Global mean (and S.D.) PVC values (all sessions combined)	Mean (and S.D.) PVC values for each session			
				S1	S2	S3	S4
French-Italian	1733	40	80.33 (30.20)	73.44 (34.16)	79.99 (29.34)	82.73 (28.61)	83.59 (28.43)
French-Arabic	765	38	80.92 (30.83)	82.04 (29.25)	76.79 (35.09)	80.06 (30.37)	84.44 (28.00)
French-Mandarin	359	45	80.39 (30.48)	76.56 (32.15)	77.89 (34.33)	84.86 (27.68)	81.95 (31.05)

Table 33: Mean PVC values (and standard deviations) for the three linguistic groups.

Figure 37 gives a visual representation of the evolution of mean PVC values for each linguistic group across the four sessions. It can be seen that, for all three groups, mean PVC values are initially above 70% and increase from the first to the last session. Still, the evolution curves differ from one group to the other. Mean PVC values continuously increase over the four sessions for French-Italian bilinguals and, as indicated in Table 33, mean standard deviation values similarly continuously decrease from S1 to S4. Mean PVC values are initially higher, above 80%, in French-Arabic bilinguals and then decline to subsequently increase again. The curve of the two French-Mandarin participants goes up from S1 to S3, to finally fall down at S4. This final decrease in their mean PVC values is in line with the falling PHI values previously observed, suggesting a slight regression for all vowels productions at S4. Mean PVC values of all three groups converge above 80% at the fourth session.

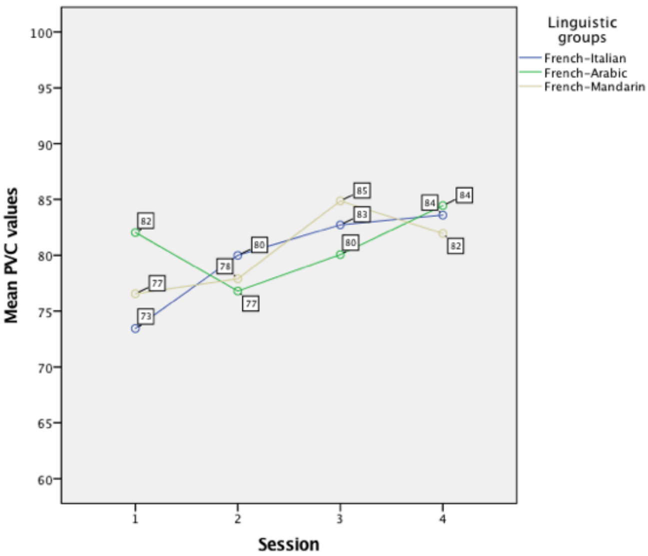

Figure 37: Evolution of global PVC values for each linguistic group over the four sessions.

We now turn to individual variation. Figure 38 presents line graphs with PVC values for all participants, with separate graphs for the three linguistic groups. Each coloured line corresponds to one subject and the marks on the lines correspond to the different sessions. We observe that PVC values increase from S1 to S4 for almost all children, with one notable exception: the French-Italian participant B09 for whom the PVC curve is sharply falling at S4. The lowest values are seen in the youngest participants in whom PVC tends to fluctuate, as is the case for several French-Italian toddlers (B01, B10 and B18) and for all the young French-Arabic (B05, B06 and especially B14). This explains the falling curve at S2 for French-Arabic bilinguals that could be observed in Figure 37. Besides, the very high performance of B10 at S4 is explained by the fact that this child produced fewer items on that particular session and that all attempted vowels were correctly produced. Then, from about 30 months of age, the PVC values increase rather linearly in all groups. Also, the two French-Mandarin participants have initial mean PVC values above 70%, with a more pronounced later increase for B15 than for B16.

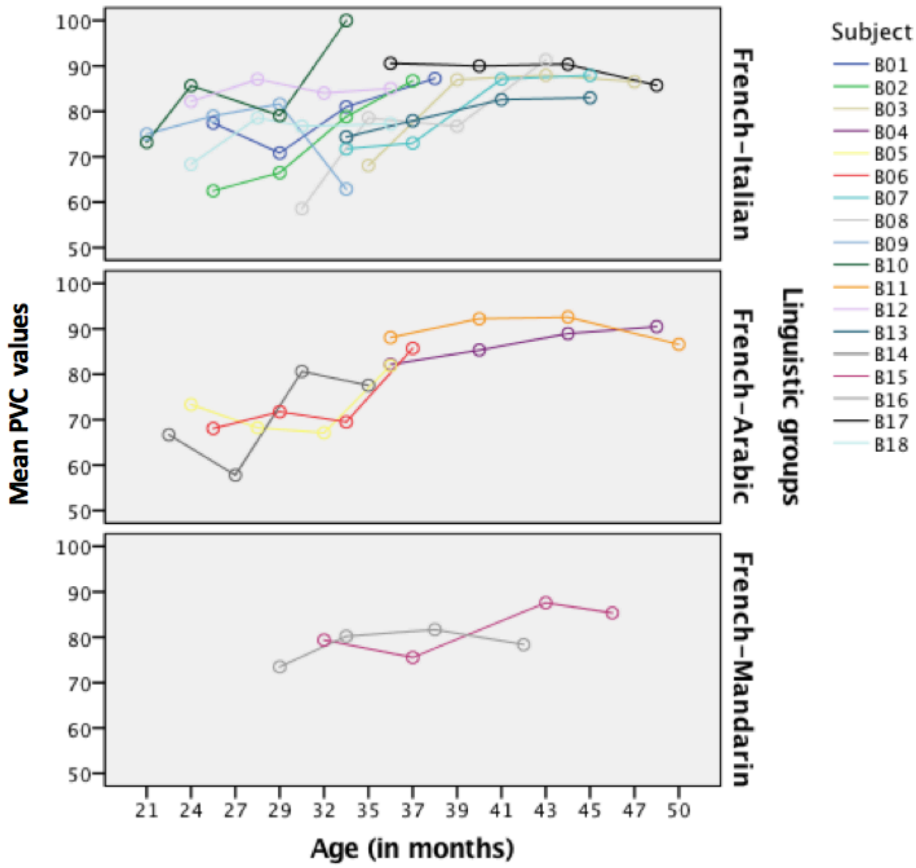

Figure 38: Evolution of PVC values over the four sessions for all participants from the three linguistic groups.

In order to assess the impact of different independent variables on PVC within each linguistic group, we conducted a series of non-parametrical Kruskal-Wallis (from now on, KW) tests. These analyses are made possible because PVC measures consist in multiple datapoints per participant per session (at least one per word produced). KW tests were used to investigate the impact of the following variables:

- independent variables related to the subject: session, chronological age, linguistic dominance, vocabulary scores, gender and the presence of siblings;
- independent variables related to the item (i.e., the word): elicitation, phonological complexity and lexical frequency.

We chose to include the French-Mandarin participants in the subsequent analyses despite their restricted number. However, the subject-related independent variables of linguistic dominance, gender and siblings have not been tested on these two participants as these variables are confounded with the subject and therefore, potentially found effects might be attributable to the subject him/herself instead of the variable of interest (besides, both French-Mandarin participants have siblings). Results obtained for the other variables on the French-Mandarin participants will be taken with particular caution. Linguistic dominance and gender are not listed below, as there was no significant effect of these variables on PVC values in any linguistic group.

III.1.2.1 Independent variables related to the subject

III.1.2.1.1 Session

Results from the KW tests show a significant effect of session only for the French-Italian group (Chi square = 26.27, $p < .001$, df = 3). Pairwise comparisons (Dunn-Bonferroni post hoc test) more precisely reveal that PVC values from S1 significantly differ from those of S3 ($p <.001$) and S4 ($p <.001$). PVC values significantly increase from S1 to S3 and S4, as shown by Figure 39 which displays mean PVC values (+/- 1 standard deviation) of the four sessions for the French-Italian group.

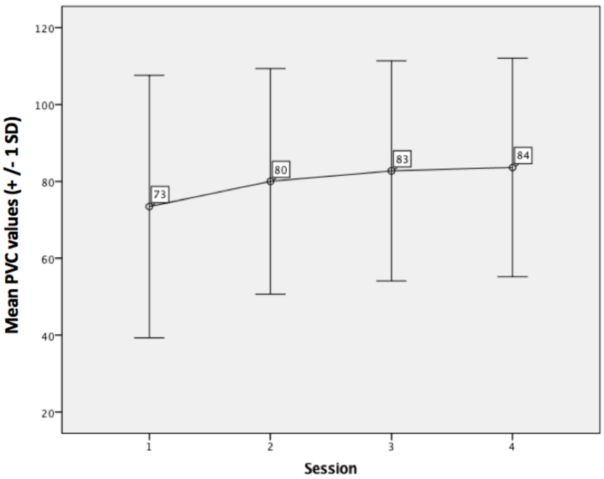

Figure 39: Mean PVC values (+/- 1 standard deviation) as a function of session for the French-Italian group.

No statistically significant differences in PVC values between the different sessions were found for the French-Arabic and French-Mandarin groups. This absence of effect is not surprising for the two French-Mandarin participants whose PVC values do not increase much, as shown by the previous line graphs (Figure 38). As for the French-Arabic group, this might be explained by the almost flat curves of the two older participants B04 and B11(Figure 38).

III.1.2.1.2 Chronological age

Results from the KW tests show a significant effect of chronological age for the French-Italian (Chi square = 47.73, $p < .001$, df = 5) and French-Arabic (Chi square = 53.92, $p < .001$, df = 5) groups. Stepwise-stepdown comparisons (Campbell and Skilling's post-hoc procedure) yield two homogenous subsets: age ranges 1 to 3 (from 21 to 35 months) and age ranges 4 to 6 (from 36 to 53 months) for both groups. In other words, post hoc tests indicate statistically differences between the age ranges of the two subsets. Figure 40 presents the mean PVC values (+/- 1 standard deviation) for each age range in the two groups. As shown by the graphs, PVC values increase with chronological age and French-Arabic display lower mean PVC values and greater variability in the first two age ranges than French-Italian bilinguals. No effect of chronological age on PVC values was found for the French-Mandarin bilinguals, as could be expected from their individual curves on the above line graph (Figure 38).

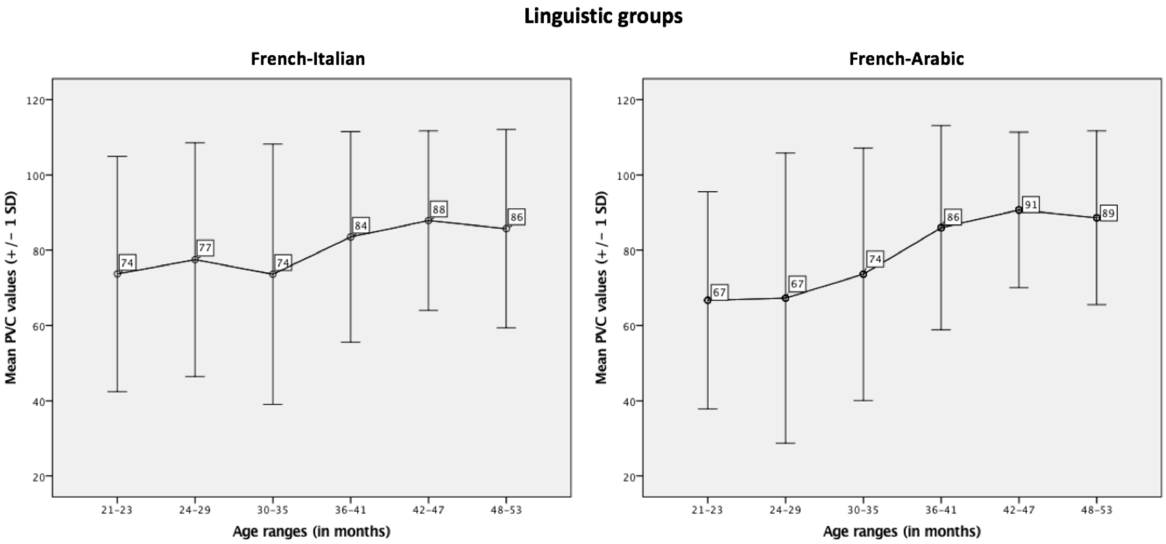

Figure 40: Mean PVC values (+/- 1 standard deviation) as a function of chronological age for the French-Italian and French-Arabic groups.

III.1.2.1.3 Vocabulary scores

A significant effect of the two vocabulary scores on PVC values was found for the French-Italian and French-Arabic groups (see Table 34). Stepwise-stepdown comparisons yield slightly different homogenous subsets for the different vocabulary scores for each group but globally, PVC values increase alongside lexical development (see Figure 41). For French vocabulary, the score ranges are the following: (1) 27-155 words, (2) 156-284 words, (3) 285-413 words, (4) 414-542 words, (5) 543-670 words. For total vocabulary, the score ranges are the following: (1) 54-272 words, (2) 273-491 words, (3) 492-710 words, (4) 711-929 words, (5) 930-1150 words.

Linguistic group	KW results		Stepwise-stepdown comparisons
French-Italian	French vocabulary score	Chi square = 36.86, p < .001 df = 4	Two homogeneous subsets: Score ranges 1 - 2 Score ranges 3 to 5
	Total vocabulary score	Chi square = 32.76, p < .001 df = 4	Two homogeneous subsets: Score ranges 1 to 3 Score ranges 4 - 5
French-Arabic	French vocabulary score	Chi square = 33.1, p < .001 df = 4	Three homogeneous subsets: Score range 1 Score ranges 2 to 4 Score range 5
	Total vocabulary score	Chi square = 23.9, p < .001 df = 4	Two homogeneous subsets: Score ranges 1 - 2 Score ranges 3 to 5

Table 34: Results of KW tests with vocabulary scores as a grouping variable for the French-Italian and French-Arabic groups.

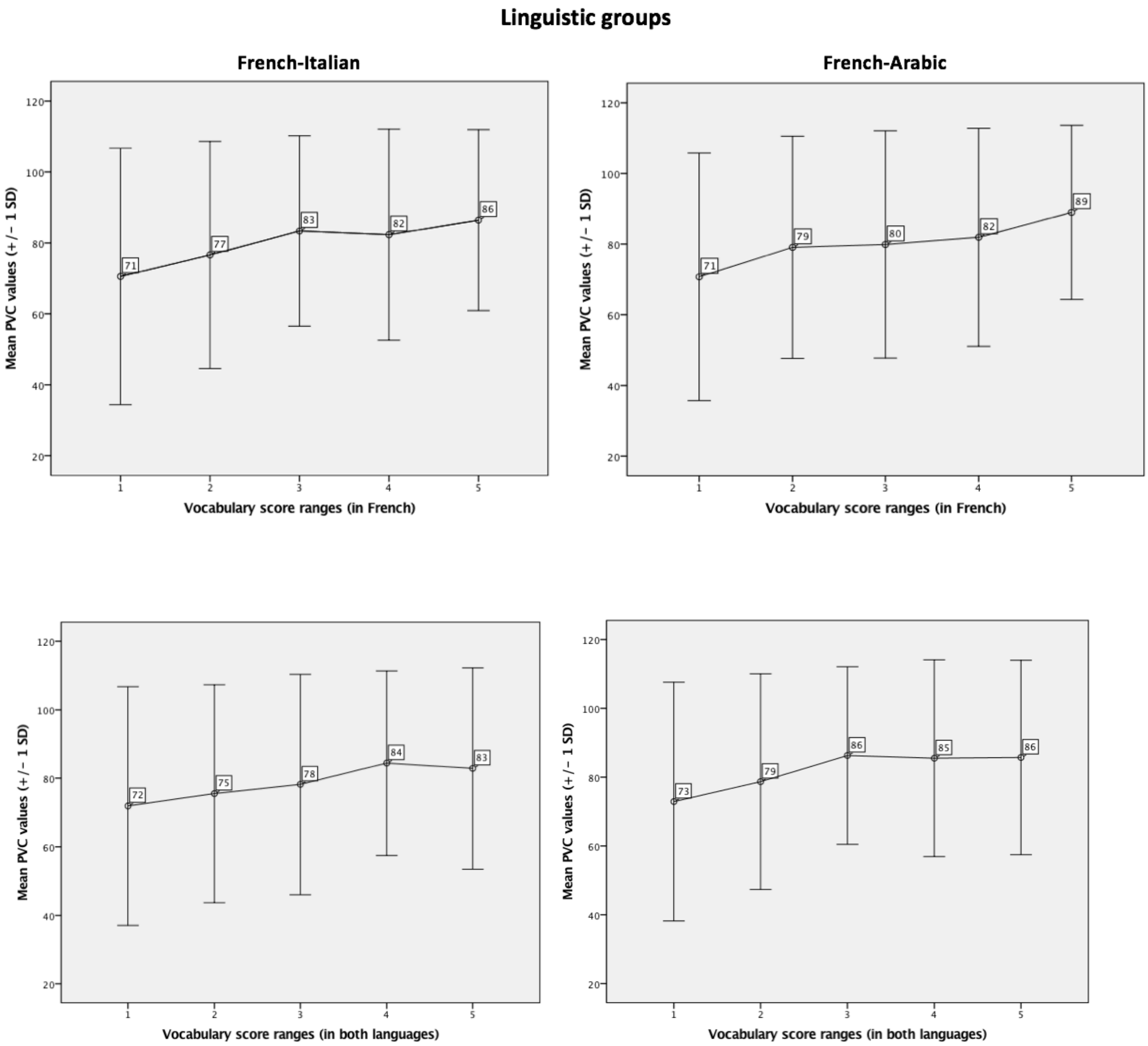

Figure 41: Mean PVC values (+/- 1 standard deviation) as a function of French vocabulary score (1=27-155 words, 2=156-284 words, 3=285-413 words, 4=414-542 words, 5=543-670 words) and total vocabulary score (1=54-272 words, 2=273-491 words, 3= 492-710 words, 4= 711-929 words, 5=930-1150 words) for the French-Italian (left) and French-Arabic (right) groups.

III.1.2.1.4 Presence of siblings

A significant effect of presence/absence of siblings was found only for the French-Arabic group (Chi square = 21.9, $p < .001$, df = 1). Moreover, the PVC values are significantly lower in children with siblings, while the opposite would rather be expected. However, there is only one child without siblings, the participant B11, who is one of the oldest child and has the highest PVC values. It is unclear from these data whether the presence *vs.* absence of siblings has any significant effect on the children's PVC values.

III.1.2.2 Independent variables related to the item

III.1.2.2.1 Elicitation

Results from the tests showed a significant effect of elicitation on PVC values for the French-Italian (Chi square = 12.5, p value = .002, df = 2) and French-Arabic (Chi square = 18.7, p value < .001, df = 2) groups. For the French-Italian group, post-hoc tests show that there is a significant difference between PVC values for repetition of unknown words on one hand, and PVC values for naming (p value = .002) and repetition of known words (p value = .005) on the other hand. Then, for French-Arabic bilinguals, PVC values of named words are statistically different from those of both repeated known words (p value <.03) and repeated unknown words (p value <.001). These tendencies can be directly observed on the line graphs (see Figure 42).

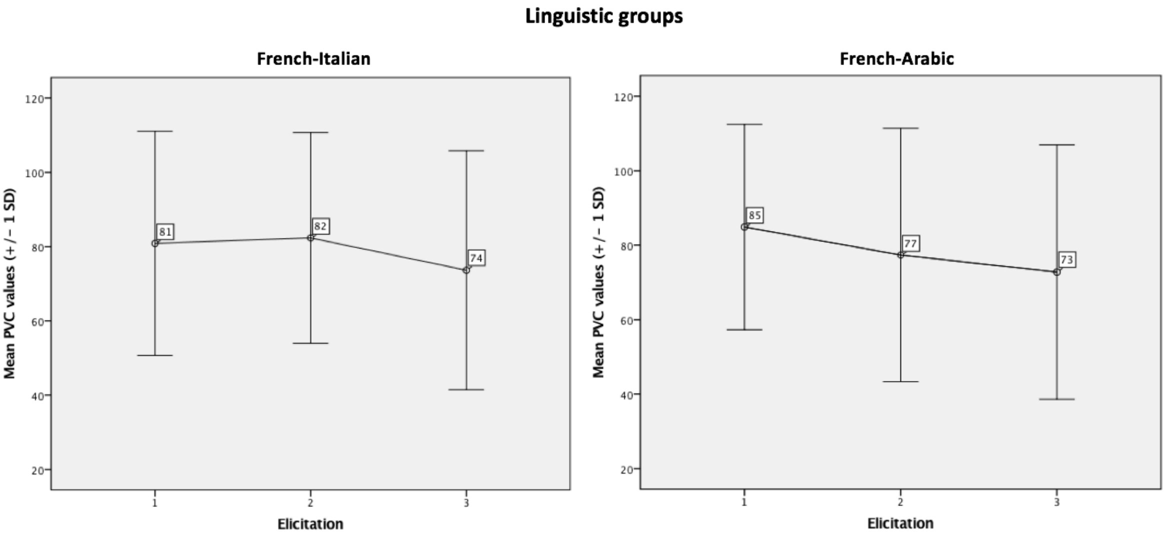

Figure 42: Mean PVC values (+/- 1 standard deviation) as a function of elicitation in the French-Italian and French-Arabic groups (naming = elicitation 1, repetition of known words = elicitation 2, repetition of unknown words = elicitation 3).

III.1.2.2.2 Phonological complexity and lexical frequency

The item-related variables of phonological complexity and lexical frequency are discussed together given that the KW tests show a statistically significant effect of both variables and similar tendencies for all three linguistic groups. Results are reported in Table 35. Pairwise comparisons have only been computed for phonological complexity as there are only two levels of lexical frequency. There are three levels of phonological complexity (1 = not complex words, 2 = moderately complex, 3 = complex) and two levels of lexical frequency (1 = not frequent, 2 = frequent).

Linguistic group	KW results		Pairwise comparisons
French-Italian	Phonological complexity	Chi square = 167.85 p < .001 df = 2	There are statistical differences between PVC values of all three ranges of phonological complexity (p <.001) with a difference less marked between ranges 2-3 (p=.001)
	Lexical frequency	Chi square = 25.1 p < .001 df = 1	/
French-Arabic	Phonological complexity	Chi square = 67.38 p < .001 df = 2	There are statistical differences between PVC values of all three ranges of phonological complexity (p <.001) with a difference less marked between ranges 2-3 (p=.02)
	Lexical frequency	Chi square = 28.17 p < .001 df = 1	/
French-Mandarin	Phonological complexity	Chi square = 36.36 p < .001 df = 2	There are statistical differences between PVC values of all three ranges of phonological complexity (p <.001) except between ranges 2-3
	Lexical frequency	Chi square = 10.28 p = .001 df = 1	/

Table 35: Results of KW tests with phonological complexity and lexical frequency as grouping variables for the three linguistic groups.

These results indicate that, for all three groups, there are statistically significant differences in PVC values between items of different phonological complexity and lexical frequency. The effect of lexical frequency is less significant for French-Mandarin bilinguals than for French-Italian and French-Arabic. Pairwise comparisons yield similar tendencies, except for the fact that there are no significant differences in PVC values of moderately and highly complex items for the French-Mandarin bilinguals. Mean PVC values (+/- 1 standard deviation) for each level of item complexity and frequency in the three groups are showed in Figure 43. As can be seen, in all three linguistic groups, PVC values increase as the level of lexical frequency increases and the level of phonological complexity decreases.

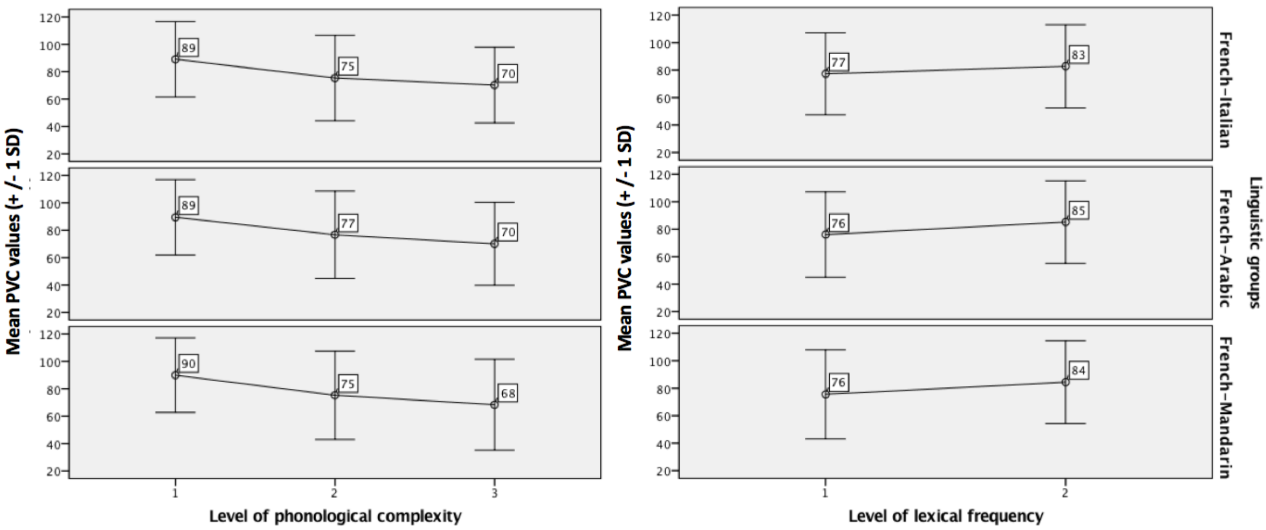

Figure 43: Mean PVC values (+/- 1 standard deviation) as a function of phonological complexity (1 = not complex words, 2 = moderately complex, 3 = complex) and lexical frequency (1 = not frequent, 2 = frequent) for the three groups.

Before moving to the next section, Table 36 summarizes the results obtained for each variable separately in each linguistic group.

Independent Variable	French-Italian	French-Arabic	French-Mandarin
Session	Chi square = 26.27 p < .001, df = 3	NS	NS
Chronological Age	Chi square = 47.73 p < .001, df = 5	Chi square = 53.92 p < .001, df = 5	NS
French Vocabulary score	Chi square = 36.86 p < .001, df = 4	Chi square = 33.1 p < .001, df = 4	NS
Total Vocabulary score	Chi square = 32.76 p < .001, df = 4	Chi square = 23.9, p < .001, df = 4	NS
Presence of Siblings	NS	Chi square = 21.9 p < .001, df = 1	
Elicitation technique	Chi square = 12.5 p = 002, df = 2	Chi square = 18.7 p < .001, df = 2	NS
Phonological complexity	Chi square = 167.85 p < .001, df = 2	Chi square = 67.38 p < .001, df = 2	Chi square = 36.36 p < .001, df = 2
Lexical frequency	Chi square = 25.1 p < .001, df = 1	Chi square = 28.17 p < .001, df = 1	Chi square = 10.28 p = .001, df = 1

Table 36: KW tests results on PVC values.

III.1.3 Phonological processes

We examine here whether the three linguistic groups differ or not in how the use of the phonological processes of vowel substitution and deletion evolves over time. Pie charts in Figure 44 display the proportion of correct, substituted and deleted vowels calculated for the different sessions for the three linguistic groups, based on the subcategories generated by PHON for the computation of global PVC. Several remarks can be made based on these pie charts. First, it appears that French-Arabic participants display lower rates of substituted and deleted vowels (i.e., 16% and 2%) for the first session compared to the other groups. Then, substitution and deletion rates increase at S2 to become very similar to those of the French-Italian and French-Mandarin participants. French-Mandarin participants show a strong improvement from S2 to S3 with a higher rate of correct vowels and no vowel deletion. For all three groups, substitution and deletion rates evolve in a very similar way from S2 to S3 and as could be expected, there is a relatively low rate of vowel deletion with nearly no vowel deletion remaining at S4.

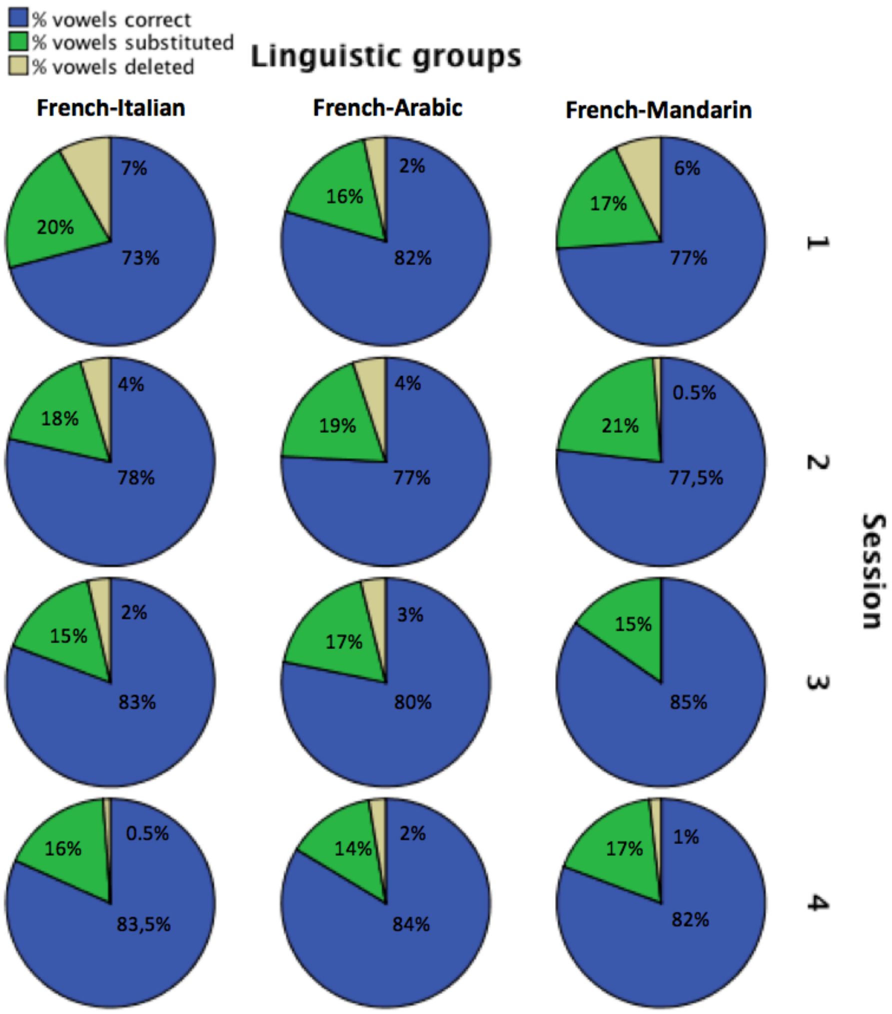

Figure 44: Proportion of correct, substituted and deleted vowels across the four sessions for the three linguistic groups.

Then, we further investigated the types of substitution applied by children inside each linguistic group in order to examine the differences and similarities between the three types of bilinguals. Table 37 presents the types of vowel substitution common to all three groups (column IPA actual common) and specific to each group (i.e., only observed in this group). It appears that no common substitution processes affect the front mid-low oral vowel /œ/ and the nasal /ɑ̃/. The high-front and mid-low back rounded vowels /i/ and /ɔ/ are the vowels for which there is the greatest number of substitution processes common to all three groups. In contrast, there is only one common substitution type affecting the low-front oral vowel /a/. All common substitution processes involve the modification of one or two phonetic features. Interestingly, there are no type of vowel substitution specific to the French-Mandarin participants (i.e., only observed in the participants of that group). French-Italian bilinguals obviously present much more diverse types of substitution processes affecting vowels than the French-Arabic group (and even more than the French-Mandarin participants). Then, certain processes draw our attention for they involve the modification of more than two phonetic features. First, for French-Italian bilinguals, we note the following processes: (1) substitutions of the low-front vowel /a/ by either the high-back rounded [u] or the high-front vowel [i], (2) substitutions of the mid-high front vowel /e/ by the nasal vowel [ɑ̃], (3) substitutions of the high front vowel /i/ by the the mid-low back rounded vowel [ɔ] and (4), substitution of the nasal vowel [ɑ̃] by either the high front vowel [i] or the high front rounded vowel [y]. Then, for the French-Arabic bilinguals, we note one type of substitution involving vowels quite opposed in terms of articulatory characteristics: (1) substitutions of the nasal vowel [ɔ̃] by the high front rounded vowel [y]. Finally, the nasal vowel /ɑ̃/ is affected by substitution processes only in the French-Italian group.

IPA Target	**IPA Actual common**	**IPA Actual French-Italian**	**IPA Actual French-Arabic**	**IPA Actual French-Mandarin**
i	y – e – ø - ɛ	u - ɔ		
y	i	u - ɛ		
u	ɔ	e - œ	i	
e	i - ø - ɛ	y - ɛ̃ - œ - ɑ̃	u - ə	
ø	e	y	o	
o	i - e - ø	u - ɔ̃ - ɛ		
ə	ɔ	i - ɛ - œ - a	u	
ɛ	i - e - a	ø	œ	
ɛ̃	i - a	ə - ɔ	ɔ̃ - ɑ̃	
œ		ɔ	ø	
ɔ	ø – o – œ – a - ɑ̃	/	ɔ̃	
ɔ̃	u - ɔ - ɑ̃	ɛ - œ	y	
a	ɛ	i - u - ø - ɛ̃ - ɔ̃	œ - ɔ	
ɑ̃		i - y - ɛ - ɛ̃		

Table 37: Common and group-specific vowel substitutions.

III.1.4 Discussion

Results obtained for the different analyses conducted on the children's vowels are discussed in this section, following the same order of presentation: (1) the evolution of the vocalic system organization, (2) the evolution of vowel accuracy and (3) the phonological processes affecting vowels. Data available in the literature will be referred to as much as possible, as only a limited number of studies have focused on French vowel acquisition.

We summarize the working hypotheses previously stated (see section I.4.) about vowel acquisition.

First, we made assumptions about the effect of the linguistic group in interaction with the developmental variables. We assumed that different development patterns could emerge – over the subsequent sessions and as chronological age increases – in the different linguistic groups, resulting from potential cross-linguistic interaction between the two languages in contact. More precisely, we postulated that:

- children exposed to French and Italian might be advantaged in French vowel acquisition and show a faster vocalic development in comparison to children exposed to French and Arabic and, to a lesser extent, to children exposed French and Mandarin;
- children exposed to French and Arabic might be disadvantaged in French vowel acquisition and show a slower vocalic development in comparison to children exposed to French and Italian and, to a lesser extent, to children exposed to French and Mandarin

Then, we presumed that vowel acquisition might be influenced by a series of independent variables related to the subject and the item. More specifically, we postulated that:

- all children would display better performances from one session to the other and as chronological age increases;
- children who are more exposed to French would be advantaged in French phonetic and phonological development, in comparison to children less exposed to French;
- a more advanced lexical development in French and in both languages would benefit French phonetic and phonological development;
- French-Italian bilingual children might be more advantaged by a greater lexical development in both languages than French-Arabic and French-Mandarin bilingual children;
- if there is an effect of gender on French phonetic and phonological development, girls could have an advantage over boys;
- if there is an effect of siblings on French phonetic and phonological development, children with older siblings could have an advantage over children without siblings;
- children's speech productions should be more accurate for less complex and more frequent items than for more complex and less frequent items in French.

Finally, we also expected a high individual variability in the evolution of vowel production and this, for children exposed to all three language pairs.

III.1.4.1 Evolution of the vocalic system organization

Two measures have been used to assess the evolution of the vocalic system organization: the traditional VSA and the PHI index. For each measure, one value was computed per session per participant; in parallel, correlation tests have been conducted to examine the relations between the two measures and different variables; namely, chronological age, linguistic dominance and vocabulary scores.

III.1.4.1.1 Vocalic space area

Globally, the evolution of VSA values is rather non-linear, with values fluctuating between sessions, as much so in younger as in older children. As shown by correlation tests, VSA values increase with age only for the French-Arabic participants. This is confirmed by the representations of vocalic triangles for each linguistic group across the four sessions. Indeed, an expansion of the vocalic space area can be observed for the French-Arabic bilingual children (especially in the area of the vowel /u), while vocalic triangles are more overlapping for the two other groups. Besides, the French-Mandarin participants globally show a very constricted vocalic space area. This expansion over time of the vocalic space towards the high-back region (vowel /u/) observed on the French-Arabic group could be related to the longitudinal studies involving Canadian English- and French-speaking toddlers conducted by Rvachew et al. (2006 and 2008). Indeed, an expansion of the infants' vowel space towards high-front and high-back regions with age was observed in both studies. Still, the children were much younger than those involved in our study.

The reduced vocalic space in French-Mandarin bilinguals could be an example of a deflecting pattern (Kehoe, 2015) similar to that observed in the study led by Yang et al. (2015). To recall, the emergent English-Mandarin bilingual toddler observed in that study went through a temporarily restructuring phase in which he reduced his L2 (English) vowel space while enlarging his L1 vowel space, in order to maximize the contrast between his two vowel systems. His reduced English vowel space subsequently re-expanded. The French-Mandarin participants of our sample could be following a similar developmental path and be in a phase of momentary reduction of their French vowel space in order to keep their two vowel systems distinct. However, this is only speculation, as data from before and after the recording sessions as well as about the children's Mandarin vowel space would be needed to observe if we are actually in presence of a deflecting pattern.

III.1.4.1.2 PHI index

Our results show that PHI values globally increase with age for all participants (all linguistic groups combined) with the lowest values found in younger children and the highest in older children. This tendency was confirmed by a correlation test which yielded a moderate positive correlation between PHI values and age. In other words, the vocalic system gets more organized as children get older. As we expected, vowel production improves with chronological age. Moreover, results indicate that vowels are still in the process of being acquired during the age range investigated in our study; that is, from 21 months to 50 months. In her doctoral dissertation, Grandon (2016) observed that the various vocalic categories (determined by height and frontness) seemed to be already acquired by the youngest children of her sample aged around 5 years. It is thus possible that the vowel system achieves stability between 4 and 5 years of age. However, another two sessions, at least, would have been necessary to verify this, given the lack of evidence in the literature. Still, the development of the vocalic system organization appears to be non-linear, as PHI values are found to be rather fluctuating between one session and another, especially in the younger children. Some fluctuation is also observed in older children who nevertheless display higher PHI values. These results thus suggest high individual variability in the development of the vocalic system organization.

The highest Phi values are found in children from the French-Italian group, indicating that they better distinguish the vocalic categories /a, i, u/ and produce them with less intra-categorical variability. This seems to be confirmed by the vowel dispersion graphs for all four sessions of each linguistic group, which show that the vocalic system of the French-Italian bilingual children is initially more organized and displays a more linear development than that of the two other groups. Contrary to our expectations, the least organized vocalic system is observed in the French-Mandarin participants whose vowel productions are rather scattered over a more restricted area of the vocalic space. They also present a final regression at S4, whereas the French-Arabic participants, expected to have a slower vowel acquisition, globally show more progress from the first to the last session. In line with these results, the correlation test conducted between PHI values and age for each group indicates a stronger relation between the two variables for the French-Arabic group and a non-significant one for the French-Mandarin group. This non-significant result for the French-Mandarin bilingual children is presumably due to the insufficient number of data for that group and a correlation might have been found if there were more participants in that group.

Globally, for all three groups, the vowel /i/ is more quickly better defined as a phonetic category, while productions of /a/ and /u/ appear to be more dispersed and begin to get more clustered around the centre of the category only during the last (two) session(s). This questions the speech sounds' sequence of acquisition established by Jakobson (1968), according to which the vocalic contrast between the low vowel [a] and the high vowel [i] would be acquired by children before the contrast between the front vowel [i] and the back vowel [u]. Indeed, our data suggest that, for all three groups, productions of [a] and [u] are characterized by a great amount of variability and begin to stabilize more or less at the same time.

No correlation was found between PHI values and linguistic dominance for none of the three groups. It might be possible that the effect of linguistic dominance is mitigated by that of another variable. Globally, a low correlation was found between PHI values and both vocabulary scores for all participants (all groups combined). However, when groups are taken separately, the correlations are the highest for the French-Arabic group, indicating that the relation between the vocalic system organization and the lexical development is stronger for that group, and correlations are non-significant for the French-Mandarin bilinguals, again probably due to the limited amount of data for that group. We do not have a straightforward explanation for the stronger relation between the vocalic system organization and the lexical development in the French-Arabic group. Indeed, we were more expecting a stronger relation with the global vocabulary score (i.e., the score for both languages combined) for the French-Italian group, given the larger number of shared vocalic phonemes between French and Italian. Still, French-Arabic bilinguals might have benefited more from a more advanced lexical development in French given that French and Arabic share less phonological properties but then, it does not explain the higher correlation with the global vocabulary score for that group too.

A stronger correlation was found between PHI and CM_{inter} values than between PHI and CM_{intra} values for all three groups, meaning that the evolution of the vocalic system organization is more related to the progressive distinction of the vocalic categories than to the diminution of the variability within the vocalic categories. Still, different developmental trajectories are observed within the three groups. First, the higher CM_{inter} values and CM_{intra} values observed in French-Italian participants indicate that, indeed, they better distinguish the vocalic categories from the start while displaying smaller intra-categorical variability. Then, the correlation between PHI and CM_{intra} values is less strong for the French-Arabic group and non-significant for the French-Mandarin participants. This indicates that, for both groups, the increasing organization of the vocalic system is less (or not at all for the French-Mandarin participants) due to the reduction of the intra-categorical variability. In other words, French-Arabic and French-Mandarin bilinguals progressively acquire distinct vocalic categories but are less improving with regard to the dispersion of the productions for a given category. It is possible that the reduced Arabic vocalic system allows for more intra-categorical variability, as the vocalic space is less crowded, which, in turn, would impact early vowel production in French. The development pattern is less easily explained for the French-Mandarin group, given that the vocalic system includes less oral vowels than French but involves diph- and triphthongs.

Finally, correlation tests between PHI and VSA values show that, for the French-Italian and French-Arabic groups, the vocalic space area grows as the vocalic system is becoming more organized. Indeed, VSA and PHI values are increasing in parallel. These results suggest that, the constraints on the F1-F2 area at that age are not only in the sense of a reduction due to the lengthening of the vocal tract associated with growth, as reported in the literature (Vorperian & Kent, 2007). On the contrary, in the present study, the vocalic space area appears more reduced in younger children, as they might tend to produce centralized vowels, and then subsequently enlarges, as vocalic categories become more distinct from each other. Thus, the vocalic space area increases, presumably under the effect of cognitive development, as children are progressively acquiring more distinct vocalic categories for the cardinal vowels /a, i, u/.

However, different individual developmental patterns are also observed, even between children with similar ages within the same linguistic group. Indeed, for some children, the system gains concomitantly in organization and in space while, for others, the system gains in organization while the vocalic space area is reducing. This, again, indicates large individual variability as well as speaker-specific patterns for the evolution of the vocalic system organization. In the first case, the increasing organization results from a progressive distinction of the categories whereas, in the second case, it results from a clustering around each centre of category.

III.1.4.1.3 Evolution of vowel accuracy

The evolution of global vowel accuracy in the children's productions was assessed using the PVC measure, which was calculated based on all vowels included in all items produced per session. The effect of all independent variables on PVC was tested; that is, the subject-related variables of session/chronological age, linguistic dominance, vocabulary scores, gender, siblings and the item-related variables of elicitation technique, phonological complexity and lexical frequency.

For all three groups, mean PVC values are initially high, above 70% of correct realizations, and are very close over the four sessions, indicating a similar and limited evolution of vowel accuracy. Still, a more linear development is observed in the French-Italian group which could indicate a more stable development of vowel production. Contrary to our expectations, the French-Italian group did not present an advantage for vowel acquisition, nor the French-Arabic a delay, compared to the other bilinguals. Besides, these results are not supporting those obtained for the PHI values which suggested better organization for the French-Italian group. Still, the two measures convey different information, based on different data. Indeed, PHI values give an indication of the degree of organization of the system based on the three cardinal vowels' formants values (/a, i u/), whereas global PVC is based on phonetic transcriptions of the vowels produced and encompasses all French vowels. Given the difficulty to reliably transcribe vowels, results from PVC might be taken with more caution that those based on acoustic measures.

Globally, both developmental variables (session and chronological age) have been shown to have an effect on vowel accuracy. Indeed, PVC values increase with age for all three groups, although only significantly for the French-Italian group, impacted by both session and chronological age, and for the French-Arabic participants impacted by chronological age. None of the developmental variables has a significant effect on PVC values for the French-Mandarin bilinguals, which is consistent with the results obtained with the PHI values. This absence of an age effect is probably explained by the fact that the two French-Mandarin participants display rather similar curves of evolution of vowel accuracy and show a regression in accuracy in the last session. This specific developmental path is reflected by the analyses based on the acoustic measures.

Similar to what was observed for the PHI, no effect of linguistic dominance was found for none of the groups, as vowel accuracy was not higher for French-dominant children. This is consistent with the findings of Kehoe and Havy (2019) who tested French-speaking bilingual children aged 2;6. Even if an effect of linguistic dominance has been found in several bilingual speech production studies (e.g., Gildersleeve-Neumann et al., 2008; MacLeod et al., 2011), it might not impact all phonological structures in the same way, as pointed out by Kehoe and Havy (2019). Likewise, vowel production is also not affected by gender, again similarly to Kehoe and Havy's results (2019). If an effect of gender has been found in other bilingual studies involving children of different ages (McCormack & Knighton, 1996; Kenny & Prather, 1986; Dodd et al., 2003), it is possible that this variable would have a greater effect on consonant accuracy than on vowel accuracy. As for siblings, an effect was only found for the French-Arabic participants but in that particular case, it is most probably confounded with other specificities of that individual subject.

Vowel accuracy was found to increase in parallel with the two vocabulary scores for the French-Italian and French-Arabic groups but not for the French-Mandarin participants, suggesting a lesser impact of lexical development on vowel accuracy for that group. Apart from that group, our results suggest that a more advanced lexical development – in French and in both languages – would benefit vowel production, as was expected. French-Italian bilingual children are not more advantaged by a more advanced general lexical development than French-Arabic bilingual children. Note that Kehoe and Havy (2019) found no effect of neither French nor total vocabulary score on PVC measures of French-speaking bilingual children aged 2;6 exposed to different L1s.

Mixed results were found for the impact of elicitation type. Indeed, this variable does not affect vowel accuracy for the French-Mandarin participants. Then, for the French-Italian and French-Arabic groups, vowels are less accurately produced in unknown repeated words. However, the two groups differ with regard to the repetition of known words. Indeed, for the French-Italian group, there is no difference between named and known repeated words, whereas the French-Arabic participants produce vowels more accurately in spontaneously named words. These results indicate two things. First, children are not more accurate when given a model to reproduce, in fact quite the contrary for the French-Arabic bilinguals, confirming the results from several studies (Grandon, 2016; Goldstein & Fabiano-Smith, 2004). Second, children are less accurate when they do not know the word. This effect was to be expected, given that an additional process of word learning occurs for the production of unknown words. As children mobilize their resources on learning a new form-meaning association, their productions might lose precision. Finally, for all three groups, vowel accuracy is better for less complex and more frequent words. Vowel accuracy is thus impacted by the two item-related variables in the expected direction. In turn, these results support our Complexity Index as a reliable measure to assess the complexity of words.

III.1.4.1.4 Phonological processes

Lower rates of substituted and deleted vowels are initially observed in French-Arabic bilingual children in comparison to French-Italian and French-Mandarin participants. Then, a similar evolution of vowel substitution and deletion rates is globally observed in the three groups with an increase of the rate of correct vowels and a decrease of the rate of substituted and deleted vowels with age. There is thus no apparent difference in the rates of vowel substitution and deletion between the three groups, contrary to our expectations.

Then, there is no type of vowel substitution which would be specific to the French-Mandarin participants (i.e., only observed in those children), as substitution types are more restricted in that group. In contrast, French-Italian bilingual children apply much more diverse types of vowel substitution that the two other groups. This can certainly be explained by the larger number of participants in this group. Still, it could also result from different production strategies either reflecting group-specific and/or individual trends/preferences. Besides, this phenomenon can also be related to the initially higher CM_{intra} values observed in the French-Italian, which indicates a greater intra-categorical variability in that group. In other words, the greater intra-categorical dispersion might be reflected in the perceived vowel substitutions. Although the PHI values are based on the three cardinal vowels only, it might be postulated that the other vocalic categories are characterized by the same intra-categorical variability.

III.2 CONSONANTS

III.2.1 CONSONANT ACCURACY

III.2.1.1 Global consonant accuracy

To assess the evolution of global consonant accuracy in the children's productions, we have calculated the global percentage of consonants correct (PCC) for all items produced by each participant in each session, based on all consonants included in each item, just like for the assessment of global vowel accuracy. Global PCC was similarly automatically computed by PHON based on the comparison between the phonetic transcriptions of the actual productions *vs.* the intended targets. In total, 2857 items have been analysed.

Table 37 presents the mean PCC values for each linguistic group, both globally and for each session. We note that global mean PCC values (all sessions combined) are obviously lower and not as close to one another than were global mean PVC values. KW test reveals significant differences between the groups (Chi square = 92.38, $p < .001$, df = 2). The global mean PCC value of French-Italian participants is significantly lower than those of the two other groups ($p < .001$) which do not present significant differences for global PCC.

Linguistic group	Total number of items (all participants, all sessions)	Mean number of items per child per session	Global mean (and S.D.) PCC values (all sessions combined)	Mean (and S.D.) PCC values for each session			
				S1	S2	S3	S4
French-Italian	1733	40	65.64 (31.75)	53.38 (33.25)	59.77 (31.48)	70.23 (30.72)	75.97 (27.19)
French-Arabic	765	38	77.78 (28.67)	70.80 (32.30)	69.35 (30.95)	79.13 (27.64)	86.59 (22.64)
French-Mandarin	359	45	74.35 (30.49)	61.24 (34.46)	75.54 (28.18)	78.12 (30.9)	80.61 (27.7)

Table 38: Mean PCC values (and standard deviations) for the three linguistic groups.

The line graph below (Figure 45) gives a visual representation of mean PCC values' evolution for global consonant accuracy for each linguistic group across the four sessions. Mean PCC values continuously increase over the four sessions for French-Italian bilinguals and, as indicated in Table 38, mean standard deviation values similarly continuously decrease from S1 to S4. This developmental pattern is similar to that described for their mean PVC values (see Figure 37), suggesting a parallel development of vowels and consonants in that group. The evolution is less linear in the two other groups. Indeed, mean PCC values are initially higher, above 70%, in French-Arabic bilinguals and then decline at S2 to subsequently increase during the following sessions. Again, evolution curves of global PCC are similar to those of PVC values previously observed for that group. The curve of the two French-Mandarin participants goes up sharply from S1 to S2 and then, in a less pronounced way from S2 to S4. In contrast to the two other groups, PVC and PCC evolution curves are not alike for the two French-Mandarin participants. Indeed, their mean PVC value was barely increasing from S1 to S2 but more blatantly at S3 and was finally declining at S4. Thus, global PCC and PVC evolve almost in opposite ways and are inversely proportional at S4 for these two children, suggesting a non-parallel development of vowels and consonants.

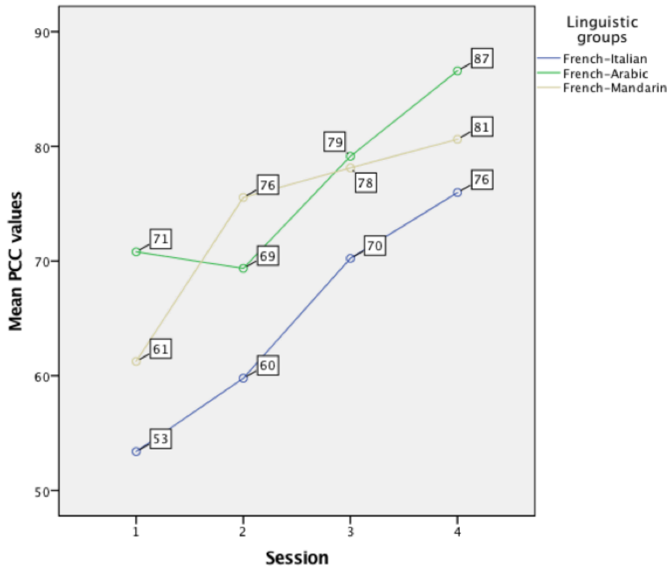

Figure 45: Evolution of global PCC values for each linguistic group over the four sessions.

Figure 46 presents line graphs with global PCC values for all participants, with separate graphs for the three linguistic groups. We observe that PCC values increase rather linearly from S1 to S4 for almost all children, with one notable exception: the French-Arabic participant B14 for whom the PCC curve is sharply falling from S1 to S2. This strong regression results in the falling curve at S2 for French-Arabic bilinguals observed in Figure 45. Also, the high PCC value of this participant at S1 is due to the fact that this particular child produced only a few words during the first session and that the few attempted consonants were rather accurately produced. Like for global PVC, the lowest PCC values are mostly seen in the youngest participants, such as the French-Italian participants B01, B02, B10 and the French-Arabic participants B05, B06 and B14 (at S2). However, low PCC values are also found in two older French-Italian bilingual children (B07 and B08) and in one of the French-Mandarin bilinguals (B16). It should be noted that French-Italian participant B07 has the lowest *No-risk index* value, indicating the risk for a potential delay in language development. Still, his PCC values are increasing with age. The highest global PCC values can be observed in the oldest participants. Global PCC values tend to fluctuate less and to increase more linearly than global PVC values.

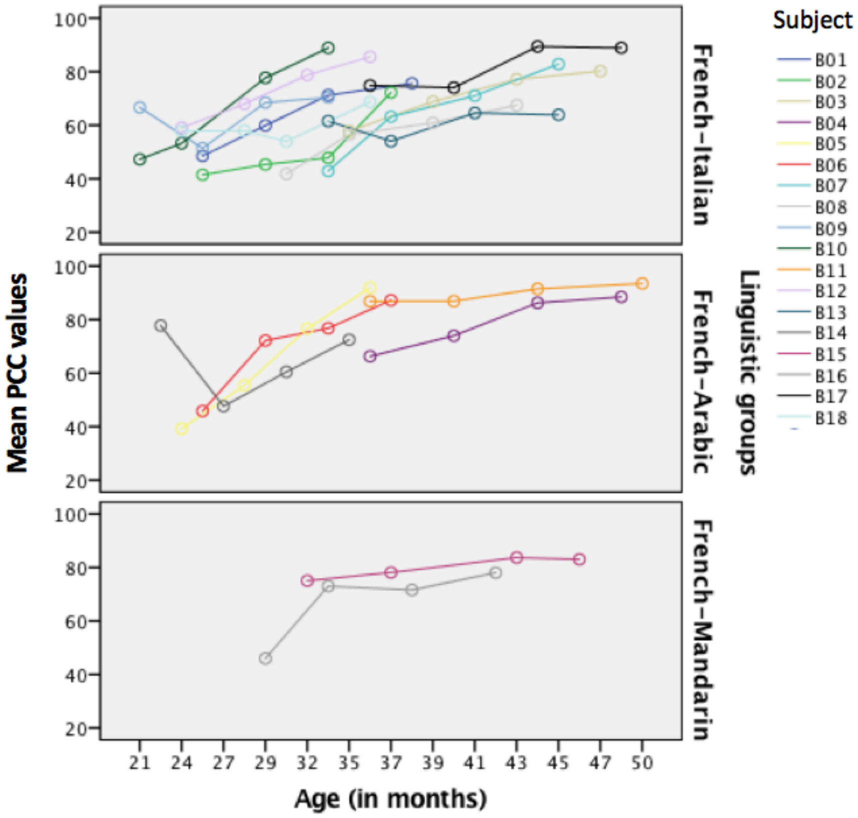

Figure 46: Evolution of global PCC values over the four sessions for all participants from the three linguistic groups.

Like with global PVC values, we conducted a series of non-parametrical KW test within each linguistic group to investigate the impact of subject-related (session, chronological age, linguistic dominance, vocabulary scores, gender and siblings) and item-related (elicitation, phonological complexity and lexical frequency) independent variables. As for PVC, subject-related independent variables of linguistic dominance, gender and siblings have not been tested on the French-Mandarin group as only two individuals are compared and therefore, these variables cannot be distinguishable form the subject variable. Results obtained for each variable are presented separately. We precise that the effect of siblings was tested only on the French-Italian group, given that the only French-Arabic participant who has no siblings appears to be the oldest child who moreover outperforms the other children for nearly all measures (as was previously highlighted with global PVC).

III.2.1.1.1 Independent variables related to the subject

III.2.1.1.1.1 Session and chronological age

The two developmental variables of session and chronological age are presented together given that results from the KW tests show a statistically significant effect of both variables on PCC values for all three linguistic groups. Pairwise comparisons have been conducted for session (4 levels) and stepwise comparisons for chronological age (6 levels). Results are reported in Table 39.

Linguistic group	KW results		Pairwise and stepwise comparisons
French-Italian	Session	Chi square = 125.36 p < .001, df = 3	All four sessions are statistically different (p <.001) with a difference less marked between S1 and S2 (p=.043) and between S3 and S4 (p=.043)
	Chronological age	Chi square = 123 p < .001, df = 5	One homogeneous subset: Age ranges 1 - 2 - 3
French-Arabic	Session	Chi square = 45.36 p < .001, df = 3	There are statistically differences between all sessions (p <.001), except between S1-S2 and S1- S3 The difference is less marked between S2 and S3 (p=.004) and between S3 and S4 (p=.028)
	Chronological age	Chi square = 111.04 p < .001, df = 5	Two homogeneous subsets: Age ranges 1 – 3 and age ranges 5 - 6
French-Mandarin	Session	Chi square = 36.36 p < .001, df = 3	S1 is statistically different from all other sessions (p <.001)
	Chronological age	Chi square = 34.9 p = .001, df = 3	One homogeneous subset: Age ranges 3 – 4 - 5

Table 39: Results of KW tests with session and chronological age as grouping variables for the three linguistic groups.

For all three linguistic groups, there are thus statistically significant differences in PCC values between the different sessions and chronological age ranges. Figure 47 presents mean PCC values (+/- 1 standard deviation) for each session and each age range in the three groups. As can be seen, PCC values globally increase with session and chronological age for all three groups, except for a slight decrease at S2 and for the second age range for French-Arabic participants. We also note a strong increase in PCC values from the second to the third age range in French-Mandarin participants.

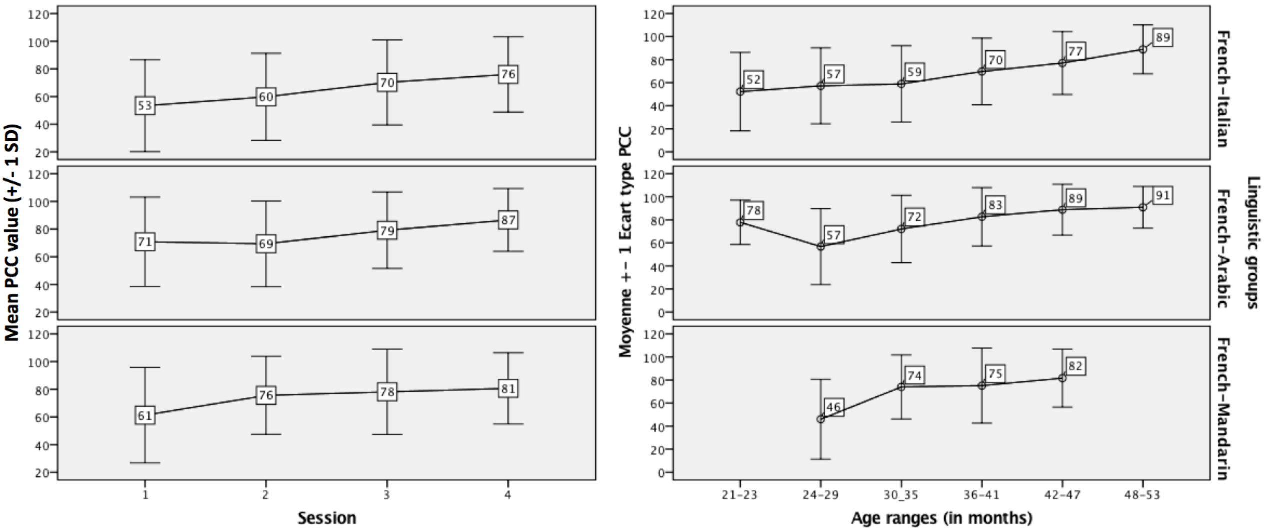

Figure 47: Mean PCC values (+/- 1 standard deviation) as a function of session and chronological age for the three groups.

III.2.1.1.1.2 Linguistic dominance

A significant effect of linguistic dominance was found for the French-Arabic group (Chi square = 11.04, p = .004, df = 2). Moreover, pairwise comparisons indicate significant differences only between French-dominant children and balanced bilinguals (p = .004), with lower PCC values for the balanced bilinguals. PCC values from French-dominant and Arabic-dominant children are thus not statistically different, as shown by Figure 48.

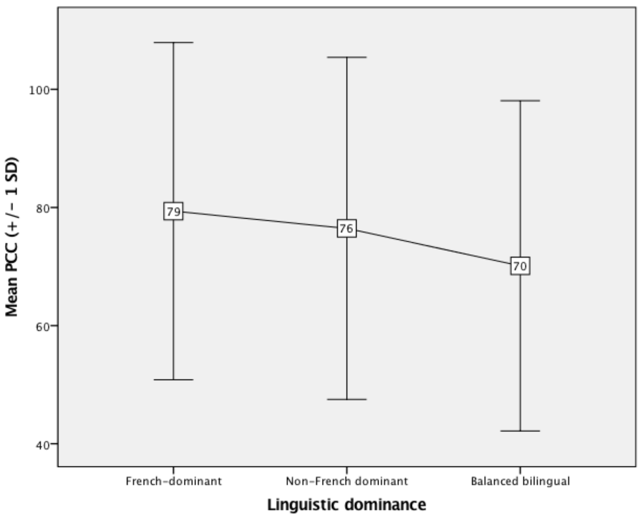

Figure 48: Mean PCC values (+/- 1 standard deviation) as a function of linguistic dominance for the French-Arabic group.

III.2.1.1.1.3 Gender

Results from the KW tests show a significant effect of gender for the French-Italian (Chi square = 7, p = .008, df = 1) and French-Arabic groups (Chi square = 11.45, p = .001, df = 1). Girls appear to have higher PCC values in the French-Italian group, whereas boys perform better in the French-Arabic group, as shown by Figure 49.

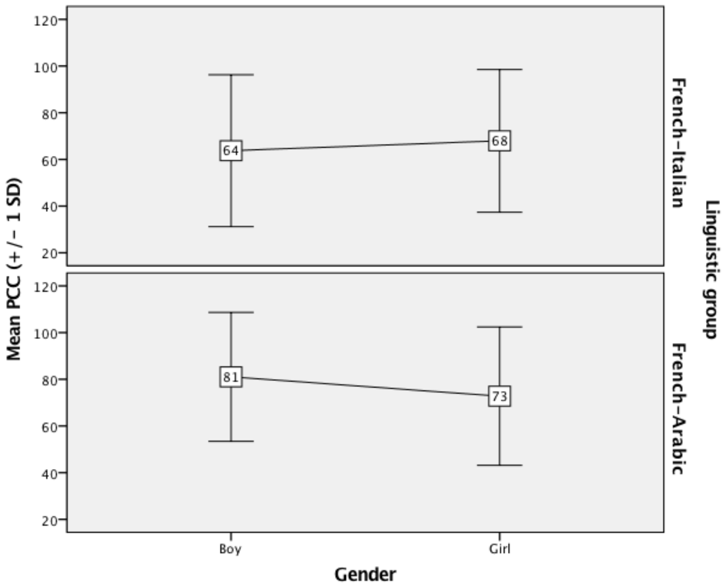

Figure 49: Mean PCC values (+/- 1 standard deviation) as a function of gender for the three groups.

III.2.1.1.1.4 Siblings (tested only for the French-Italian group)

A significant effect of siblings was found for the French-Italian group (Chi square = 4.54, p = .03, df = 1), meaning that there are significant differences in PCC values between the children with and without siblings. Moreover, the PCC values are significantly higher in children with siblings.

III.2.1.1.1.5 Vocabulary scores

The KW tests showed a significant effect of the two vocabulary scores (i.e., French and total) on PCC values for all three groups. Results are reported in Table 40.

Linguistic group	KW results		Stepwise-stepdown comparisons
French-Italian	French vocabulary score	Chi square = 190.8, $p < .001$ df = 4	No homogeneous subset, all vocabulary ranges are different
	Total vocabulary score	Chi square = 178.4, $p < .001$ df = 4	One homogeneous subset: Score ranges 2 - 3
French-Arabic	French vocabulary score	Chi square = 115.5, $p < .001$ df = 4	One homogeneous subset: Score ranges 4 - 5
	Total vocabulary score	Chi square = 130.5, $p < .001$ df = 4	One homogeneous subset: Score ranges 3 - 4 - 5
French-Mandarin	French vocabulary score	Chi square = 30.8, $p < .001$ df = 3	One homogeneous subset: Score ranges 2 – 3 - 4
	Total vocabulary score	Chi square = 15.8, $p = .001$ df = 3	Two homogeneous subsets: Score ranges 1- 2 - 4 Score ranges 1 - 3 - 4

Table 40: Results of KW tests with vocabulary scores as a grouping variable for the three groups.

These results indicate that, for all three groups, there are statistically significant differences in PCC values between children with different French and total vocabulary scores. Stepwise-stepdown comparisons yield slightly different homogenous subsets for the different vocabulary scores for each group but globally, PCC values increase alongside the lexical development.

III.2.1.1.2 Independent variables related to the item

III.2.1.1.2.1 Elicitation technique

Results from the KW tests showed a significant effect of elicitation on PCC values for all three groups (see Table 41, naming = elicitation 1, repetition of known words = elicitation 2, repetition of unknown words = elicitation 3).

Linguistic group	KW results	Pairwise comparisons
French-Italian	Chi square = 51.46 p = .008 df = 2	There are significant differences between elicitation 3 and elicitation types 1 and 2 ($p < .001$)
French-Arabic	Chi square = 105.1 p < .001 df = 2	All elicitation types are significantly different (p value < .001)
French-Mandarin	Chi square = 12.3 p = .002 df = 2	There are significant differences between elicitation 1 and 3 ($p < .001$)

Table 41: Results of KW tests with elicitation technique as a grouping variable for the three groups.

Globally, PCC values are lower for unknown repeated words but pairwise comparisons yield slightly different tendencies for all three groups. Indeed, there is a significant difference between PCC values for repetition of unknown words and PCC values for both naming and repetition of known words for the French-Italian group, as previously observed with global PVC values. PCC values of all three elicitation types are significantly different for the French-Arabic group and PCC values for repetition of unknown words are only significantly different from those for naming for the French-Mandarin participants. Figure 50 offers a clear visualization of these tendencies.

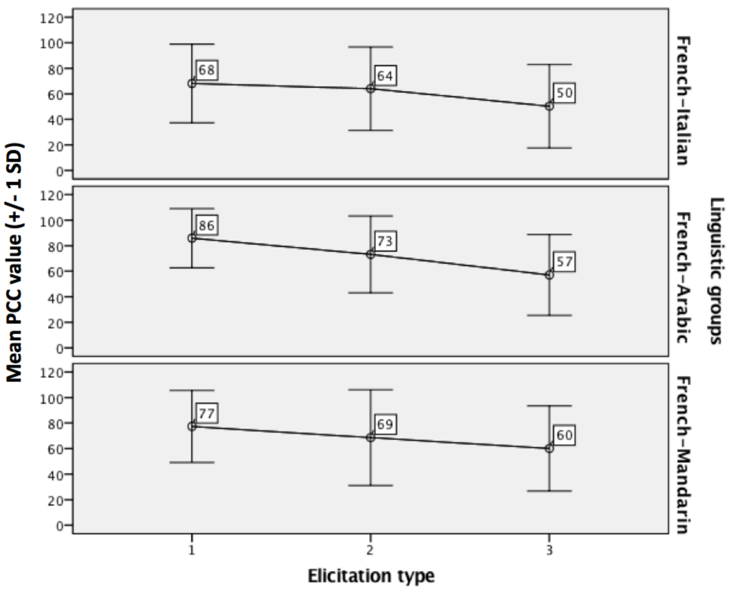

Figure 50: Mean PCC values (+/- 1 standard deviation) as a function of elicitation (naming = elicitation 1, repetition of known words = elicitation 2, repetition of unknown words = elicitation 3) for the three groups.

III.2.1.1.2.2 Phonological complexity and lexical frequency

The item-related variables of phonological complexity and lexical frequency are again presented together given that results from the KW tests show a statistically significant effect of both variables and similar tendencies for all three linguistic groups. Results are reported in Table 42.

Linguistic group	KW results		Pairwise comparisons
French-Italian	Phonological complexity	Chi square = 82.6 $p < .001$ df = 2	There are statistical differences between PCC values of all three ranges of phonological complexity ($p <.001$)
	Lexical frequency	Chi square = 9.1 $p = .003$ df = 1	/
French-Arabic	Phonological complexity	Chi square = 26.7 $p < .001$ df = 2	There are statistical differences between PCC values of all three ranges of phonological complexity ($p <.001$) except between ranges 2-3
	Lexical frequency	Chi square = 9.3 $p = .002$ df = 1	/
French-Mandarin	Phonological complexity	Chi square = 8.5 $p < .001$ df = 2	There are statistical differences between PCC values of ranges 1 and 3 ($p = .01$)
	Lexical frequency	Chi square = 6.7 $p = .01$ df = 1	/

Table 42: Results of KW tests with phonological complexity and lexical frequency as grouping variables for the three linguistic groups.

These results indicate that, for all three groups, there are statistically significant differences in PCC values between items of different phonological complexity and lexical frequency. As for PVC, the effect of lexical frequency is less significant for French-Mandarin bilinguals than for French-Italian and French-Arabic. Pairwise comparisons yield similar tendencies for the three groups except for the fact that there are only significant differences between PCC values of not complex and highly complex items for the French-Mandarin bilinguals and no statistical differences between PCC values of moderately and highly complex items for the French-Arabic bilinguals. As can be seen in Figure 51, PCC values decrease as the level of phonological complexity increases, whereas they increase as the level of lexical frequency increases in all three linguistic groups.

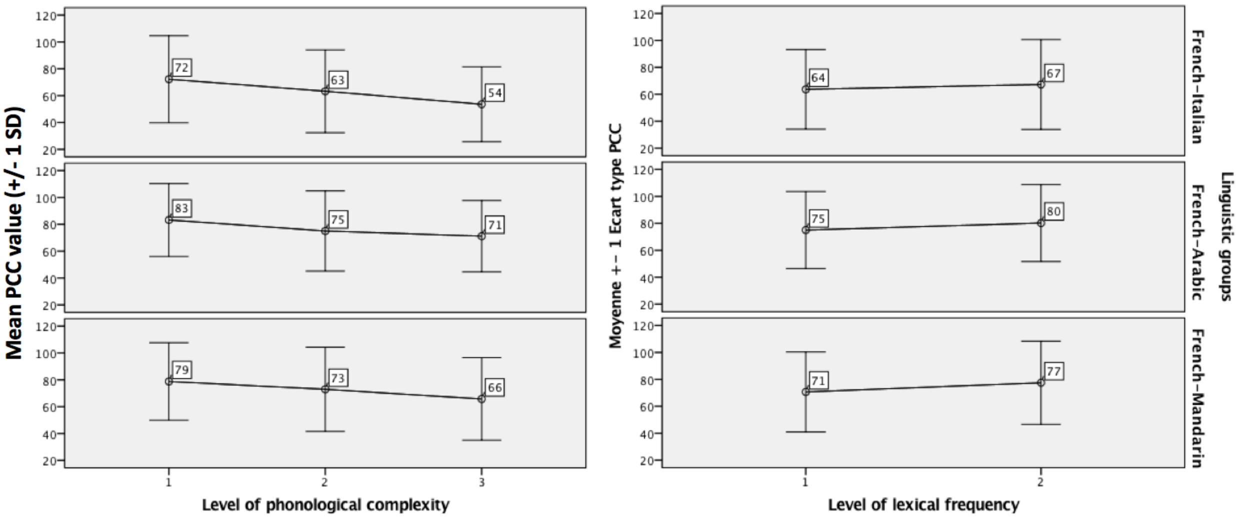

Figure 51: Evolution of the mean PCC values (+/- 1 standard deviation) as a function of phonological complexity (1 = not complex words, 2 = moderately complex, 3 = complex) and lexical frequency (1 = not frequent, 2 = frequent) for the three groups.

Before moving to the next section, Table 43 summarizes the results obtained for each variable separately in each linguistic group.

Independent Variable	French-Italian	French-Arabic	French-Mandarin
Session	Chi square = 125.36 p < .001, df = 3	Chi square = 45.36 p < .001, df = 3	Chi square = 36.36 p < .001, df = 3
Chronological Age	Chi square = 123 p < .001, df = 5	Chi square = 111.04 p < .001, df = 5	Chi square = 34.9 p = .001, df = 3
Linguistic dominance	NS	Chi square = 11.04, p = .004, df = 2	
Gender	Chi square = 7, p = .008, df = 1	Chi square = 11.45, p = .001, df = 1	
Presence of Siblings	Chi square = 4.54, p = .03, df = 1		
French Vocabulary score	Chi square = 190.8, p < .001, df = 4	Chi square = 115.5, p < .001, df = 4	Chi square = 30.8, p < .001, df = 3
Total Vocabulary score	Chi square = 178.4, p < .001, df = 4	Chi square = 130.5, p < .001, df = 4	Chi square = 15.8, p = .001, df = 3
Elicitation technique	Chi square = 51.46 p = .008, df = 2	Chi square = 105.1 p < .001, df = 2	Chi square = 12.3 p = .002, df = 2
Phonological complexity	Chi square = 82.6 p < .001, df = 2	Chi square = 26.7 p < .001, df = 2	Chi square = 8.5 p < .001, df = 2
Lexical frequency	Chi square = 9.1 p = .003, df = 1	Chi square = 9.3 p = .002, df = 1	Chi square = 6.7 p = .01, df = 1

Table 43: KW tests results on PCC values.

III.2.1.1.3 Comparison with monolingual children

We now compare the mean PCC values (and standard deviations) that were obtained in our three bilingual groups with similar measures reported in the literature concerning monolingual children. As previously mentioned, MacLeod and collaborators (2011) examined French consonantal acquisition in a large cohort of Canadian children aged 20-53 months and made available the mean PCC and standard deviation values for six defined age ranges (from 23 to 53 months). Mean PCC values and standard deviations of monolingual and bilingual children from the two studies are presented in the two line graphs below (Figures 52 and 53) for the different age ranges selected by MacLeod et al. (2011). The following Table 44 summarizes all measures for all children's groups.

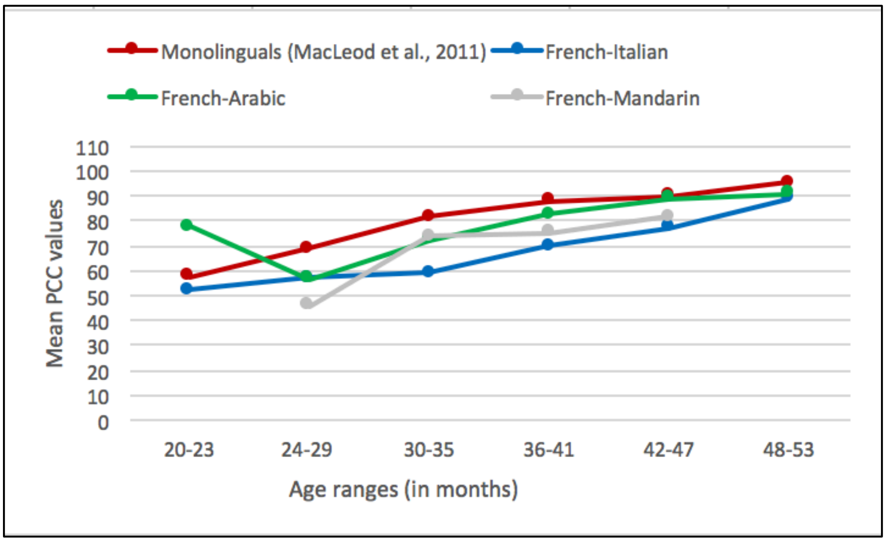

Figure 52: Mean PCC values of monolingual and bilingual children for the different age ranges.

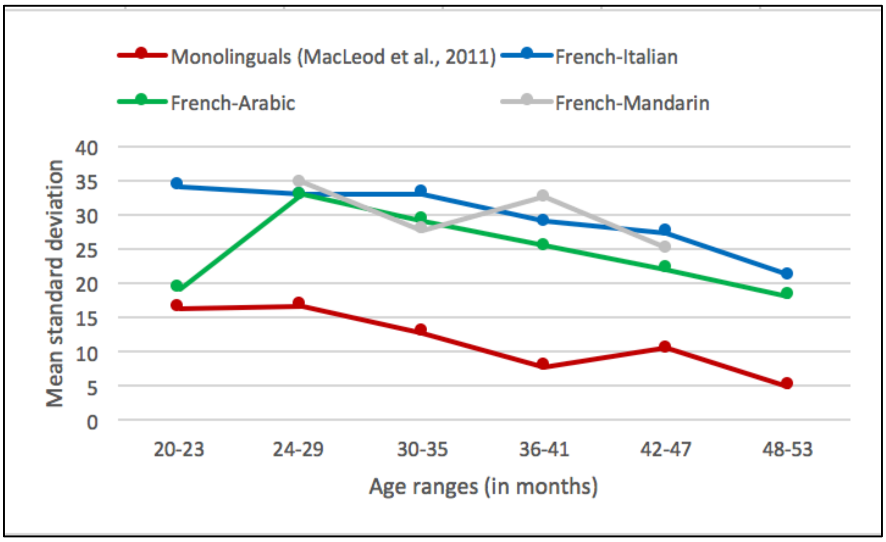

Figure 53: Mean standard deviations of monolingual and bilingual children for the different age ranges.

Age ranges	Mean PCC Mono-linguals	Mean SD Mono-linguals	Mean PCC French-Italian	Mean SD French-Italian	Mean PCC French-Arabic	Mean SD French-Arabic	Mean PCC French-Mandarin	Mean SD French-Mandarin
20-23	57.4	16.3	52.26	34.04	77.78	19.24		
24-29	68.8	16.6	57.24	32.94	56.82	32.91	46.01	34.65
30-35	81.5	12.7	58.94	33.1	72.06	29.16	73.96	27.77
36-41	87.8	7.7	69.73	28.94	82.66	25.32	75.11	32.61
42-47	89.9	10.4	77.08	27.32	88.75	22.09	81.62	25.13
48-53	95.3	4.9	88.91	21.21	90.89	18.12		

Table 44: Mean PCC and standard deviation values for monolinguals and all three bilingual groups.

As can be observed from both graphs above, monolinguals outperform all three bilingual groups on all age ranges, having higher PCC values and much lower standard deviation values, which indicates a greater variability in bilingual children. Still, the French-Arabic group displays very close PCC values to those of monolinguals for the three last age ranges (i.e., from 36 to 53 months). They even initially outperform monolinguals but then their PCC values decline – and their standard deviation increases in parallel – to get closer to the values of the French-Italian group. These latter globally display the lowest PCC values and highest standard deviations but catch up with French-Arabic and monolingual children in the last age range (i.e., between 48 and 53 months). More fluctuation is seen in the PCC and standard deviation values of the French-Mandarin group which shows a strong increase between 30 and 35 months to subsequently fall between the two bilingual groups (above French-Italian but below French-Arabic participants).

III.2.1.2 Accuracy of targeted syllabic constituents and fricatives

III.2.1.2.1 Consonants in targeted syllabic constituents

Based on the PCC measure, we assessed the evolution of consonant accuracy in different targeted syllabic constituents, namely: (1) word-final singleton codas, (2), word-initial branching onsets, (3) word-final complex codas. To this end, a nuanced PCC was calculated for the set of items previously listed (see Table 24) for all participants' sessions. In total, 1127 items have been analysed for word-final codas, 695 items for word-initial branching onsets and 378 items for word-final complex codas.

Each syllabic constituent will be discussed separately, using the same approach and presentation structure as previously with global PVC and PCC. The evolution of mean PCC values for each linguistic group over the four sessions is first described, followed by the description of all individual PCC curves within each linguistic group. Then, the time evolution of accuracy for each syllabic constituent is described as a function of consonant manner class for word-final codas and across cluster types for word-initial branching onsets and word-final complex codas. To avoid redundancy, results from the series of KW test conducted within each linguistic group to investigate the impact of subject-related and item-related independent variables will be presented globally for both targeted syllabic constituents and fricatives in a separate upcoming section.

III.2.1.2.1.1 Word-final singleton codas

Table 44 presents the mean PCC values for word-final codas for each linguistic group, both globally and separately for each session. KW test reveals significant differences between the groups (Chi square = 20.96, $p < .001$, df = 2). The PCC values of French-Italian participants are significantly lower than those of the French-Arabic ($p < 0.001$) and French-Mandarin bilinguals ($p = .01$) which are not significantly different from one another.

Linguistic group	Total number of items (all participants, all sessions)	Mean number of items per child per session	Global mean (and S.D.) PCC values (all sessions combined)	Mean (and S.D.) PCC values for each session			
				S1	S2	S3	S4
French-Italian	681	15	61.31 (48.73)	55.17 (49.90)	58.47 (49.42)	62.23 (48.6)	67.95 (46.79)
French-Arabic	303	15	74.91 (43.42)	65.21 (48.15)	73.33 (44.51)	74.44 (43.86)	81.52 (39.02)
French-Mandarin	143	18	73.42 (43.32)	54.55 (50.56)	78.95 (41.31)	81.82 (39.16)	76.92 (42.68)

Table 45: Mean PCC values (and standard deviations) for the three linguistic groups.

Figure 54 allows visualizing the evolution of mean PCC values for word-final codas for each linguistic group over the four sessions. French-Italian participants display lower PCC values than those of the two other groups and their values are slightly and linearly increasing over the four sessions, as their mean standard deviations similarly decrease (see Table 45). French-Arabic participants present the highest mean PCC values for the first and last sessions with mean standard deviation values decreasing at each session (see Table 45). Finally, the evolution is less linear for the two French-Mandarin participants who begin with the lowest PCC values and, in contrast, have the highest mean values at S2 and S3. Their values then decrease at S4, falling between those of the two other groups.

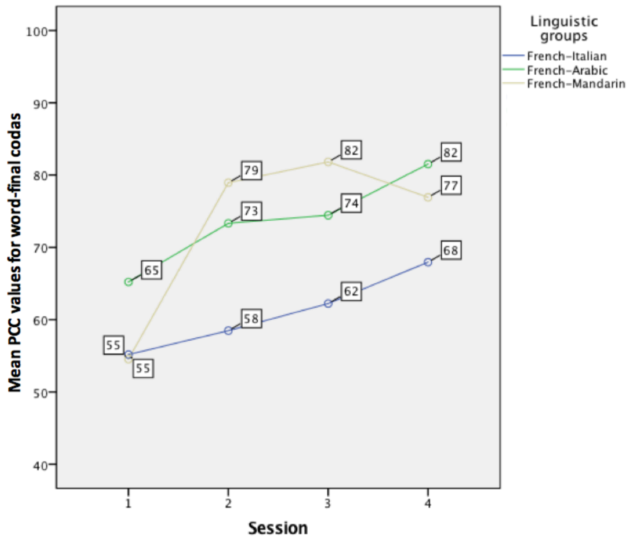

Figure 54: Evolution of PCC values for word-final codas for each group over the four sessions.

Figure 55 presents the individual PCC curves for word-final codas, with separate graphs for the three linguistic groups. The French-Italian group's mean PCC values are globally lower than those of the two other groups, whether in younger and older participants. Moreover, values are rather fluctuating between sessions for most participants. However, there is one notable exception: the participant B10 whose PCC values strongly increase from S1 to S4. Still, the maximal value obtained at S4 is again explained by the fact that this child produced fewer items on that particular session and that all attempted word-final codas were correctly produced. Higher mean PCC values are exhibited by French-Arabic participants, whether in younger and older children. A sharp increase is observed at S2 for the youngest child (B14) who initially does not produce any correct word-final codas. As for B10, this particular pattern can be explained by the fact that this child produced only a few items at S1 but that, unlike B10, all attempted word-final codas were incorrectly produced. The French-Mandarin participant B15 presents very high PCC values with a slight regression at S4. In contrast, the other child (B16) begins with low PCC values (under 40%) at S1 that strongly increase at S2 and rather stagnate between S3 and S4.

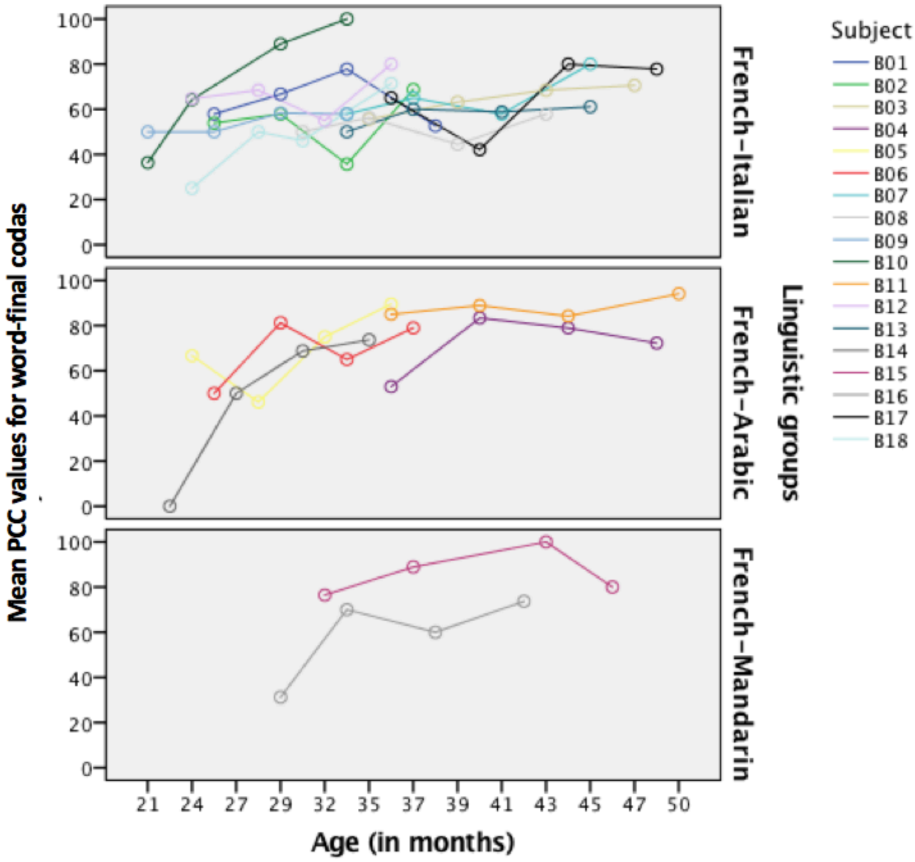

Figure 55: Evolution of PCC values for word-final codas over the four sessions for all participants from the three linguistic groups.

The evolution of accuracy for word-final codas was also investigated as a function of the consonants' manner of articulation. Figure 56 presents the evolution of PCC values over the four sessions for: (1) stops, (2) fricatives, (3) nasals, (4), liquids, (5) rhotics and (6), glides. For all three groups, the lowest PCC values are observed for stops and fricatives, especially for the French-Italian group and the highest PCC values are globally observed for glides and the liquid /l/. PCC values of the rhotic are particularly high and remain stable over the four sessions for the French-Arabic group. Glides and the liquid /l/ have particularly high values for the French-Mandarin group and nasals are more accurately produced by French-Italian bilingual children. PCC values are decreasing for the French-Mandarin participants at S4 which probably result from the regression observed for the participant B15 in Figure 55.

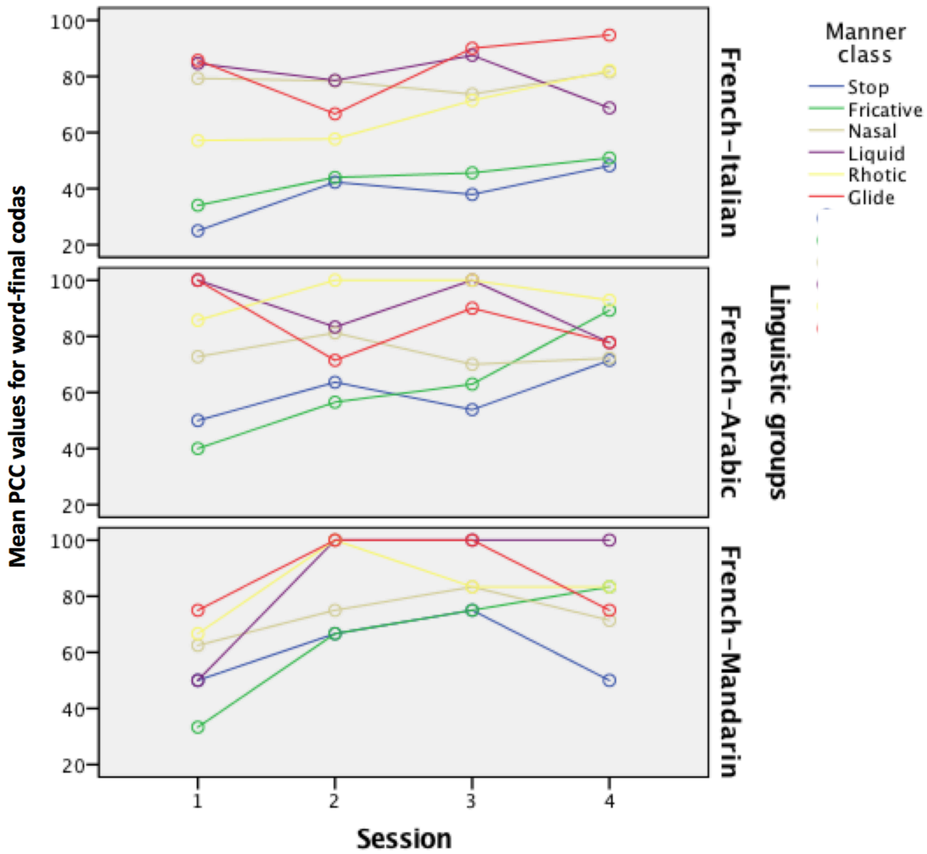

Figure 56: Mean PCC values for word-final codas by manner class for each group over the four sessions.

III.2.1.2.1.2 Word-initial branching onsets

Table 45 presents the mean PCC values for word-initial branching onsets for each linguistic group, both globally and for each session. Global mean PCC values (all sessions combined) from the three groups are different. French-Italian participants have the lowest global mean PCC value and the highest mean standard deviation and French-Arabic bilinguals display the highest global mean value and the lowest mean standard deviation. KW test reveals significant differences between the groups (Chi square = 10.87, p = .004, df = 2). Pairwise comparisons show that only the French-Italian and the French-Arabic groups have significantly different PCC values (p = .003).

Linguistic group	Total number of items (all participants, all sessions)	Mean number of items per child per session	Global mean (and S.D.) PCC values (all sessions combined)	Mean (and S.D.) PCC values for each session			
				S1	S2	S3	S4
French-Italian	423	10	67.25 (34.87)	52.77 (36.31)	60.90 (32.94)	73.45 (35.4)	78.5 (29.72)
French-Arabic	185	10	77.02 (31.69)	76.92 (32.34)	62.5 (37.89)	81.48 (27.97)	85.1 (24.94)
French-Mandarin	87	11	70.3 (36.86)	55.26 (43.76)	73.48 (33.19)	70.45 (36.7)	79.17 (32.7)

Table 46: Mean PCC values (and standard deviations) for the three linguistic groups.

The evolution of mean PCC values for word-initial branching onsets is represented for each linguistic group over the four sessions in Figure 57. Again, French-Italian participants display lower mean PCC values than those of the two other groups and their values linearly increase over the four sessions, with a steeper increase from S2 to S3. The evolution of accuracy over time is the least linear in the French-Arabic group. Starting with the highest mean PCC values and the lowest mean standard deviation values at S1, French-Arabic participants undergo a regression at S2, but still have superior values to those of French-Italian bilinguals. They have again the highest mean PCC on S3 and S4. The French-Mandarin group begins with low mean PCC values (and the highest mean standard deviation values) at S1 and, in contrast, displays the highest mean value at S2. Their mean PCC and standard deviation values come close to those of French-Italian at S3 and S4.

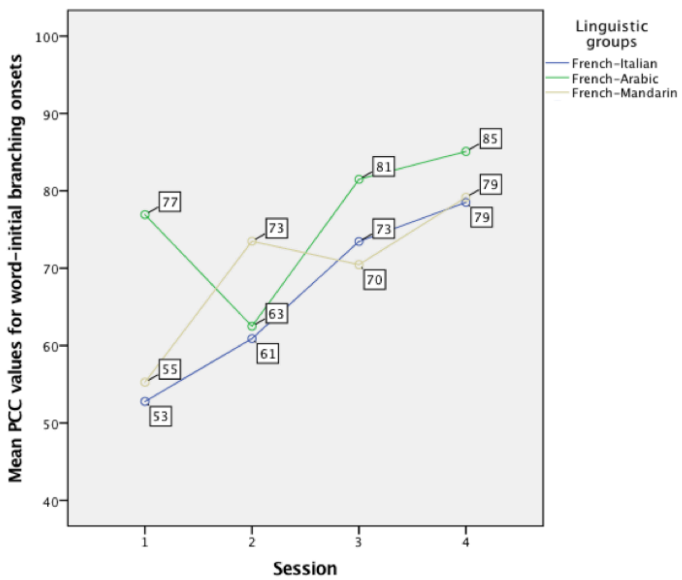

Figure 57: Evolution of PCC values for word-initial branching onsets for each linguistic group over the four sessions.

Figure 58 presents the individual PCC curves for word-initial branching onsets, with separate graphs for the three linguistic groups. PCC values are fluctuating and variable from one subject to the other in the French-Italian group. Indeed, very low values can be observed in the first two sessions of the participant B02, whereas the participants B09, B10 and B13 display maximal values at S1 (for B09 and B13) and at S4 (for B10). As was already the case for word-final codas for the participant B10, these three children produced fewer words involving word-initial branching onsets and all branching onsets tempted were accurately produced. Less fluctuating curves can be observed in the French-Arabic participants. The younger participants B05 and B14 initially present very low values which strongly increase at S2 for B14 and at S3 for B05 (which explains the regression observed at S2 for the French-Arabic group in Figure 57). These initial low values indicate opposite production patterns than those of the French-Italian participants B09, B10 and B13; that is, B05 and B14 initially also produced fewer words involving word-initial branching onsets but when tempted, branching onsets were rather inaccurately produced. From about 32 months of age, PCC values from all French-Arabic participants are above 60%. Finally, the French-Mandarin participant B15 presents relatively high PCC values from the start and show slight improvement over the next sessions. In contrast, the other child (B16) begins with low PCC values at S1 that strongly rise at S2 and evolve not much at S3 and S4.

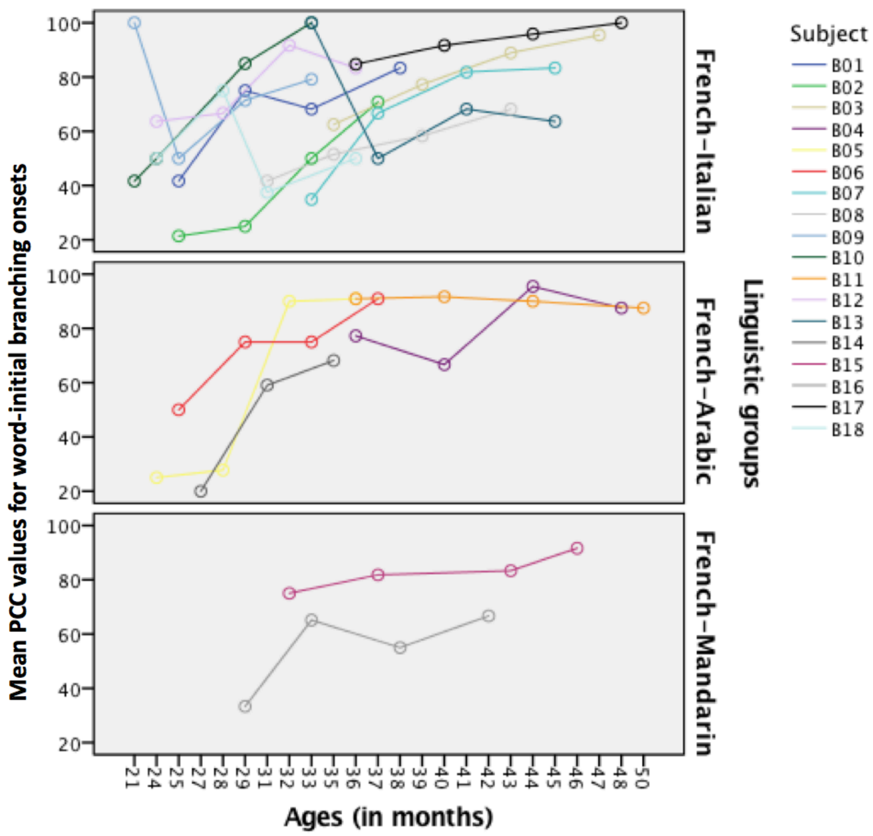

Figure 58: Evolution of PCC values for word-initial branching onsets over the four sessions for all participants from the three linguistic groups.

Figure 59 presents the evolution of PCC values for word-initial branching onsets by cluster type over the four sessions for each linguistic group. Three types of consonant sequences in word-initial position are included in our corpus: (1) obstruent-liquid (as in [flœʁ], i.e., fleur), (2) obstruent-rhotic (as in [bʁa], i.e., bras) and (3), obstruent-glide (as in [pwasɔ̃], i.e., poisson). Globally, for all three groups, obstruent-liquid sequences are more accurately realized, followed by obstruent-glide sequences and in last position, obstruent-rhotic sequences. A less linear development is observed for obstruent-rhotic sequences in the French-Arabic group and the French-Mandarin participants display very low values for this type of cluster at S1.

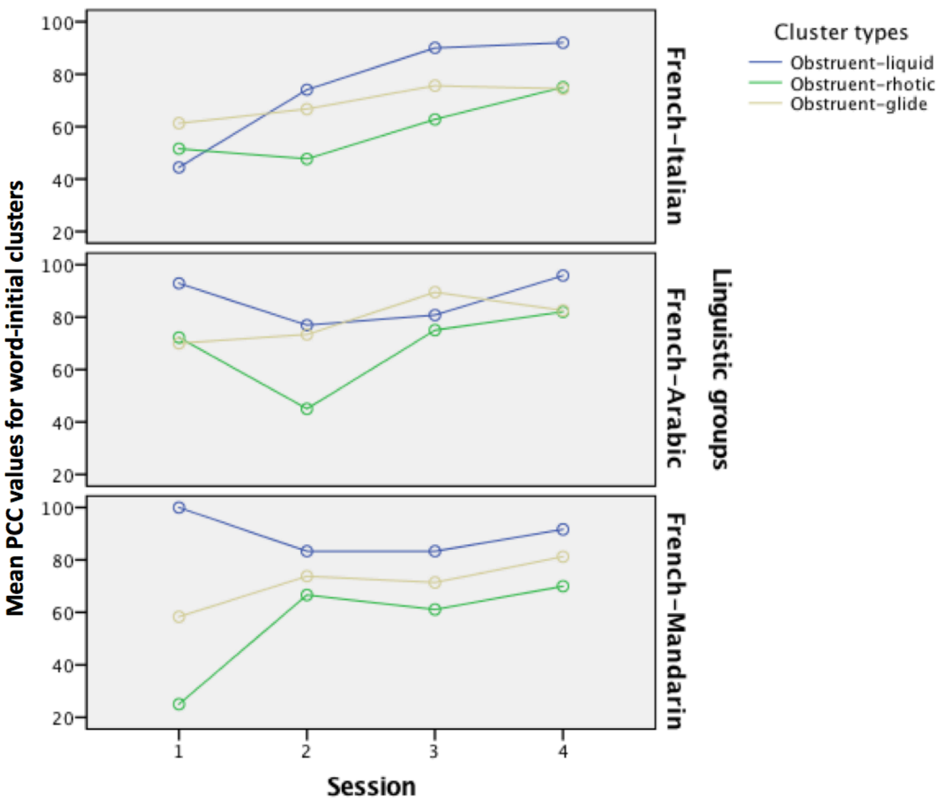

Figure 59: Mean PCC values for word-initial branching onsets by cluster type for each group over the four sessions.

III.2.1.2.1.3 Word-final complex codas

Table 46 presents the mean PCC values for word-final complex codas for each linguistic group, both globally and for each session. The global mean PCC values (all sessions combined) from the three groups are different. KW test reveals significant differences between the groups (Chi square = 39.95, $p < .001$, $df = 2$). Pairwise comparisons show that PCC values of the French-Arabic group significantly differ from those of French-Italian ($p < .001$) and French-Mandarin participants ($p = .001$), the latter being not significantly different from each other.

Linguistic group	Total number of items (all participants, all sessions)	Mean number of items per child per session	Global mean (and S.D.) PCC values (all sessions combined)	Mean (and S.D.) PCC values for each session			
				S1	S2	S3	S4
French-Italian	227	5	42.51 (34.13)	33.68 (30.98)	30.50 (28.44)	48.15 (36.79)	53.38 (33.88)
French-Arabic	101	5	70.13 (33.36)	57.14 (36.81)	58.33 (32.6)	73.56 (34.07)	80.88 (28.47)
French-Mandarin	50	6	46.66 (38.68)	18.33 (33.74)	47.62 (36.89)	40.28 (35.86)	71.43 (32.96)

Table 47: Mean PCC values (and standard deviations) for the three linguistic groups.

Figure 60 presents the evolution of mean PCC values for word-final codas for each linguistic group over the four sessions. The French-Arabic group obviously displays higher PCC values increasing more linearly than those of the two other groups. The French-Mandarin participants display the less linear development of word-final complex codas' accuracy. They initially display very low mean PCC values that increase sharply at S2. Their mean PCC values decline at S3 to again strongly rise at S4. Mean PCC values of the French-Italian group increase much more slowly with a slight decrease at S2 to reach 50% of correct realizations at S4.

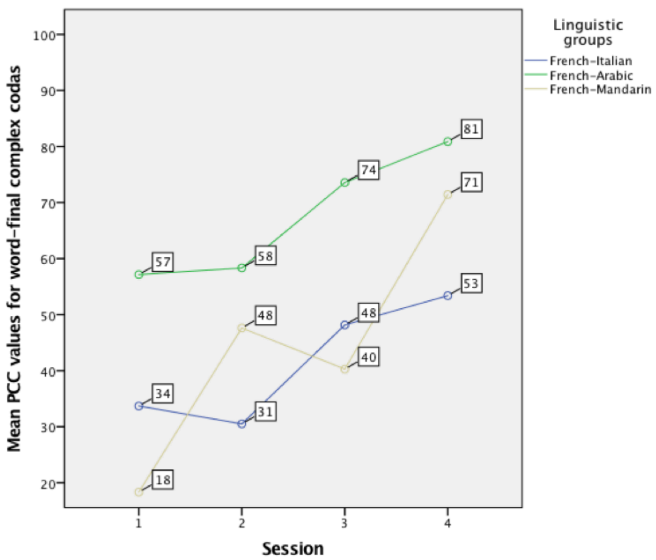

Figure 60: Evolution of PCC values for word-final complex codas for each linguistic group over the four sessions.

Figure 61 presents the individual PCC curves for word-final complex codas, with separate graphs for the three linguistic groups. It should be noted that not all sessions are represented on the graph for the two youngest subjects, namely the French-Italian participant B10 and the French-Arabic participant B14. This results from the fact that those children did not produce items comprising word-final complex codas on those particular sessions. We observe that, globally, PCC values are very low for the younger children. Again, very fluctuating and variable PCC values can be observed in French-Italian participants. Most younger children have low PCC values except for the participant B12. PCC values get higher from 36 months of age, as shown by the curves of the participants B03, B07 and B17. Similar individual patterns as for word-initial branching onsets are seen in the French-Arabic group: very low PCC values for the younger participants and much higher values from 28-29 months, indicating fast improvement in that group. Besides, the two older French-Arabic participants (B04 and B11) present the highest PCC values for all groups combined. As usual, the French-Mandarin participant B15 shows a rather slow and linear development but his PCC values are lower than for the other syllabic constituents investigated. PCC values of the participant B16 fluctuate a lot but we observe a steep increase from S1 (0%) to S4 (almost 80%).

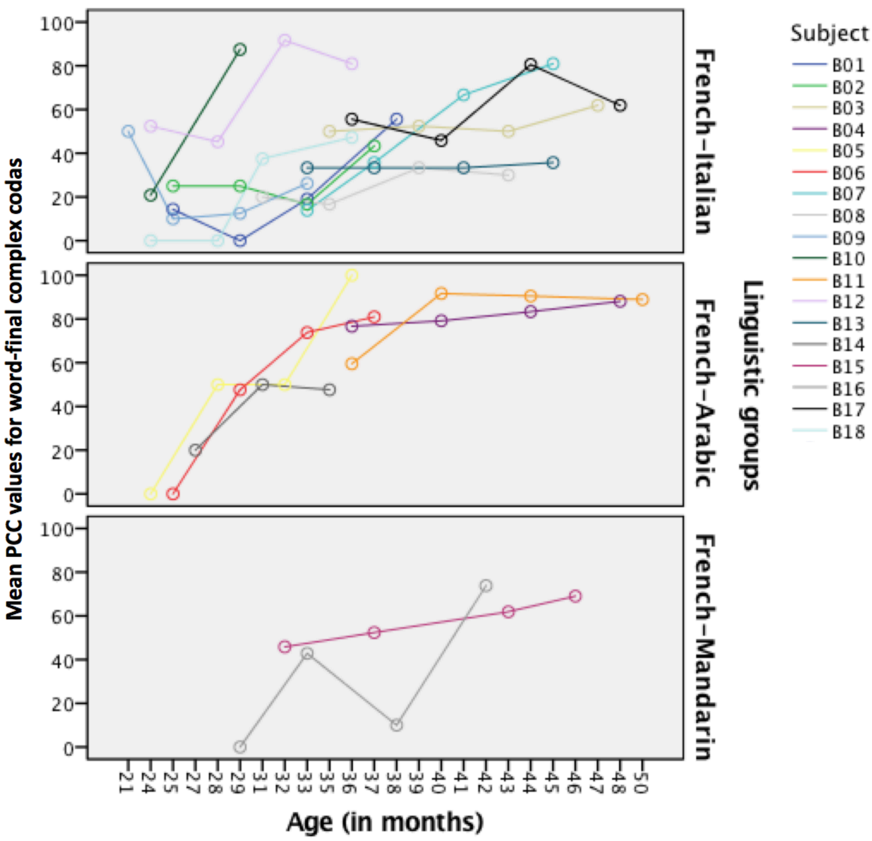

Figure 61: Evolution of PCC values for word-final complex codas over the four sessions for all participants from the three linguistic groups.

Figure 62 presents the evolution of PCC values for word-final complex codas by cluster type over the four sessions for each linguistic group. There are two types of consonant sequences in word-final position included in our corpus: (1) obstruent-liquid (as in [livʁ], i.e., livre) and (2), liquid-obstruent (as in [paʁk], i.e., parc). For the French-Italian and French-Arabic groups, liquid-obstruent sequences have higher PCC values on almost all sessions. For the French-Italian participants, the two types of clusters have close PCC values until S4 at which liquid-obstruent sequences are clearly more accurately realized than obstruent-liquid sequences. Liquid-obstruent sequences are steadily better produced than obstruent-liquid sequences during the first three sessions of French-Arabic bilingual children and PCC values of both cluster types become very close at S4. The opposite pattern is seen in the French-Mandarin participants for whom obstruent-liquid sequences have initially higher PCC values until S3 at which the trend is reversing.

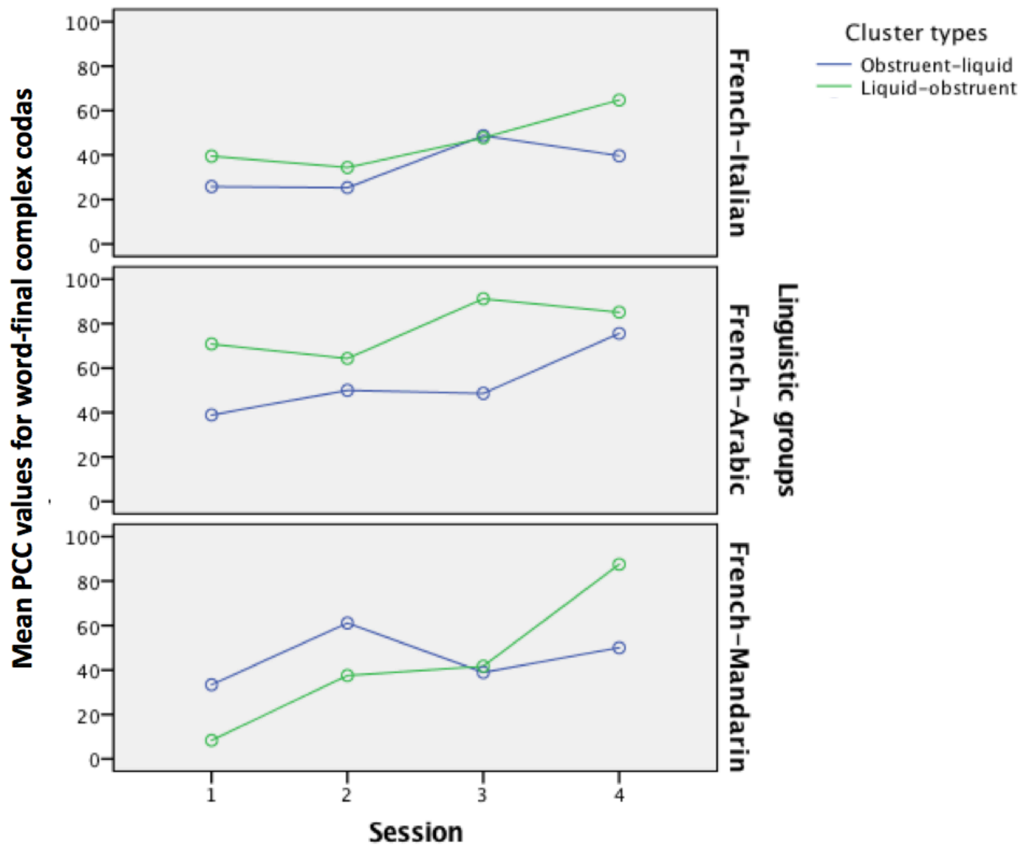

Figure 62: Mean PCC values for word-final complex codas by cluster type for each group over the four sessions.

III.2.1.2.2 Fricatives

In addition to consonants in targeted syllabic constituents, the accuracy of the targeted fricatives (i.e., the alveolars /s, z/ and post-alveolars /ʃ, ʒ/) was similarly longitudinally investigated. To this end, a nuanced PCC was calculated for the set of items previously listed (see Table 23) for all participants' sessions. In total, 962 items have been analysed for the subset of fricatives. In the presentation of the results below, we first examine the evolution of mean PCC values for each linguistic group across the four sessions, followed by the description of individual PCC curves within each linguistic group. Then, the evolution of accuracy is examined for each fricative taken separately.

Table 47 presents the mean PCC values for the targeted fricatives for each linguistic group, both globally and for each session. The global mean PCC values (all sessions combined) from the three groups are different. KW tests reveals a statistically significant effect of the linguistic group (Chi square = 83.89, $p < .001$, df = 2). Pairwise comparisons show that PCC values from the French-Italian group significantly differ from those of the two other groups ($p < .001$) which are not significantly different from one another.

Linguistic group	Total number of items (all participants, all sessions)	Mean number of items per child per session	Global mean (and S.D.) PCC values (all sessions combined)	Mean (and S.D.) PCC values for each session			
				S1	S2	S3	S4
French-Italian	583	13	37.86 (47.15)	26.89 (43.56)	27.58 (43.67)	44.57 (47.99)	48.70 (48.66)
French-Arabic	260	13	69.42 (44.78)	54.76 (49.15)	62.9 (46.98)	64.18 (47.19)	86.58 (32.44)
French-Mandarin	119	15	61.34 (47.58)	43.75 (49.59)	54.83 (47.18)	61.29 (49.51)	80.3 (39.4)

Table 48: Mean PCC values (and standard deviations) for the three linguistic groups.

Figure 63 gives a graphic representation of the mean PCC values' evolution for targeted fricatives for each linguistic group over the four sessions. It appears that the French-Arabic and French-Mandarin groups display very similar developmental curves for the evolution of fricatives' accuracy, with higher mean PCC values for the French-Arabic bilinguals (especially at S1 and S2). Initially very close, mean standard deviations of these two groups begin to differ at S4 at which that of French-Arabic bilinguals is the lowest (see Table 48). Both groups achieve above 80% of correct fricatives at S4. In contrast, the French-Italian group presents much lower mean PCC values at all sessions, barely increasing from S1 to S2 and ending up with less than 50% of correct realizations (and the highest mean standard deviation) at S4.

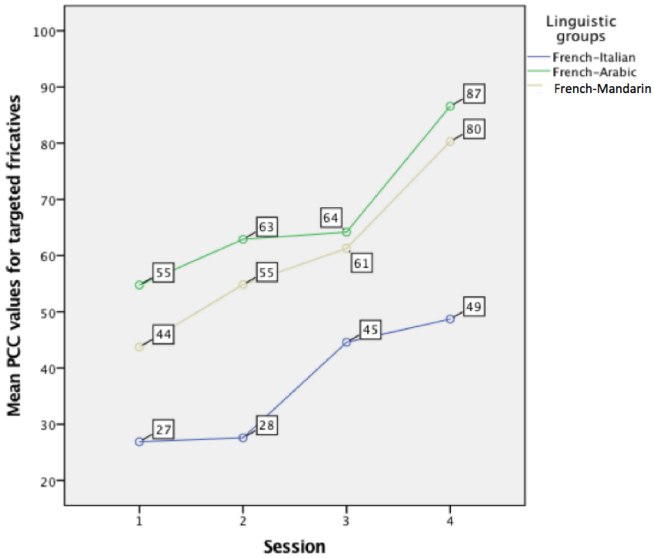

Figure 63: Evolution of PCC values for targeted fricatives for each group over the four sessions.

Figure 64 presents the individual PCC curves for targeted fricatives, with separate graphs for the three linguistic groups. Almost none of the French-Italian participants have PCC values above 60%, except for a couple of them: B09, B12 and B17. Again, for B09, the initial maximal value is explained by the fact that few words with fricatives are initially produced and when tempted, fricatives are accurately produced. Consequently, a decline is observed at S2 when the child produces more words with fricatives. PCC values appear to be variable from one participant to the other in the French-Arabic group. The same pattern observed for B09 is seen for the participant B14. The participant B06 displays particularly high PCC values compared to all other subjects of that age and the highest value at S4. A rather linear development is seen for the older participants B04 and B11. Finally, the same linear developmental pattern is found for the French-Mandarin participant B15 and again, PCC values are more fluctuating for the younger participant B16 with a strong improvement from S1 to S4.

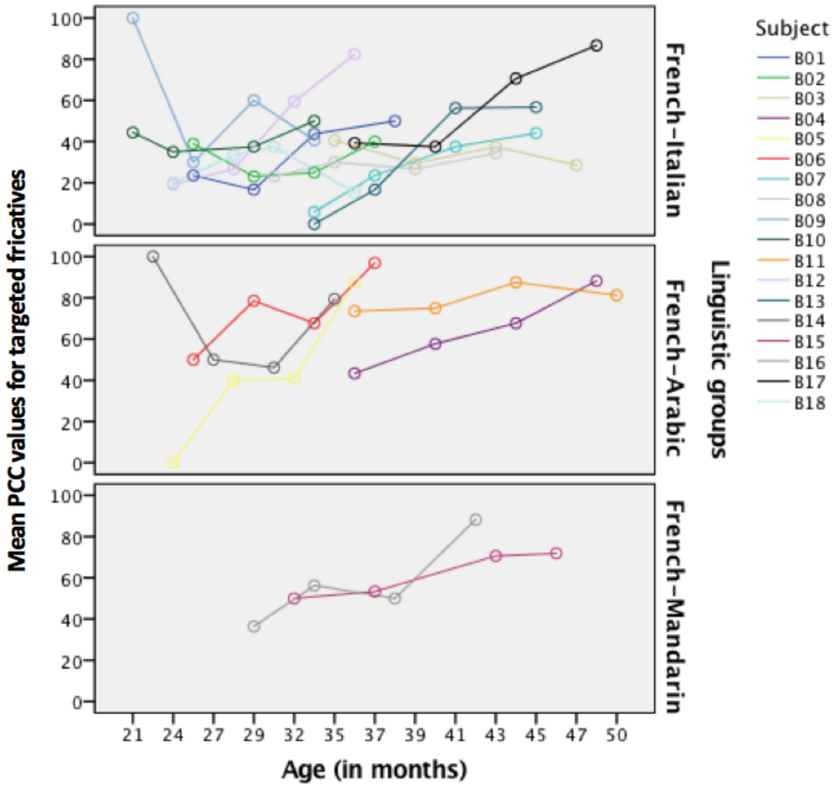

Figure 64: Evolution of PCC values for fricatives over the four sessions for all participants from the three linguistic groups.

Figure 65 presents the evolution of PCC values for each consonant (/s, z, ʃ, ʒ/) over the four sessions for each linguistic group. Globally, for all three groups, the lowest PCC values are exhibited by the post-alveolar /ʒ/, and remain very low until S4 for French-Italian participants (i.e., below 40 %). The alveolar /s/ has the highest PCC values for the French-Italian and French-Arabic participants, however at different levels (above 80 % for the French-Arabic group and below 80 % for the French-Italian group). The post-alveolar /ʃ/ is much less well realized by the French-Italian participants than by French-Arabic and French-Mandarin bilinguals. It seems that French-Arabic produce better the two voiceless fricatives (/s, ʃ/) than their voiced equivalents (/z, ʒ/), while French-Italian realize alveolars (/s, z/) more accurately than post-alveolars (/ʃ, ʒ/). Another pattern is found in French-Mandarin participants for whom the two voiceless fricatives (/s, ʃ/) have very close PCC values and the voiced alveolar /z/ is most accurately produced on all sessions. Finally, PCC values of all four fricatives are getting closer to one another at S4 for the French-Arabic and French-Mandarin participants.

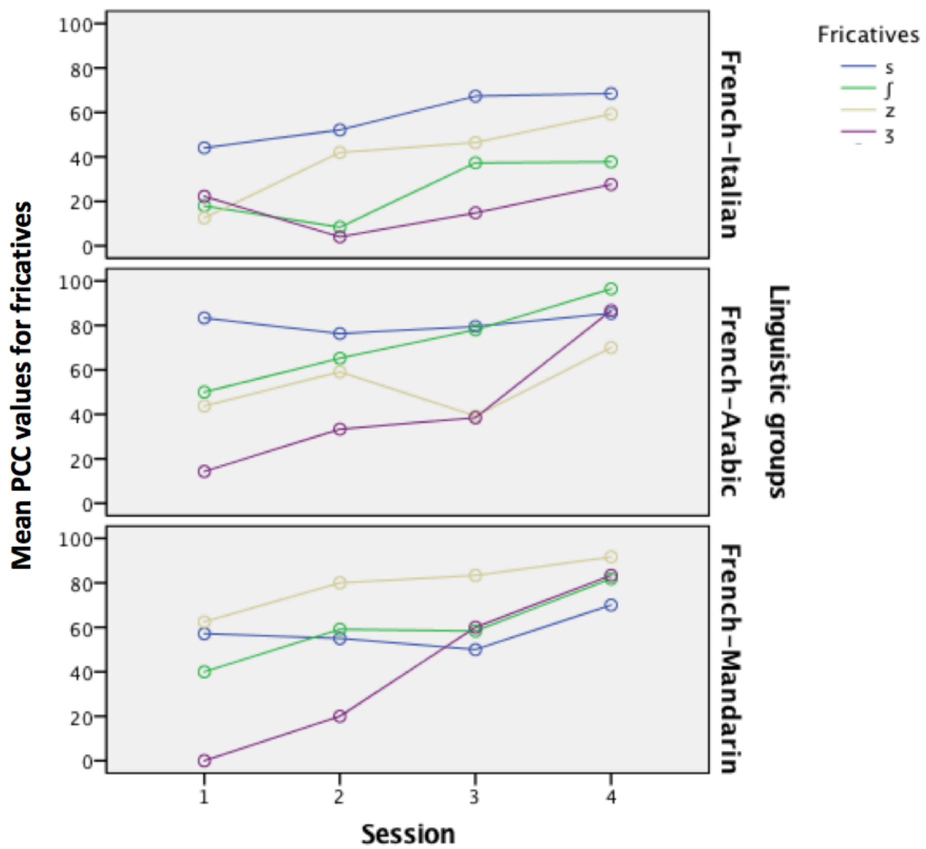

Figure 65: Mean PCC values for the different fricatives for each group over the four sessions.

Like with global PVC and PCC, we conducted a series of non-parametrical KW tests within each linguistic group to investigate the impact of subject-related and item-related independent variables on the different nuanced PCC measures; that is: (1) PCC values for word-final codas, (2) PCC values for word-initial branching onsets, (3) PCC values for word-final complex codas and (4), PCC values for fricatives. To recall, subject-related independent variables involve the two developmental variables of session and chronological age, linguistic dominance, gender, siblings and both vocabulary scores. In regards to item-related independent variables, phonological complexity was not included in the subsequent analyses. Indeed, given the limited subset of items involving the targeted syllabic constituents and fricatives, all levels of phonological complexity could not have been included in the analyses. As previously, we describe the results obtained for each variable separately. Again, the effect of subject-related independent variables of linguistic dominance, gender and siblings are not tested on the French-Mandarin group given that all three variables are confounded with the subject. As with global PCC, the effect of siblings was only tested on the French-Italian group, given that the only French-Arabic participant who has no siblings appears to be the oldest child of that group who outperforms the other children for nearly all measures.

III.2.1.2.3 Independent variables related to the subject

III.2.1.2.3.1 Session and chronological age

Results for the two developmental variables of session and chronological age are presented together. For all three linguistic groups, results from the KW tests show a statistically significant effect of both variables on all nuanced PCC values, with the following exceptions:

- no effect of session was found for PCC values of word-final codas in the French-Italian and French-Arabic groups, indicating no statistical differences between the PCC values of word-final codas for the different sessions;

- no effect of chronological age was found for PCC values of word-final codas in the French-Italian participants, indicating no statistical differences between the PCC values of word-final codas for the different age ranges;

- no effect of session was found for PCC values of word-initial branching onsets in the French-Mandarin group, indicating no statistical differences between the PCC values of word-initial branching onsets for the different sessions.

Results and post-hoc comparisons are reported in Table 49 with non-significant results highlighted in grey. Apart from the mentioned exceptions, the effect goes in the same direction for all groups, as nuanced PCC values are all increasing with chronological age and over subsequent sessions.

SESSION	French-Italian	French-Arabic	French-Mandarin
Word-final codas	Chi square = 6.3 p = .09, df = 3 /	Chi square = 4.5, p = .2, df = 3 /	Chi square = 8, p = .04, df = 3 S1 is different from all other sessions
Word-initial branching onsets	Chi square = 36.13 p < .001, df = 3 S1 different from S3-S4 S2 different from S3	Chi square = 12.4, p = .006, df = 3 S2 is different from S3 – S4	Chi square = 3.9, p = .3, df = 3 /
Word-final complex codas	Chi square = 17.1 p = .001, df = 3 S2 different from S3-S4 S1 different from S4	Chi square = 8.5, p = .03, df = 3 S2 is different from S4	Chi square = 11.8, p = .008, df = 3 S1 is different from S4
Fricatives	Chi square = 25.4 p < .001, df = 3 S1 different from S3-S4 S2 different from S3	Chi square = 18.4, p < .001, df = 3 S4 is different from all other sessions	Chi square = 9.3, p = .02, df = 3 S1 is different from S4

AGE	French-Italian	French-Arabic	French-Mandarin
Word-final codas	Chi square = 10.6 p = .5, df = 5 /	Chi square = 15.2 p = .009, df = 5 One homogeneous subset: age ranges 4-5-6	Chi square = 17.9 p < .001, df = 3 One homogeneous subset: age ranges 3-4-5
Word-initial branching onsets	Chi square = 46.5 p < .001, df = 5 One homogeneous subset: age ranges 1-2-3	Chi square = 37.1 p < .001, df = 5 One homogeneous subset: age ranges 4-5-6	Chi square = 9.7 p = .02, df = 3 Two homogeneous subsets: age ranges 2-3-4 and 3-4-5
Word-final complex codas	Chi square = 24.6 p < .001, df = 5 One homogeneous subset: age ranges 2-3	Chi square = 35.04 p < .001, df = 5 One homogeneous subset: age ranges 4-5-6	Chi square = 16.3 p = .001, df = 3 Two homogeneous subsets: age ranges 3-4 and 3-5
Fricatives	Chi square = 23.9 p < .001, df = 5 One homogeneous subset: age ranges 1 to 5	Chi square = 13.2 p = .02, df = 5 Two homogeneous subsets: age ranges 2-3-4 and 5-6	Chi square = 10.6 p = .01, df = 3 One homogeneous subset: age ranges 2-3-4

Table 49: Results of KW tests with session and chronological age as grouping variables for the three linguistic groups.

III.2.1.2.3.2 Linguistic dominance

A statistically significant effect of linguistic dominance was found for the French-Arabic group only for the nuanced PCC values of fricatives (Chi square = 6.8, p = .03, df = 2). Pairwise comparisons show that there are only significant differences between non-French dominant children and balanced bilinguals (p = .03). As shown by Figure 66, non-French dominant children have slightly higher values than French-dominant children.

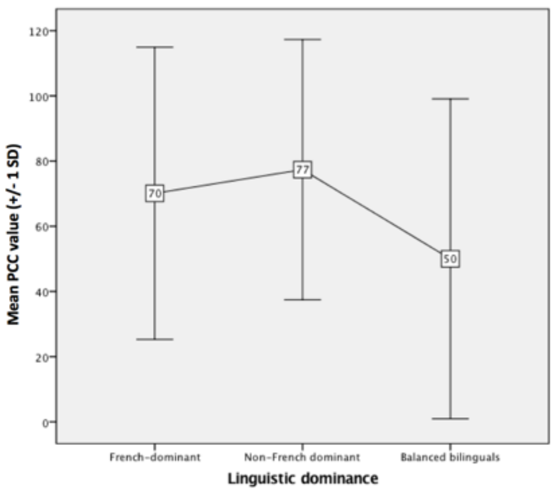

Figure 66: Mean PCC values of fricatives (+/- 1 standard deviation) as a function of linguistic dominance for the French-Arabic group.

III.2.1.2.3.3 Gender

A statistically significant effect of gender was found only for the nuanced PCC of word-branching onsets (Chi square = 4.1, p = .04, df = 1) in the French-Italian group, with girls having the highest PCC values.

III.2.1.2.3.4 Siblings (tested only for the French-Italian group)

A statistically significant effect of siblings was found solely for word-final complex codas (Chi square = 13.4, p < .001, df = 1), with higher PCC values in children with siblings.

III.2.1.2.3.5 Vocabulary scores

Results from the KW tests show a statistically significant effect of French vocabulary score on all nuanced PCC values for all three linguistic groups. A statistically significant effect of total vocabulary score was similarly found for all nuanced PCC values in the French-Italian and French-Arabic groups. Stepwise-stepdown comparisons yield slightly different homogenous subsets for the different vocabulary scores for each group but overall, PCC values increase alongside lexical development as indexed by vocabulary scores. For the French-Mandarin participants, results obtained indicate a statistically significant effect of total vocabulary score only for PCC values of word-final codas. Globally, the nuanced PCC values do not increase alongside with lexical competence in both languages in that group. Results and post-hoc comparisons are reported in Table 50 with non-significant results highlighted in grey.

	French-Italian	French-Arabic	French-Mandarin
Word-final codas French vocabulary score	Chi square = 40.43 p < .001, df = 4 One homogeneous subset: ranges 1-2-3-4	Chi square = 13.4 p = .009, df = 4 Two homogeneous subsets: ranges 1-2-3/4-5	Chi square = 16.87 p = .001, df = 3 Two homogeneous subsets: ranges 1/2-3-4
Total vocabulary score	Chi square =11.6 p = .02, df = 4 Two homogeneous subsets: ranges 1-2-3/4-5	Chi square =20.02 p < .001, df = 4 Two homogeneous subsets: ranges 1/2-3-4-5	Chi square =8.1 p = .04, df = 3 Two homogeneous subsets: ranges 1-2-4/1-3-4
Word-initial branching onsets French vocabulary score	Chi square = 79.87 p < .001, df = 4 Two homogeneous subsets: ranges 1-2-3/4-5	Chi square = 27.29 p < .001, df = 4 Three homogeneous subsets: ranges 1/2-3/4-5	Chi square = 8.85 p = .03, df = 3 Two homogeneous subsets: ranges 1/2-3-4
Total vocabulary score	Chi square = 66.14 p < .001, df = 4 Two homogeneous subsets: ranges 1-2-3/4-5	Chi square = 37.11 p < .001, df = 4 Two homogeneous subsets: ranges 1/2-3-4-5	Chi square = 7.6 p = .6, df = 3 /

	French-Italian	French-Arabic	French-Mandarin
Word-final complex codas			
French vocabulary score	Chi square = 29.7 p < .001, df = 4 Two homogeneous subsets: ranges 1-2-3/4-5	Chi square = 30.43 p < .001, df = 4 Three homogeneous subsets: ranges 1/2-3/3-4-5	Chi square = 12.65 p = .005, df = 3 Two homogeneous subsets: ranges 1/2-3-4
Total vocabulary score	Chi square = 31.13 p < .001, df = 4 Three homogeneous subsets: ranges 1-2-3/4/5	Chi square = 24.19 p < .001, df = 4 Two homogeneous subsets: ranges 1-2/3-4-5	Chi square = 5.8 p = .1, df = 3 /
Fricatives			
French vocabulary score	Chi square = 40.43 p < .001, df = 4 Three homogeneous subsets: ranges 1-2-3/2-3-4/4-5	Chi square = 40.43 p < .001, df = 4 Two homogeneous subsets: ranges 1-2-3/4-5	Chi square = 9.08 p = .02, df = 3 Two homogeneous subsets: ranges 1/2-3-4
Total vocabulary score	Chi square = 28.21 p < .001, df = 4 Three homogeneous subsets: ranges 1-2-3/1-2-4/5	Chi square = 31.69 p < .001, df = 4 Three homogeneous subsets: ranges 1/2-4/3-5	Chi square = 5.4 p = .1, df = 3 /

Table 50: Results of KW tests with both vocabulary scores as grouping variables for the three linguistic groups.

III.2.1.2.4 Independent variables related to the item

III.2.1.2.4.1 Elicitation

Results from the KW tests show a statistically significant effect of elicitation on all nuanced PCC values for the French-Arabic group. A statistically significant effect of elicitation was found for all nuanced PCC values except for word-final complex codas in the French-Italian group, whereas an effect of elicitation was only found for word-final codas in the French-Mandarin participants. Results and post-hoc comparisons are reported in Table 51 with non-significant results highlighted in grey (naming = 1, repetition of known words = 2, repetition of unknown words = 3).

	French-Italian	French-Arabic	French-Mandarin
Word-final codas	Chi square = 7.4 p = .02, df = 2 Elicitation 1 different from 3	Chi square = 20.73 p < .001, df = 2 Elicitation 1 different from 2 and 3	Chi square = 7.5 p = .02, df = 2 Elicitation 1 different from 3
Word-initial branching onsets	Chi square = 12.45 p = .002, df = 2 Elicitation 1 different from 3	Chi square = 27.9 p < .001, df = 2 Elicitation 1 different from 2 and 3	Chi square = 1.79 p = .2, df = 2 /
Word-final complex codas	Chi square = 2.8 p = .24, df = 2 /	Chi square = 16.2 p < .001, df = 2 Elicitation 3 different from 1 and 2	Chi square = 4.42 p = .1, df = 2 /
Fricatives	Chi square = 14.5 p = .001, df = 2 Elicitation 3 different from 1 and 2	Chi square = 18.4 p < .001, df = 2 Elicitation 1 different from 2 and 3	Chi square = 2.82 p = .2, df = 2 /

Table 51: Results of KW tests with elicitation (naming = 1, repetition of known words = 2, repetition of unknown words = 3) as a grouping variable for the three linguistic groups.

Globally, pairwise comparisons show that, for all three groups and all nuanced PCC values, there are significant differences between named and unknown repeated words with lower PCC values for the latter. Then, named words and known repeated words can either be significantly different from each other (as for most nuanced PCC values in the French-Arabic group) or not. Figure 67 presents the PCC values for word-final codas according to elicitation type in all three groups, showing the different pattern found in French-Arabic *vs.* French-Italian and French-Mandarin participants.

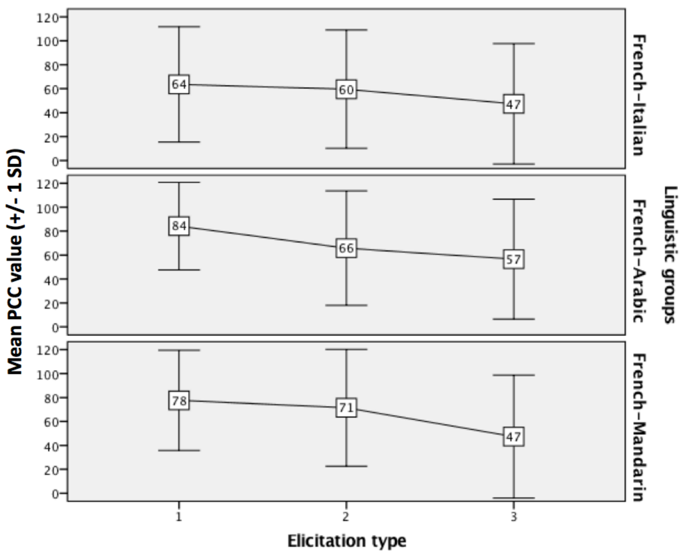

Figure 67: Mean PCC values of word-final codas (+/- 1 standard deviation) as a function of elicitation for all three groups.

III.2.1.2.4.2 Lexical frequency

For the three linguistic groups, KW tests show a statistically significant effect of lexical frequency only for the fricatives' PCC values (see Table 52). Moreover, and as shown in Figure 68, the effect has the same direction for all three groups, with PCC values increasing in parallel to lexical frequency.

French-Italian	French-Arabic	French-Mandarin
Chi square = 15.22 $p < .001$, df = 1	Chi square = 5.2, $p = .02$, df = 1	Chi square = 4.7, $p = .03$, df = 1

Table 52: Results of KW tests with lexical frequency as a grouping variable for all three groups.

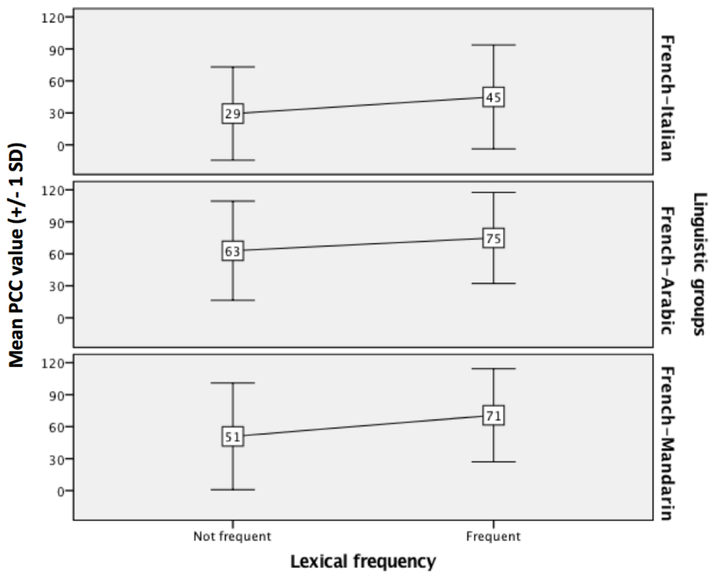

Figure 68: Mean PCC values of fricatives (+/- 1 standard deviation) according to lexical frequency for all three groups.

The key results obtained from the series of KW tests can be summarized as follows:

- Both developmental variables of session and chronological age have a significant effect for nearly all nuanced PCC measures for all three linguistic groups with PCC values increasing with time.
- Linguistic dominance has a significant effect on PCC values for fricatives in the French-Arabic group with Non-French dominant participants having the highest PCC values.
- A significant effect on gender was found for PCC values of word-initial clusters in the French-Italian group, with higher values for the girls.
- The French vocabulary score has a significant effect on all nuanced PCC values for all three groups, with PCC values increasing in parallel to vocabulary score. The total vocabulary

score has a significant effect on all nuanced PCC values for the French-Italian and French-Arabic groups with PCC values similarly increasing with an increasing total vocabulary score. This effect of total vocabulary score is only found for word-final codas in the French-Mandarin group.

- An effect of elicitation was found for all nuanced PCC for the French-Arabic group and for all nuanced PCC values but one (word-final complex codas) for the French-Italian group. A significant effect of elicitation is only found for word-final codas in the two French-Mandarin participants. For all three groups, all nuanced PCC values are significantly lower for repetition of unknown words.
- Lexical frequency has a significant effect only on PCC values for fricatives for all three groups, as fricatives' accuracy increases for frequent words.

III.2.2 EMERGENCE OF THE PLACE-OF-ARTICULATION CONTRAST BETWEEN THE VOICELESS SIBILANT FRICATIVES

We now focus more particularly on the emergence of the place-of-articulation contrast between the voiceless alveolar fricative /s/ and the post-alveolar /ʃ/ investigated through spectral moment analysis. As highlighted in the section about spectral moment analysis, centre of gravity and skewness are the two spectral moments that best differentiate the two sibilants /s/ and /ʃ/. Indeed, the centre of gravity reflects the average energy concentration; that is, the frequency area primarily excited during the production of the fricative, which should be localised in a higher frequency zone for the alveolar /s/ than for the post-alveolar /ʃ/. The skewness is an indicator of the dissymmetry of noise energy around the mean and a positive skewness corresponds to a concentration of energy in lower sound frequencies, whereas a negative skewness corresponds to a concentration of energy in higher sound frequencies. Consequently, /s/ and /ʃ/ should respectively tend to negative and positive skewness.

Therefore, we decided to focus more particularly on these two specific spectral moments for our examination of the potential emergence of the place-of-articulation contrast in the three linguistic groups. We have excluded fricatives occurring in unintelligible words as well as those substituted by consonants of other manner-of-articulation class from our analyses which are based on a total of 686 fricative productions. Table 53 presents mean values for each spectral moment for the two fricatives for each linguistic group.

Linguistic group	Fricative	Total number of fricatives	Mean number of fricatives per child per session	Mean centre of gravity in Hz	Mean skewness
French-Italian	s	145	3	7410 (2938)	0.16 (1.01)
	ʃ	251	6	7221 (2974)	0.37 (1.18)
French-Arabic	s	82	4	7811 (2518)	0.04 (1.22)
	ʃ	120	6	6534 (2119)	0.68 (1.21)
French-Mandarin	s	30	4	4658 (3569)	0.68 (1.41)
	ʃ	58	7	4427 (3310)	0.65 (1.06)

Table 53: First and third mean spectral moments (with standard deviations) for the fricatives /s/ and /ʃ/ for the three linguistic groups.

Figure 69 shows the evolution of centre of gravity (on the left) and skewness (on the right) for the two fricatives, for each linguistic group separately over the four sessions.

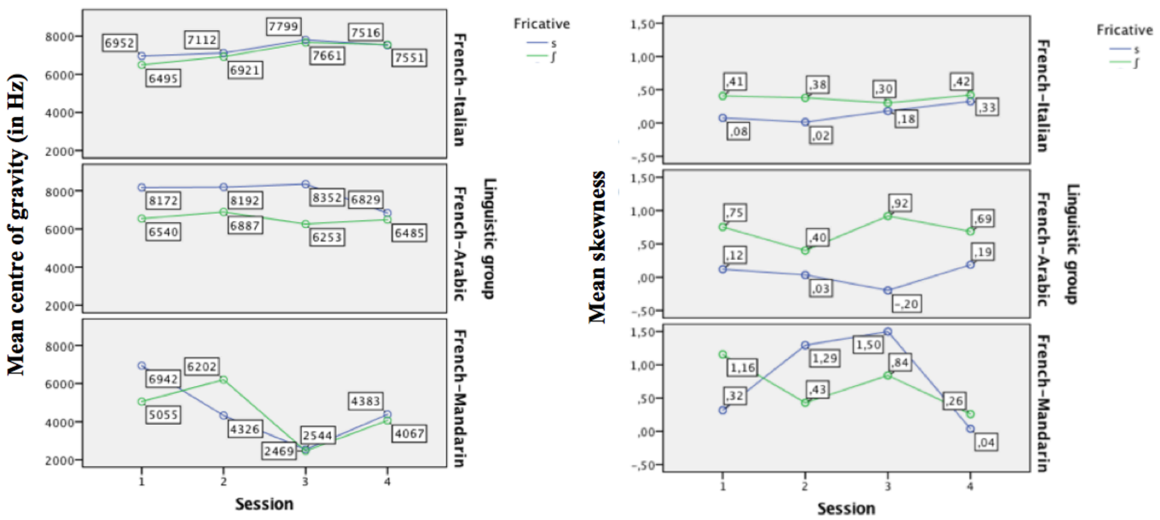

Figure 69: Evolution of centre of gravity (on the left) and skewness values (on the right) for the fricatives /s/ - /ʃ/ over the four sessions for each linguistic group.

As can be observed in Figure 69, curves of the two fricatives' centre of gravity are both very stable and very close to each other, almost confounding, in the French-Italian group. This indicates that the two fricatives are not yet well distinguished by the children in any of the four sessions. In other word, the contrast between the two consonants does not seem to emerge yet in this group. Moreover, centre of gravity values of the two fricatives are concentrating in very high frequency zones (above 6000 Hz), suggesting that, when tempting to produce a /ʃ/, children would tend to utter a sound closer to an [s] than to a [ʃ]. Skewness curves of both fricatives on the right graph also appear to be close to one another. Still, the skewness of /s/ is slightly below that of /ʃ/ in a slightly more pronounced way at S1 and S2.

In contrast, the curves of the two fricatives' centres of gravity are more distinct from one another during the first three sessions of the French-Arabic participants, with higher centres of gravity for /s/ than for /ʃ/, suggesting an existing contrast between the two consonants. The distance between the two curves reaches its maximum at S3 to subsequently become much more reduced at S4. The reduced distance appears to be due to both a decrease of the centre of gravity of /s/ and an increase of the centre of gravity of /ʃ/, as children could produce an intermediary sound halfway between the two fricatives. Skewness curves evolve in correspondence to centres of gravity. Indeed, lower skewness values can be observed for /s/ at all sessions, with expected negative values at S2 and S3, and both fricatives' skewness values become again close to one another at S4.

Production patterns of the two fricatives are much messier in the two French-Mandarin participants. The two fricatives seem to be well distinguished at S1, with a centre of gravity localized in higher frequency zones for /s/ than for /ʃ/ and a lower skewness for /s/ than for /ʃ/. However, curves of the two spectral moments evolve in a rather chaotic way at from S2 to S3, probably indicating that children are still experimenting and that neither fricatives are produced with stability. At S3, the centres of gravity of both fricatives reach very low frequency values while their skewness increase in parallel. Finally, the two fricatives' realizations seem to get closer to the target sounds again at S4. Indeed, the centres of gravity of both fricatives increase and that of /s/ rises again above that of /ʃ/. Accordingly, the skewness of /s/ falls back below that of /ʃ/ but still does not achieve a negative value.

III.2.3 Phonological processes

We now examine the phonological processes affecting consonants. Precisely, we investigated whether the three linguistic groups would differ or not in how consonant substitution and deletion rates evolve over time. Pie charts in Figure 70 display the proportion of correct, substituted and deleted consonants calculated for the different sessions for the three linguistic groups, based on the subcategories generated by PHON for the computation of global PCC.

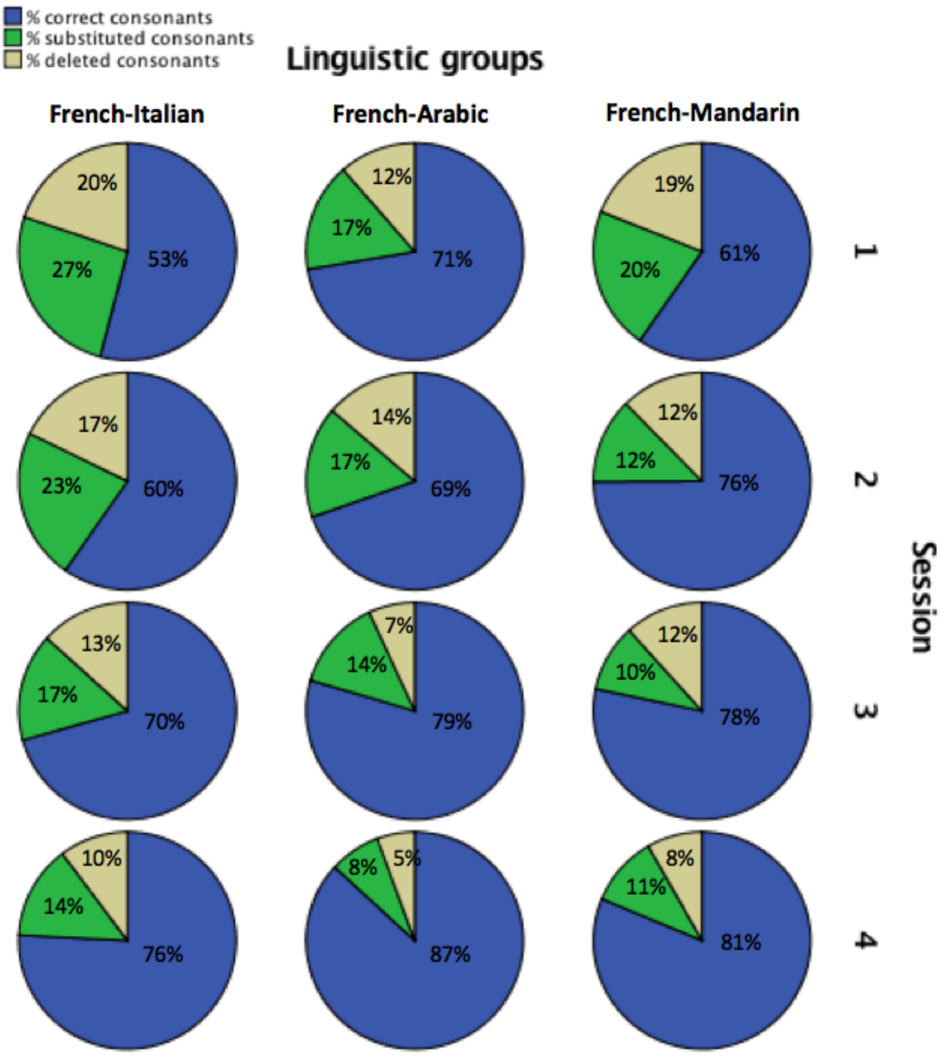

Figure 70: Proportion of correct, substituted and deleted consonants over the four sessions for the three linguistic groups.

As can be seen in Figure 70, the French-Arabic bilingual children display the lowest substitution and deletion rates on all sessions but the second one, during which they undergo a temporary regression as they outperform again the two other groups on S3. The difference between their substitution and deletion rates and those of the two other groups is very marked at S1 and gradually reduced from session to session. In contrast, the French-Italian bilingual children present the highest substitution and deletion rates in all sessions which decrease in a rather linear way from S1 to S4. The French-Mandarin participants fall between the two other groups except at S2, where their substitution and deletion rates strongly decrease and are lower than those of the French-Arabic participants. They subsequently evolve at a much slower pace on the next two sessions. As could be expected, deletion rates are globally much higher than what was observed for vowels. Deletion rates are globally lower than substitution rates for all sessions in all three groups. However, the difference is minimal for the French-Mandarin participants who display almost equal rates of substitution and deletion at sessions 1, 3 and 4 and equal rates at S2. In contrast, the deletion rate of the French-Arabic group at S3 is twice as low as the substitution rate, indicating that more consonants are attempted by the children of this group.

Subtypes of the phonological processes used by the different linguistic groups have also been looked at. Figure 71 shows the mean rates of the types of consonant substitution applied by the children from each group over the four sessions. The processes[64] are the following: (1) coronal backing (e.g., [**k**ɔʁty] instead of /**t**ɔʁty/, i.e., *tortue*), (2) velar fronting (e.g., [**d**ʁənuj] instead of /**g**ʁənuj/, i.e., *grenouille*), (3) devoicing (e.g., [**p**ebe] instead of /**b**ebe/, i.e., *bébé*), (4) voicing (e.g., [**b**aʁk] instead of /**p**aʁk/, i.e., *parc*), (5) fricative stopping (e.g., [**k**evø] instead of /**ʃ**əvø/, i.e., *cheveux*) and (6), lateralization (e.g., [**b**alan] instead of /**b**anan/, i.e., *banane*).

Several observations can be drawn from these graphs. Three processes are used by all three groups on all sessions: coronal backing, devoicing and fricative stopping. For all three groups, the most frequent process is devoicing and the less frequent is lateralization. All types of processes are observed in all sessions for the French-Italian and French-Arabic participants. Process rates decrease rather linearly over time in the French-Italian group, while more fluctuation from session to session is observed in the other two groups. The second most frequent process used by French-Italian bilinguals is fricative stopping, which rate is much lower than in the other two groups. This is in line with the lower PCC curves for fricatives observed in that group. In comparison with the two other groups, the French-Arabic participants globally display a higher rate of velar fronting which decreases at S2 and S3 to increase again at S4. This group also presents a particularly high rate of voicing at S1 and globally lower rates of coronal backing than the French-Italian and French-Mandarin groups. Not all the processes are observed for all sessions in the French-Mandarin participants. Velar fronting

[64] Rates of glidization processes are not included in the graphs, as this process was only very marginally used by a low number of our participants (i.e., less than a third of all participants).

appears to be the second most frequent process applied by these children at S1 and does not occur anymore on the next two sessions to reappear again at S4.

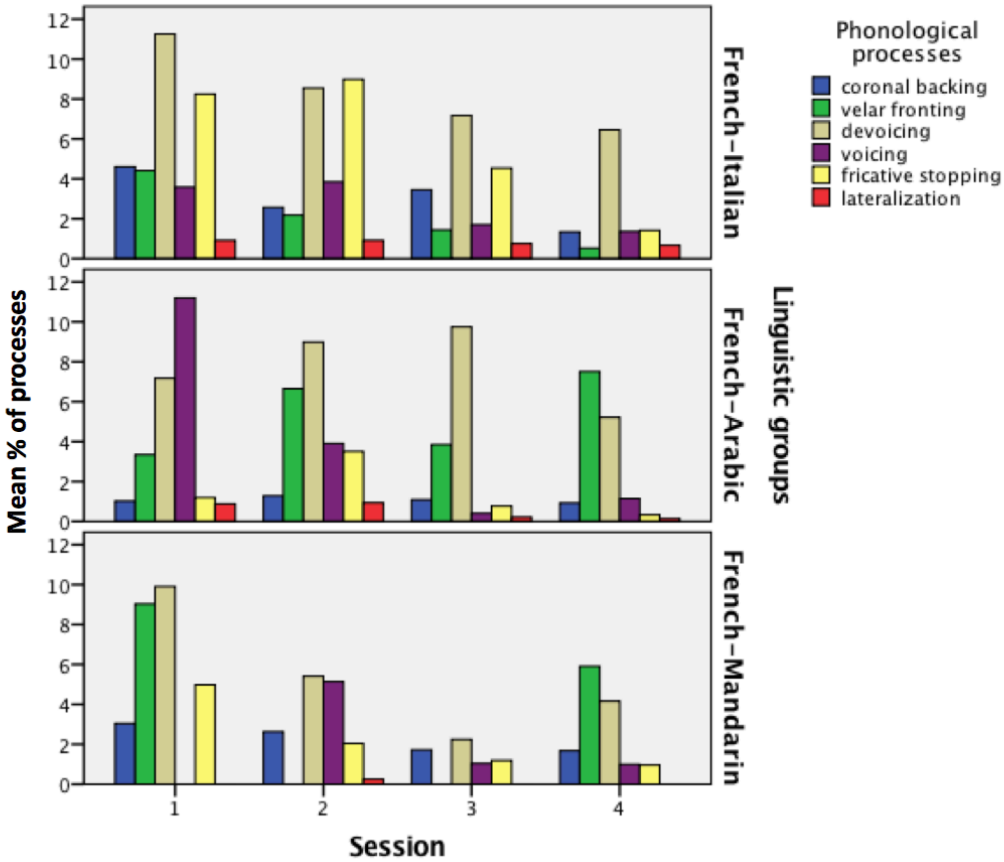

Figure 71: Rates of phonological processes across the four sessions for all the linguistic groups.

The phonological processes specifically affecting the voiceless fricatives /s/ - /ʃ/ were investigated, in order to complement the spectral moment analysis that focused on the emergence of the place-of-articulation contrast between the two consonants presented above (see section III. 2.2.). We more particularly examined in which proportion each fricative was accurately produced *vs.* substituted by the other fricative in order to observe if either one or both consonants were acquired by the children and, in the first case, if the acquired consonant would be produced in place of the other. Indeed, results from spectral moment analysis suggested, amongst other things, that French-Italian bilinguals are producing a similar sound for both consonants seemingly closer to a [s]. Figure 72 displays the rate of correct realizations (i.e., target /s/ produced [s] and target /ʃ/ produced [ʃ]) for the two fricatives as well as the rate of substitutions of one fricative by the other (i.e., target /s/ produced [ʃ] and target /ʃ/ produced [s]).

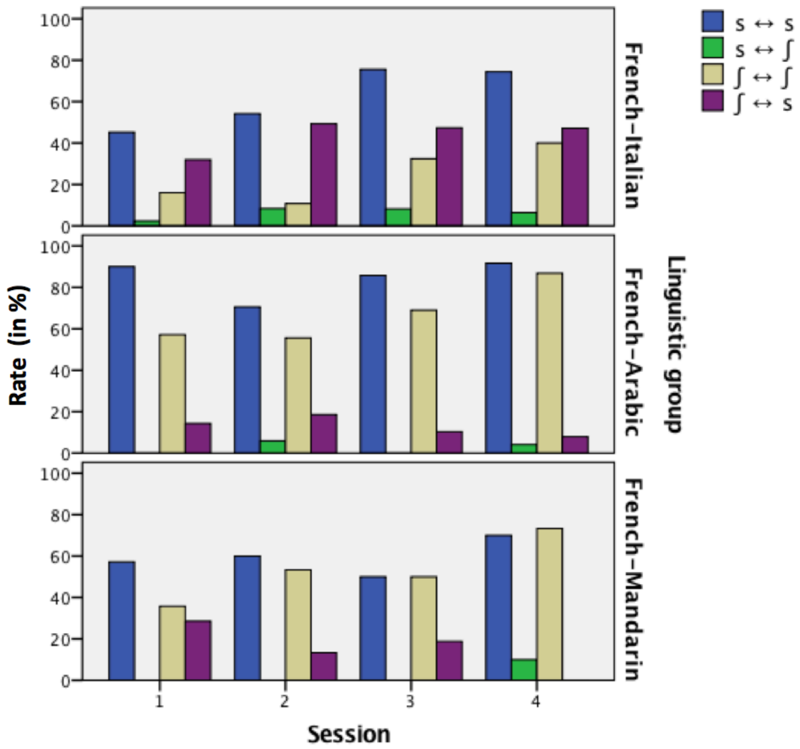

Figure 72: Rates correct realizations *vs.* substitutions of the fricatives /s/ - /ʃ/ over the four sessions for each group.

As can be seen on the graph, French-Italian indeed produce /s/ much more accurately than /ʃ/ and moreover, tend to realize /ʃ/ as a [s]. Results from transcription-based analyses thus correlate with results from the acoustic analyses (see section III. 2.2.). It seems that correct realizations of /ʃ/ are progressively increasing from S2 to S4; however, the rate of substitutions of /ʃ/ by [s] barely decreases. In other words, French-Italian bilinguals produce /ʃ/ either as [ʃ] or as [s] and initially predominantly as [s]. The French-Arabic and French-Mandarin groups display much lower rates of substitutions of /ʃ/ by [s]. If they initially also produce /s/ more accurately (i.e., as [s]) than /ʃ/, the rate of correct realizations for the two consonants become very similar on the last session. Besides, the higher rates of correct realizations for both fricatives are to be found in the French-Arabic bilinguals, which seems to also corroborate results from previous spectral moments analyses (see section III. 2.2.). Still, their apparent regression in the production of the contrast observed in the spectral moment graphs (Figure 69) is not reflected by the rates of correct realizations *vs.* substitutions based on transcriptions, given that they achieve above 80 % of correct realizations for the two fricatives. Similarly, the more chaotic production patterns of both fricatives previously seen in the French-Mandarin participants do not particularly correlate with the above graphs. Finally, it also appears that for all three groups, /s/ is only marginally realized as [ʃ], which suggests that the substitution is not made in both directions and that /s/ is more steadily and predominantly produced than /ʃ/.

III.2.4 Discussion

Results obtained for the different analyses conducted on the children's consonants are discussed in this section, following the same order of presentation: (1) the evolution of global consonant accuracy, (2) the evolution of accuracy of targeted syllabic constituents and fricatives and (3) the phonological processes affecting consonants.

We summarize the working hypotheses previously stated (see section I.4.) about consonant acquisition.

First, we made assumptions about the effect of the linguistic group in interaction with the developmental variables. We assumed that different development patterns could emerge – over the subsequent sessions and as chronological age increases – in the different linguistic groups, resulting from potential cross-linguistic interaction between the two languages in contact. More precisely, we postulated that:

- children exposed to French and Arabic might be advantaged in French consonant acquisition and show a faster consonant development in French, compared to children exposed to French and Italian and children exposed to French and Mandarin;
- children exposed to French and Italian might be slightly accelerated in French consonant acquisition in comparison with children exposed to French and Mandarin;
- children exposed to French and Arabic might be accelerated in the acquisition of word-final codas in French in comparison to children exposed to French and Italian and children exposed to French and Mandarin;
- children exposed to French and Mandarin might be slightly decelerated in their acquisition of word-final codas, word-initial branching onsets and word-final complex codas in comparison to children exposed to French and Italian and children exposed to French and Arabic.

Then, we presumed that consonant acquisition might be influenced by a series of independent variables related to the subject and the item. More specifically, we postulated that:

- all children would display better performances from one session to the other and as chronological age increases;
- children who are more exposed to French would be advantaged in French phonetic and phonological development, in comparison to children less exposed to French;
- a more advanced lexical development in French and in both languages would benefit French phonetic and phonological development;
- French-Italian bilingual children might be more advantaged by a greater lexical development in both languages than French-Arabic and French-Mandarin bilingual children;
- if there is an effect of gender on French phonetic and phonological development, girls could have an advantage over boys;
- if there is an effect of siblings on French phonetic and phonological development, children with older siblings could have an advantage over children without siblings;
- children's speech productions should be more accurate for less complex and more frequent items than for more complex and less frequent items in French.

III.2.4.1 Global consonant accuracy

As expected, French-Arabic bilingual children globally display higher consonant accuracy than the two other groups. Still, their PCC values are close to those of French-Mandarin bilinguals. In contrast, the French-Italian participants have the lowest PCC values and are significantly different from the two other groups. Overall, the acquisition of French consonants is thus slower for them than for the French-Mandarin bilingual children. However, the tendency might have been different if the French-Mandarin participants had been more numerous. Then, individual line graphs show a rather linear development for all participants, contrary to what was observed for vowels. Vowels and consonants thus seem to follow a different developmental path. Note that vowel production might be characterized by more variability while children mobilize their resources for consonant acquisition.

Consonant accuracy clearly improves with chronological age as a significant effect of both developmental variables (session and chronological age) was found for all three groups. Thus, in contrast to what was found for vowels, consonant accuracy significantly increases with age for the two French-Mandarin participants as well. This, again, points to a different developmental time course of vocalic and consonantal segments. Children could first acquire vowels due to their greater saliency in the speech flow (Jusczyk, 1997) and achieve a relatively high vocalic precision quite early. Consequently, vowel production would evolve in a much less marked fashion than consonant production for the specific age range observed in the current study.

Consonant accuracy is not impacted by linguistic dominance in the French-Italian group. Thus, French-dominant children do not produce consonants more accurately, contrary to our expectations. The greater exposure to French does not necessarily lead to better performances, as was already observed with vowel production. Still, the effect of linguistic dominance might be covered by that of chronological age, as non-French dominant children are globally older than French-dominant ones in the French-Italian group. A significant effect of linguistic dominance was found in the French-Arabic participants, although not in the expected direction. Indeed, balanced bilinguals perform significantly worse than French-dominant and Arabic-dominant children, while we would have expected them to have better consonant accuracy than Arabic-dominant children. It might be possible that a greater exposure to Arabic would lead to enhanced consonant accuracy in French given its more complex consonantal system, with regards both to its richer consonant inventory and the articulatory complexity of certain consonants.

A significant effect of gender was found for the French-Italian and French-Arabic groups but in opposite directions. Indeed, girls outperform boys in the French-Italian group, whereas boys do in the French-Arabic group. Results for the French-Italian group are in line with the findings of other bilingual studies (Dodd et al., 2003; Kehoe & Havy, 2019). The better performances observed in French-Arabic boys could be attributed to the fact that one of the two girls from that group is one of the youngest participant of the study (i.e., participant B14, initially aged 21 months). Thus, the effect of gender might be confounded with that of age. A significant effect of siblings was found in the French-Italian group with higher consonant accuracy for children with siblings, confirming findings from the literature (Bridges & Hoff, 2014).

Higher vocabulary scores (in French and in total) benefits consonant acquisition. However, French-Italian bilingual children are not more advantaged by a more advanced general lexical development than French-Arabic and French-Mandarin bilingual children. This is unexpected given that French and Italian share more phonological properties as well as more cognates. Similar to what was observed for vowels, children from all three groups best produce consonants when they spontaneously name words and show the worst performances for unknown repeated words. The greatest gap between the two elicitation types is observed in the French-Arabic group and the smallest in the French-Mandarin group. The level of consonant accuracy for known repeated words lies in-between that of the two other elicitation types. Therefore, it is apparent that children are not advantaged by the presence of a spoken model to reproduce. Still, it is also possible that children spontaneously produced the words that they were the more familiar with and repeated those that they mastered the less following an avoidance strategy, even if all those words were already part of their lexicon. Finally, the results also confirm the expectation that consonants are more accurately produced for less complex and more frequent words, in all three groups.

The comparison to monolingual data available in the literature (MacLeod et al., 2011) indicates that, globally, monolingual children produce consonants more accurately than bilingual children. In other words, French-speaking bilinguals show some deceleration in consonant acquisition in comparison to age-matched French-speaking monolinguals. These results are consistent with previous findings from the literature (Fabiano-Smith & Goldstein, 2010) but conflict with other bilingual speech production studies which showed a bilingual advantage (Goldstein & Bunta, 2012; Kehoe & Havy, 2019). Bilinguals show particularly more variability than monolinguals, as indicated by their higher standard deviation values. However, the French-Arabic bilinguals display almost similar rates of correct consonants as the monolinguals and both French-Italian and French-Arabic groups nearly reach monolinguals' performances in the last age range. This suggests that bilingual children may be temporarily delayed in consonant acquisition but eventually catch up with their monolingual peers.

III.2.4.2 Accuracy of targeted syllabic constituents and fricatives

It results from our analyses of consonant accuracy in the different targeted syllabic constituents that the French-Arabic bilingual children globally outperform the two other groups for all three nuanced PCC measures. In contrast, the French-Italian bilingual children globally show the lowest consonant accuracy in all syllable positions. From case to case, the French-Mandarin participants can present a developmental pattern either close to that of French-Arabic or that of French-Italian bilinguals. We discuss the results and developmental trends for each constituent separately.

III.2.4.2.1 Word-final codas

Contrary to our expectations, French-Mandarin participants are not decelerated in comparison to the French-Italian group. Consistent with findings of other bilingual speech production studies (Lleó et al., 2003; Kehoe & Lleó, 2003a; Keffala, Barlow & Rose, 2018; Kehoe & Havy, 2019), the French-Arabic bilinguals might have been advantaged by the greater frequency of word-final codas as well as by the greater segmental inventory allowed in that position in Arabic. However, the opposite effect is not observed in the French-Mandarin participants. Indeed, their acquisition of word-final codas is not disadvantaged although word-final codas exhibit a much lower frequency and a more restricted segmental inventory in Mandarin. Results for this group can thus not be explained neither in terms of frequency or complexity of the other L1's phonological properties. As a group, the French-Italian bilinguals present a rather linear and slow increase of consonant accuracy in word-final coda from session to session. This contrasts with the French-Mandarin group for which a more fluctuating developmental pattern is displayed with a regression observed at the last session. Still, individual performances within the French-Italian group are characterized by a high variability.

For all three groups, the lowest consonant accuracy in word-final coda is found for stops and fricatives and the highest for glides and the liquid /l/. The low accuracy of stops is not in line with findings from French monolingual acquisition studies (Dos Santos, 2007). However, we did not distinguish between voiced and voiceless stops and fricatives, which might probably have brought different results. Glides and the liquid /l/ are particularly well produced by the French-Mandarin participants. We postulate that this advantage for glide production might be due to the numerous diph-/triphthongs present in the Mandarin vocalic system.

Then, the rhotic (/ʁ/) is produced much more accurately and steadily by the French-Arabic group, suggesting a faster acquisition of this consonant in word-final coda in comparison to the two other groups. This result could indicate an accelerated acquisition of that consonant in comparison to French monolingual toddlers, given that this consonant is generally observed to be acquired the latest in that position in acquisition studies on French monolingual children (Dos Santos, 2007; Rose, 2000). Still, Hilaire-Debove and Kehoe (2004) also observed that French monolingual toddlers could produce liquids early in that position. As the liquid class encompasses both /l/ and /ʁ/, it can not be known whether children were producing the two consonants with the same level of frequency in that study. In contrast, the rhotic is the least accurately produced consonant by the French-Italian bilingual children, who show a faster acquisition of nasals in word-final coda than the two other groups.

III.2.4.2.2 Word-initial branching onsets

The performances of French-Mandarin bilinguals are halfway between those of French-Italian and French-Arabic bilinguals. Similar to word-final codas, the French-Mandarin participants are thus not found to be decelerated in comparison to the French-Italian group, which does not corroborate our assumption. Also, French-Italian and French-Arabic bilinguals present different developmental patterns for the acquisition of word-initial branching onsets. Here again – and still consistent with findings of bilingual studies (Tamburelli et al., 2015; Keffala et al., 2018) –French-Arabic bilinguals might have benefited from the frequent occurrence of complex consonant sequences in word-initial position in surface realizations in Arabic (Hamdi et al., 2004). However, the same effect is not observed in the French-Italian participants. Indeed, their acquisition of word-initial branching onsets in French is not advantaged by the high frequency of complex consonant sequences in word-initial position in Italian. Besides, French-Mandarin bilinguals show no deceleration in the acquisition of word-initial branching onsets in French despite the fact that Mandarin totally excludes consonant clusters. Results for the French-Italian and French-Mandarin groups can thus not be explained in terms of neither frequency, nor complexity of the other L1's phonological properties.

For all three groups and across all four sessions, obstruent-liquid (OL) sequences are more accurately realized, followed by obstruent-glides and then, obstruent-rhotic sequences. This is consistent with the results of several acquisition studies involving French-speaking monolingual toddlers (Kehoe et al., 2008; Dos Santos, 2007) as well as with results from bilingual studies (Almeida, 2011).

III.2.4.2.3 Word-final complex codas

French-Italian and French-Mandarin participants display similar PCC values for word-final complex codas. Again, the presence of complex consonant sequences in word-final position in Arabic

(Hamdi et al., 2004) might have benefited the acquisition of word-final complex codas in French. As for word-initial branching onsets, French-Mandarin bilinguals show no sign of deceleration in the acquisition of word-final complex codas compared to French-Italian bilinguals. Like for the two other syllabic constituents, these results are not in line with our expectation regarding that particular group and moreover, they cannot be explained neither in terms of frequency or complexity of the other L1's phonological properties.

A more linear development is observed for the evolution of accuracy of word-final complex codas for the French-Arabic participants, while much more fluctuations from one session to another is observed in the other two groups. For the French-Italian and French-Mandarin groups, PCC values are globally much lower than in the case of word-initial branching onsets. This is in line with monolingual acquisition studies according to which word-final French clusters tend to be acquired later than word-initial sequences due to the syllabic markedness and/or articulatory challenges that characterize these structures (Demuth & Kehoe, 2006; Demuth & Mccullough, 2009). French-Arabic bilingual children might also be advantaged by the high articulatory complexity of certain consonants in the Arabic consonantal inventory.

Different developmental patterns of the two types of word-final complex codas (that is, obstruent-liquid (OL) and liquid-obstruent (LO) sequences) are observed in the three linguistic groups. Similar accuracy rates are globally observed for the two types of clusters in the French-Italian. LO sequences are more accurately produced by the French-Arabic participants who achieve similar rates of accuracy for the two types of clusters at S4. Finally, developmental patterns for both cluster types are much less linear in the French-Mandarin participants who show opposite production patterns between the first two and last two sessions.

III.2.4.2.4 Targeted fricatives

Almost none of the French-Italian participants have PCC values for fricatives above 60%, except for a couple of them. Again, we were not expecting French-Italian bilinguals to have lower performances than the French-Mandarin participants. The highest PCC values observed in the French-Arabic participants could be due to the larger number of fricatives present in the Arabic consonant inventory. In line with functionalist models within the usage-based approach (Bybee, 1999), it might be assumed that the greater exposure to the fricative manner of articulation in Arabic would lead to more practice in the articulatory gestures required to produce this manner class of consonants which, in turn, would enhance their production in French.

Similar and different developmental patterns can be observed for the production of the different fricatives in the three linguistic groups. For all three groups, the post-alveolar /ʒ/ is the most challenging to produce (PCC values initially below 40 %). French-Italian and French-Arabic produce the alveolar /s/ the most accurately, whereas the French-Mandarin best produce the voiced alveolar /z/. The post-alveolar /ʃ/ is much less well realized by the French-Italian participants than by the children of the two other groups. Finally, at S4 all four fricatives achieve similar rates of correct production for French-Arabic and French-Mandarin participants, whereas the production of the two voiced (/z, ʒ/) still remains problematic for the French-Italian participants. We do not have an explanation for the low rate of correct realizations for the alveolar /z/. As for the post-alveolar /ʒ/, it might be due to the fact that the voiced post-alveolar /ʒ/ is not present in the Italian consonant inventory. However, the Italian consonant inventory involves the affricate /dʒ/ and besides, this consonant is also absent from the Mandarin consonant inventory.

III.2.4.2.5 Impact of the independent variables

As expected, the accuracy of consonant in all targeted syllabic constituents and of targeted fricatives increase with chronological age. An exception concerns word-final codas for the French-Italian group. This probably results from the greater amount of individual variability for the production of word-final codas in that group.

An effect of linguistic dominance is only found for the production of fricatives in the French-Arabic group and again, the effect found is not in the expected direction as the best performances are found in the non-French dominant participants. One might postulate that the greater exposure to the richer fricative inventory in Arabic might give these children an advantage in the acquisition of French fricatives, even over the children with greater exposure to French.

Only the production of word-initial clusters and word-complex codas undergoes a significant effect of gender and siblings respectively, and only in the French-Italian group. Consistent with previous findings (Dodd et al., 2003; Kehoe & Havy, 2019; Bridges & Hoff, 2014), girls and children with siblings in some cases perform better than boys and children without siblings.

The accuracy of consonant production in all targeted syllabic constituents as well as the accuracy of targeted fricatives increase in parallel to French vocabulary scores for all three groups. This confirms that consonant accuracy increases alongside lexical competence in French. Then, the total vocabulary score does not impact the consonant accuracy rates for the French-Mandarin participants except for singleton codas in word-final position. This nearly absent effect of total vocabulary score on the nuanced PCC values of French-Mandarin participants might be due to the fact the participant who has lower values for all nuanced PCC has on the other side the higher total vocabulary score due to her dominance profile (i.e., balanced bilingualism). This would indicate that consonant accuracy in French might not benefit from lexical knowledge in the other language of the child which, in that case, is Mandarin. As was already observed for global consonant accuracy, French-Italian bilinguals are not more advantaged by a more advanced general lexical development (as indexed by vocabulary scores in both languages) than are French-Arabic and French-Mandarin bilingual children.

The French-Arabic bilingual children are the most impacted by elicitation type. Recall that the elicitation type also had the more significant effect on global consonant accuracy for that same group of participants. A similar effect is found in the French-Italian group, except for word-final complex codas, which constitutes the syllabic constituent in which the production of consonants is found most challenging for these children. The French-Mandarin participants appear to be the least impacted by the type of elicitation as an effect is only found for word-final codas. The absence of effect for other nuanced PCCs might be due to the much reduced sample size for that group. Then, for all three groups, all nuanced PCC values are the lowest for the repetition of unknown words. Interestingly, the French-Arabic participants are always more accurate when they name words than when they repeat it, even if the repetition involves existing lexical knowledge. In other words, children from that group are definitely not advantaged by the presence of a spoken model to reproduce.

Finally, only the production of fricatives is impacted by lexical frequency and this, for all three groups, as fricatives' accuracy increases for frequent words. As for the elicitation type, it might be hypothesized that the greater articulatory difficulty characterizing the production of consonant clusters could have overshadowed the influence of lexical frequency, resulting in an absence of effect for the production of both word-initial branching onsets and word-final complex codas. Still, we cannot really provide a satisfactory explanation for the absence of a lexical frequency effect over the consonant accuracy in word-final singleton codas.

III.2.4.3 Emergence of the contrast between /s/ and /ʃ/

Spectral moment analysis suggests that the contrast between the fricatives /s/ - /ʃ/ does not seem to be acquired yet in French-Italian and French-Mandarin participants. French-Italian bilinguals tend to produce a similar sound for the two fricatives, possibly closer to a [s], whereas French-Mandarin bilinguals display much less clear production patterns for both consonants. Then, if the first three sessions suggest that French-Arabic bilinguals produce the two fricatives distinctively, both spectral moments' curves could indicate a regression in the children's production patterns at S4. Still, this regression could only temporary; however, another two sessions would be needed to decide whether the children have finally acquired the contrast or not.

This is consistent with acquisition studies involving spectral moment analyses of these two fricatives which show that this contrast would emerge from the age of 4 (Nissen & Fox, 2005). In line with this, Grandon (2016) found that these fricatives seem to be acquired by normally-hearing children between the age of 5;7 and 10;6 years, based on the manifestation of distinct centres of gravity and higher skewness values for post-alveolar *vs.* alveolar fricatives.

III.2.4.4 Phonological processes

Lower rates of substituted and deleted consonants are observed in nearly all sessions for the French-Arabic participants in comparison to French-Italian and French-Mandarin participants. Still, the differences between the French-Arabic group and the two other groups gradually reduced from session to session. A similar evolution of correct, substituted and deleted consonant rates can globally be observed in the three groups from the second session with, as expected, an increase of correct consonants' rates and a decrease of substituted and deleted consonants' rates with age.

Deletion rates are lower than substitution rates for all sessions of all three groups. The difference between deletion and substitution rates is less marked for the French-Mandarin participants and is most obvious in the French-Arabic group, suggesting that children from this group are more prone to attempt than to simply delete unmastered consonants.

Regarding the substitution types applied by the children in the three linguistic groups, coronal backing, devoicing and fricative stopping are the processes used by all three groups in all sessions. Devoicing and lateralization are respectively the most frequent and least frequent processes used by the children of all three groups. Similar patterns of substitution are thus globally found in the three groups. Differences have also been observed. Fricative stopping is more frequently applied by children of the French-Italian group, which is in line with their lower accuracy rates for fricatives. The French-Arabic bilingual children display globally lower rates of coronal backing and present a particularly high rate of voicing in the first session. Specific to that group, this pattern of substitution is rather atypical, given that voiced consonants are considered as more marked and generally acquired later than voiceless consonants. Again, this could result from the more complex consonant sounds present in Arabic. Not all the processes are observed for all sessions of the French-Mandarin participants. This is probably due to the much smaller number of participant and can be related to the more restricted vowel substitution types previously observed for that group. This could also be a production strategy specific to that group according to which these children would tend to rely on a limited number of phonological processes.

Finally, for all three groups, the alveolar fricative /s/ is only marginally realized as the post-alveolar [ʃ], suggesting an earlier acquisition of /s/. The French-Italian participants produce /s/ much more accurately than /ʃ/ and tend to realize /ʃ/ as [s], while the other two groups display much lower rates of substitution of /ʃ/ by /s/. Then, higher rates of correct realizations for the two fricatives are observed in the French-Arabic group. Thus, acoustic and perceptual measures appear to correlate for these two groups, as spectral moment analysis suggests that French-Italian bilinguals produce a sound closer to an [s] for the two fricatives, whereas the two fricatives seem to be distinctively produced by the French-Arabic participants. In contrast, there is some discrepancy between acoustic and perceptual measures for the French-Mandarin participants. Indeed, perceptual measures suggest that both fricatives are rather accurately produced, whereas spectral moments curves indicate much messier production patterns for the two consonants. One might wonder which measure to consider more reliably in that specific case, given than transcribing these two consonants did not pose any specific problem, i.e., they were quite accurately distinguished by Mandarin participants from the point of view of the transcriber.

III.3 PROXIMITY/DISTANCE TO TARGET WORD-FORMS

The proximity/distance of the children's productions to target word-forms has been assessed via two measures: PWP and PDAP-IS (see section II.4.). PWP and PDAP-IS were computed for each of the 51 items of the word-naming task – using the PHON software for the PWP and the Wagner-Fisher algorithm for the PDAP-IS – for all four sessions of each participant. In total, 2857 items have been analysed. The evolution of mean PWPs and PDAP-IS over the four sessions for each linguistic group is first examined, followed by the description of individual curves for both measures within each linguistic group.

Table 54 presents the mean PWPs and PDAP-IS for each linguistic group, both globally and separately for each session. Global mean PWPs and PDAP-IS (all sessions combined) from the three groups are different. KW tests reveal a statistically significant effect of the linguistic group for PWPs (Chi square = 88.97, $p < .001$, df = 2) and PDAP-IS values (Chi square = 88.97, $p < .001$, df = 2). Pairwise comparisons show that both PWPs and PDAP-IS for the French-Italian group significantly differ from those of the two other groups ($p <.001$) which are not significantly different from each other.

Linguistic group	Total number of items	Mean number of items per child per session	Global PWPs and PDAP-IS (with S.D.) all sessions combined		Mean PWPs and PDAP-IS (with S.D.) for each session			
French-Italian	1733	40	PWP	0.81 (0.005)	0.74 (0.01)	0.78 (0.008)	0.84 (0.008)	0.87 (0.007)
			PDAP-IS	0.88 (0.03)	1.2 (0.06)	1.03 (0.05)	0.78 (0.04)	0.56 (0.03)
French-Arabic	765	38	PWP	0.88 (0.005)	0.85 (0.02)	0.83 (0.01)	0.89 (0.01)	0.92 (0.008)
			PDAP-IS	0.59 (0.03)	0.7 (0.1)	0.85 (0.08)	0.53 (0.05)	0.39 (0.05)
French-Mandarin	359	45	PWP	0.86 (0.01)	0.77 (0.02)	0.86 (0.02)	0.88 (0.02)	0.89 (0.01)
			PDAP-IS	0.74 (0.06)	1.2 (0.1)	0.67 (0.1)	0.66 (0.1)	0.49 (0.07)

Table 54: Mean PWPs and PDAP-IS (and standard deviations) for the three linguistic groups

The evolution of mean PWPs and PDAP-IS for each linguistic group over the four sessions is represented in Figure 73. As PWP and PDAP-IS respectively measure the proximity and the distance to target word-forms, the first measure is expected to increase and the second measure to decrease with time, which is exactly what can be observed for all three groups on the two graphs. As can be seen, the French-Italian participants present lower mean PWPs and higher PDAP-IS than French-Arabic and French-Mandarin bilinguals. Moreover, the values are linearly increasing (for PWP) and decreasing (for DAP) over the four sessions, which is reflected by the continuous decrease of their mean standard deviations (see Table 54). The evolution of both measures is less linear in the French-Arabic group, as a regression (already observed for segmental accuracy) occurs at S2 for that group. Apart from that particular session, French-Arabic bilingual children outperform the two other groups in all the three other sessions, with higher PWPs and lower PDAP-IS. For both measures, the French-Mandarin group display values between those of the French-Italian and French-Arabic groups, except for S2 in which they outperform the French-Arabic participants.

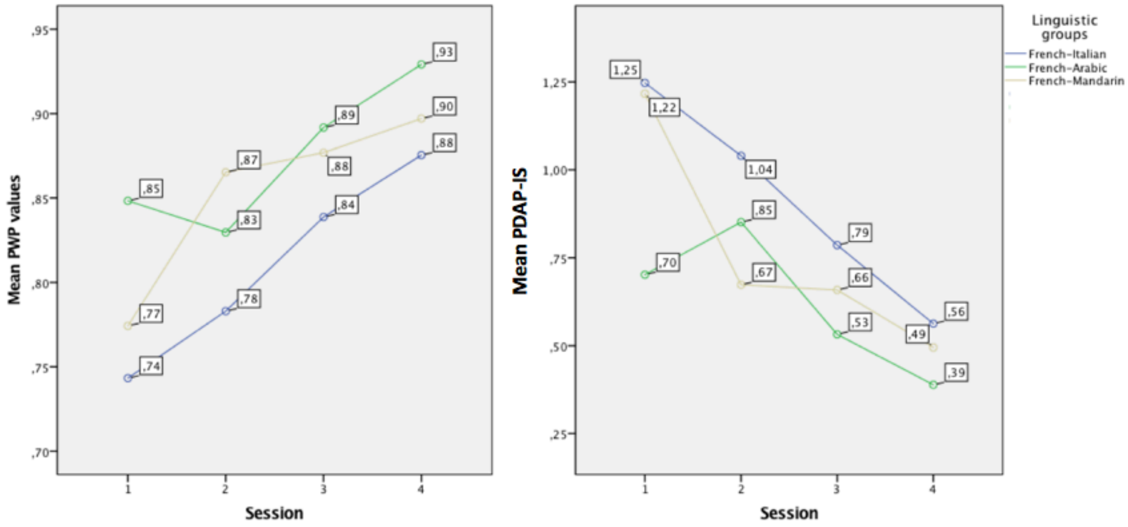

Figure 73: Evolution of PWPs and PDAP-IS for each group over the four sessions.

Figure 74 presents the individual PWP and PDAP-IS curves, with separate graphs for the three linguistic groups. It is obvious that the two measures strongly correlate, as both measures' curves of almost all participants evolve symmetrically to one another. Moreover, both measures are evolving in a rather linear way for all three groups' participants except for the French-Italian participants B09 and B13, the French-Arabic participant B14 and the French-Mandarin participant B16. Again, the two participants B09 and B14 show better performances (i.e., higher PWP values and lower PDAP-IS) at S1 to subsequently decline at S2, which results from the fact that these two children produced fewer items which were accurately produced during the first session. Globally, lower PWP values and corresponding higher PDAP-IS can be observed in the younger children, especially in the French-Italian group, and conversely, higher PWP values and corresponding lower PDAP-IS in the older children.

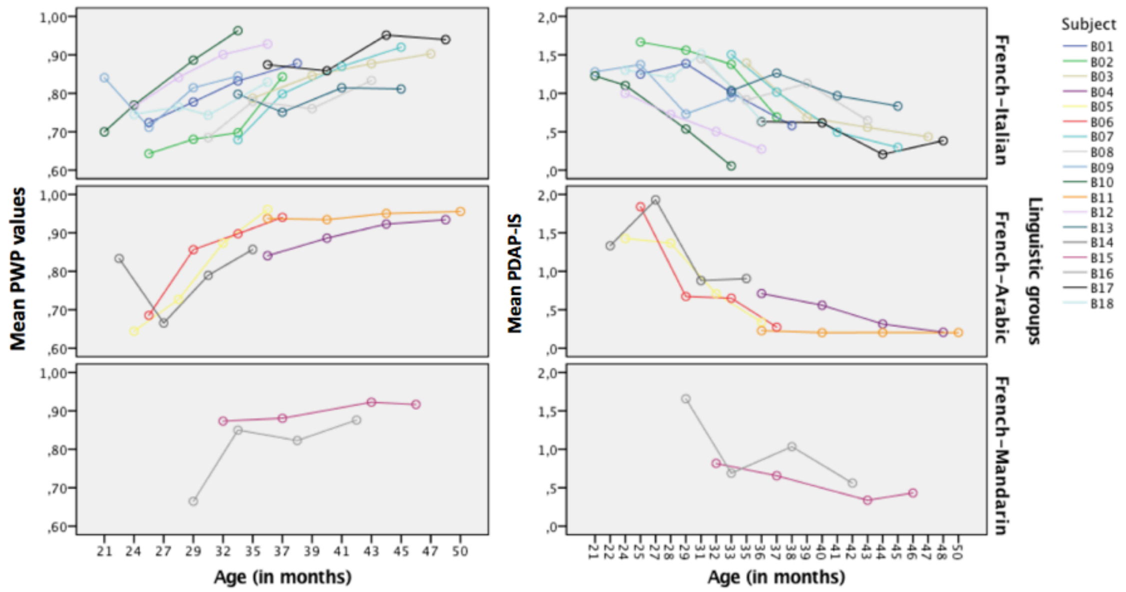

Figure 74: Evolution of PWPs and PDAP-IS over the four sessions for all participants from the three linguistic groups.

Like with segmental accuracy measures, a series of non-parametrical KW test were carried out within each linguistic group to investigate the impact of subject-related (session, chronological age, linguistic dominance, vocabulary scores, gender and siblings) and item-related (elicitation, phonological complexity and lexical frequency) independent variables. A correlation test shows that the two measures strongly correlate (r = -0.760 - p <.001). Therefore, and to avoid redundancy, we present the results obtained solely for the more refined measure; that is, the PDAP-IS.

III.3.1 Independent variables related to the subject

III.3.1.1 Session and chronological age

Results for the two developmental variables of session and chronological age are presented together given that results from the KW tests show a statistically significant effect of both variables on PDAP-IS for all three linguistic groups. Pairwise comparisons have been conducted for session and stepwise comparisons for chronological age. Results are reported in Table 55. Globally, PDAP-IS are decreasing over the subsequent sessions and as chronological age increases for all three groups.

Linguistic group	KW results		Pairwise and stepwise comparisons
French-Italian	Session	Chi square = 118.32 p < .001, df = 3	There are statistically differences between all sessions (p <.001) except between S1-S2 with a less marked difference between S3-S4 (p= .04)
	Chronological age	Chi square = 139.95 p < .001, df = 5	Four homogeneous subsets: Age ranges 1-2-3/4/5/6
French-Arabic	Session	Chi square = 34.44 p < .001, df = 3	There are statistically differences between S1 and S4 (p =.001), S2 and S3 (p =.03), S2 and S4 (p <.001), S3 and S4 (p = .02)
	Chronological age	Chi square = 137 p < .001, df = 5	Four homogeneous subsets: Age ranges 1-2/1-3/4/5-6
French-Mandarin	Session	Chi square = 20.8 p < .001, df = 3	There are statistically differences between S1 and S2 (p =.01), S1 and S3 (p =.001), S1 and S4 (p <.001)
	Chronological age	Chi square = 33.68 p < .001, df = 3	Three homogeneous subsets: Age ranges 2/3-4/4-5

Table 55: Results of KW tests with session and chronological age as grouping variables for the three linguistic groups.

III.3.1.2 Linguistic dominance

A statistically significant effect of linguistic dominance was found in the French-Arabic group (Chi square = 6.26, p = .038, df = 2). Pairwise comparisons show that there are only significant differences between French dominant children and balanced bilinguals (p = .02), with the lowest PDAP-IS (i.e., the highest performances) found in French-dominant children, as shown in Figure 75.

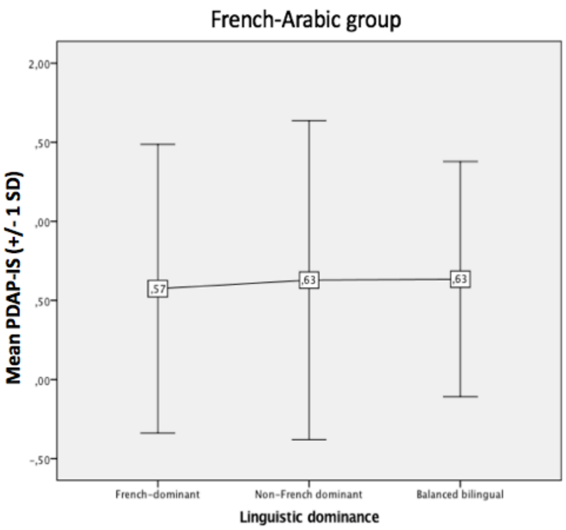

Figure 75: Mean PDAP-IS (+/- 1 standard deviation) for French-Arabic bilinguals as a function of linguistic dominance.

III.3.1.3 Gender

A statistically significant effect of gender was found in the French-Arabic group (Chi square = 11.49, p = .001, df = 1), with boys having lower PDAP-IS than girls.

III.3.1.4 Siblings (tested only for the French-Italian group)

A statistically significant effect of siblings was found (Chi square = 10.55, p = .001, df = 1), with lower PDAP-IS in children with siblings.

III.3.1.5 Vocabulary scores

Results from the KW tests showed a significant effect of the two vocabulary scores (i.e., French and total) on PDAP-IS for all three groups. Results are reported in Table 56. Stepwise-stepdown comparisons yield slightly different homogenous subsets for the two vocabulary scores for each group but globally, PDAP-IS are decreasing alongside the lexical development.

Linguistic group	KW results		Stepwise comparisons
French-Italian	French vocabulary score	Chi square = 186.9 p < .001, df = 4	There are statistically differences between all vocabulary ranges
	Total vocabulary score	Chi square = 170.6 p < .001, df = 4	Three homogeneous subsets: vocabulary ranges 1-2-3/4/5
French-Arabic	French vocabulary score	Chi square = 124.4 p < .001, df = 4	Four homogeneous subsets: vocabulary ranges 1-2/3-4/4-5
	Total vocabulary score	Chi square = 127 p < .001, df = 4	Three homogeneous subsets: vocabulary ranges 1/2/3-4-5
French-Mandarin	French vocabulary score	Chi square = 28.04 p < .001, df = 3	Two homogeneous subsets: vocabulary ranges 1/2-3-4
	Total vocabulary score	Chi square = 18.5 p < .001, df = 3	Two homogeneous subsets: vocabulary ranges 1-2-4/3

Table 56: Results of KW tests with both vocabulary scores as grouping variables for the three linguistic groups.

III.3.2 Independent variables related to the item

III.3.2.1 Elicitation

Results from the KW tests showed a statistically significant effect of elicitation on PDAP-IS for all three groups. Globally, PDAP-IS are higher for unknown repeated words but pairwise comparisons yield different tendencies for all three groups. For the French-Italian and French-Arabic participants, there are significant differences between PDAP-IS for all three elicitation types. The effect is less marked for the French-Mandarin participants for whom there are significant differences in PDAP-IS only between named and unknown repeated words. Results are reported in Table 57 (naming = 1, repetition of known words = 2, repetition of unknown words = 3) and following Figure 76 shows the different patterns found in French-Italian and French-Arabic *vs.* French-Mandarin participants.

	French-Italian	French-Arabic	French-Mandarin
PDAP-IS	Chi square = 52.65 p = .002, df = 2 All elicitation types are different from one another, 1 from 2 (p = .01) and 3 (p < .001) 2 from 3 (p = .001)	Chi square = 117.7 p < .001, df = 2 All elicitation types are different from one another (p < .001)	Chi square = 9.5 p = .009, df = 2 Elicitation 1 is different from 3 (p = .01)

Table 57: Results of KW tests with elicitation as a grouping variable for the three linguistic groups.

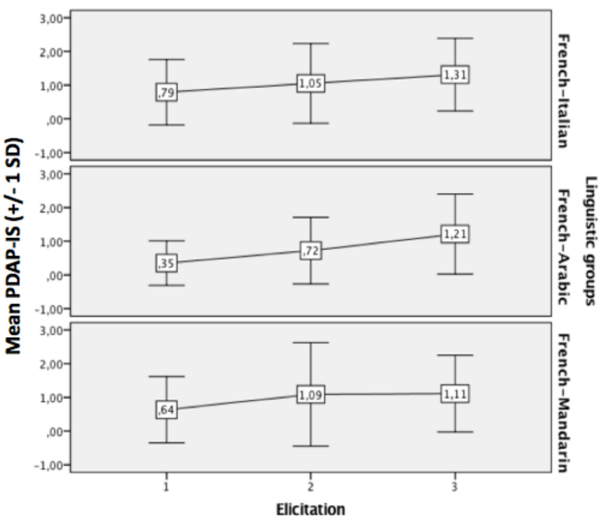

Figure 76: Mean PDAP-IS (+/- 1 standard deviation) as a function of elicitation (naming = 1, repetition of known words = 2, repetition of unknown words = 3) for all three groups.

III.3.2.2 Phonological complexity and lexical frequency

Results for the two item-related variables of phonological complexity and lexical frequency are presented together given that the KW tests show a statistically significant effect of the two variables on PDAP-IS with similar tendencies for all three linguistic groups. Results are reported in Table 58. Globally, PDAP-IS are increasing as the level of phonological complexity increases and conversely, are declining as the level of lexical frequency increases.

Linguistic group	KW results		Pairwise comparisons
French-Italian	Phonological complexity	Chi square = 146.6 p < .001, df = 2	Significant differences between all levels of phonological complexity (p < .001)
	Lexical frequency	Chi square = 25.3 p < .001, df = 1	/
French-Arabic	Phonological complexity	Chi square = 53.6 p < .001, df =2	Significant differences between all levels of phonological complexity (p < .001), less marked between levels 2-3 (p = .049)
	Lexical frequency	Chi square = 21.2 p < .001, df = 1	/
French-Mandarin	Phonological complexity	Chi square = 27.7 p < .001, df = 2	Significant differences between level 1 and levels 2 (p = .001) and 3 (p < .001)
	Lexical frequency	Chi square = 13.8 p < .001, df = 1	/

Table 58: Results of KW tests with phonological complexity and lexical frequency as grouping variables for the three linguistic groups.

Apart from a few exceptions, results for the series of conducted KW tests indicate that nearly all independent variables tested have globally the same effect on PDAP-IS for all three groups. Table 59 summarizes the results obtained for each variable separately in each linguistic group.

Independent Variable	French-Italian	French-Arabic	French-Mandarin
Session	Chi square = 118.32 p < .001, df = 3	Chi square = 34.44 p < .001, df = 3	Chi square = 20.8 p < .001, df = 3
Chronological Age	Chi square = 139.95 p < .001, df = 5	Chi square = 137 p < .001, df = 5	Chi square = 33.68 p < .001, df = 3
Linguistic dominance	NS	Chi square = 6.26, p = .038, df = 2	
Gender	NS	Chi square = 11.49, p = .001, df = 1	
Presence of Siblings	Chi square = 10.55, p = .001, df = 1		
French Vocabulary score	Chi square = 186.9 p < .001, df = 4	Chi square = 124.4 p < .001, df = 4	Chi square = 28.04 p < .001, df = 3
Total Vocabulary score	Chi square = 170.6 p < .001, df = 4	Chi square = 127 p < .001, df = 4	Chi square = 18.5 p < .001, df = 3
Elicitation technique	Chi square = 52.65 p = .002, df = 2	Chi square = 117.7 p < .001, df = 2	Chi square = 9.5 p = .009, df = 2
Phonological complexity	Chi square = 146.6 p < .001, df = 2	Chi square = 53.6 p < .001, df =2	Chi square = 27.7 p < .001, df = 2
Lexical frequency	Chi square = 25.3 p < .001, df = 1	Chi square = 21.2 p < .001, df = 1	Chi square = 13.8 p < .001, df = 1

Table 59: KW tests results on PDAP-IS values.

III.3.3 COMPARISON WITH MONOLINGUAL CHILDREN

We now compare mean PWPs and standard deviations of the three bilingual groups to the mean PWPs and standard deviations of monolingual children available from MacLeod and collaborators' study (2011) in order to examine whether there are differences between French-speaking monolingual and bilingual children. Mean PWPs and standard deviations of monolingual and bilingual children for the different age ranges selected by MacLeod et al. (2011) are presented in the two line graphs below (Figure 77 and 78). Table 60 summarizes all measures for all children's groups.

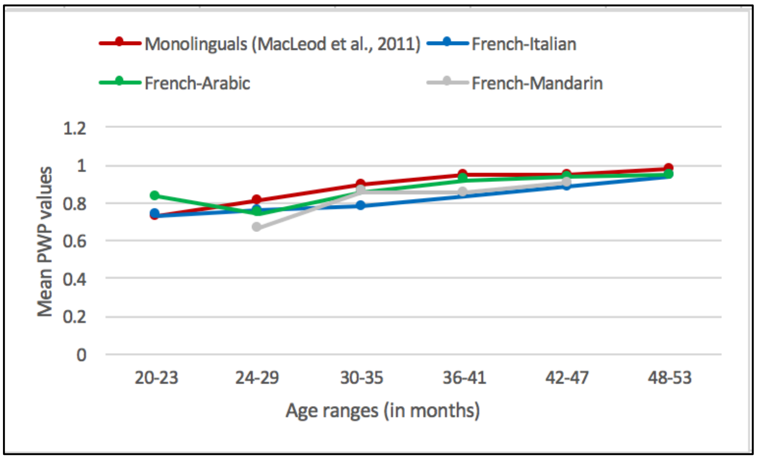

Figure 77: Mean PWPs of monolingual and bilingual children for the different age ranges.

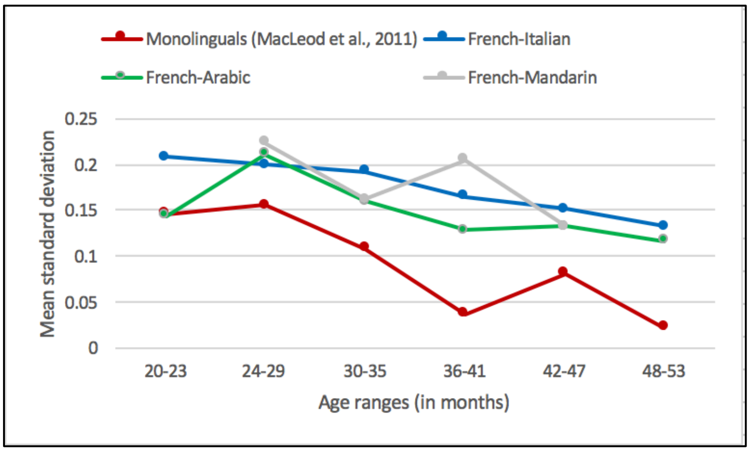

Figure 78: Mean standard deviations of monolingual and bilingual children for the different age ranges.

Age ranges	Mean PWP Mono-linguals	Mean SD Mono-linguals	Mean PWP French-Italian	Mean SD French-Italian	Mean PWP French-Arabic	Mean SD French-Arabic	Mean PWP French-Mandarin	Mean SD French-Mandarin
20-23	0.73	0.15	0.74	0.21	0.83	0.14		
24-29	0.81	0.16	0.76	0.20	0.74	0.21	0.66	0.22
30-35	0.89	0.11	0.78	0.19	0.86	0.16	0.86	0.16
36-41	0.95	0.04	0.84	0.16	0.92	0.13	0.85	0.20
42-47	0.95	0.08	0.88	0.15	0.94	0.13	0.91	0.13
48-53	0.98	0.02	0.94	0.13	0.94	0.12		

Table 60: Mean PWP and standard deviation values for monolinguals and all three bilingual groups.

As can be observed from both graphs (Figure 77 and 78), monolinguals have slightly higher PWPs and much lower standard deviation values than bilingual children on all age ranges except the first one, in which the higher mean PWPs are found in the French-Arabic bilingual children. Moreover, French-Arabic bilinguals displays PWPs very close to those of monolinguals for the age ranges going from 30 to 53 months. French-Italian bilingual children have globally the lowest PWPs except for the second age range (i.e., from 24 to 29 months) in which the French-Mandarin participants have the lowest PWPs and concomitantly, the highest standard deviation. PWP curves of these two groups almost overlap for the age ranges going from 36 to 47 months. PWPs of all children's groups (bilinguals and monolinguals) increase with age and almost converge on the last two age ranges (i.e., from 42 to 53 months). Differences in mean PWPs between bilingual and monolingual children appear to be less marked than what was previously observed for mean PCC values (see Figures 52 and 53 in section III.2.1.). Still, differences in mean standard deviations between the three bilingual groups and the monolingual children remain wide for all age ranges. This indicates much greater variability in bilingual children than in monolingual children, as what also the case with mean PCC values.

III.4 CORRELATION BETWEEN ITEM-BASED MEASURES

In this final result section, we investigate the relation between both global measures of segmental accuracy – that is, global PCV and PCC – and both measures of proximity/distance to target word forms in order to examine to which degree these different measures correlate in the three linguistic groups. To this view, correlation tests have been conducted between global PVC, global PCC, PWP and PDAP-IS within each linguistic group. Results from the correlations tests are presented in separate Tables for each group (see Tables 61, 62 and 63).

French-Italian group	Global PVC	Global PCC	PWP	PDAP-IS
Global PVC		r= 0.167 p <.001	r= 0.213 p <.001	r= -0.482 p <.001
Global PCC	r= 0.167 p <.001		r= 0.910 p <.001	r= -0.786 p <.001
PWP	r= 0.213 p <.001	r= 0.910 p <.001		r= -0.839 p <.001
PDAP-IS	r= -0.482 p <.001	r= -0.786 p <.001	r= -0.839 p <.001	

Table 61: Results from correlation tests between item-based measures for the French-Italian group.

French-Arabic group	Global PVC	Global PCC	PWP	PDAP-IS
Global PVC		r= 0.271 p <.001	r= 0.316 p <.001	r= -0.577 p <.001
Global PCC	r= 0.271 p <.001		r= 0.935 p <.001	r= -0.819 p <.001
PWP	r= 0.316 p <.001	r= 0.935 p <.001		r= -0.825 p <.001
PDAP-IS	r= -0.577 p <.001	r= -0.819 p <.001	r= -0.825 p <.001	

Table 62: Results from correlation tests between item-based measures for the French-Arabic group.

French-Mandarin group	Global PVC	Global PCC	PWP	PDAP-IS
Global PVC		r= 0.125 p =.018	r= 0.143 p =.007	r= -0.483 p <.001
Global PCC	r= 0.125 p =.018		r= 0.944 p <.001	r= -0.802 p <.001
PWP	r= 0.143 p =.007	r= 0.944 p <.001		r= -0.837 p <.001
PDAP-IS	r= -0.483 p <.001	r= -0.802 p <.001	r= -0.837 p <.001	

Table 63: Results from correlation tests between item-based measures for the French-Mandarin group.

For all three groups, the highest correlation is found between PCC and PWP. More particularly, there is a very high positive correlation between the two measures for all three groups, meaning that both measures are increasing in parallel. This result is not surprising, given that PWP gives credit to both vowels and consonants' presence but rewards only consonant accuracy. The second highest correlation is the one between the two measures of whole-word forms' distance to targets, between which there is a high negative correlation for all three groups. This means that these two measures are inversely proportional. In other words, PDAP-IS decrease as PWPs increase, as can be seen on scatter plots below (Figure 79). This could also have been expected based on the correlation test previously conducted for all participants and based on the symmetrical individual curves previously described as well (see Figure 74).

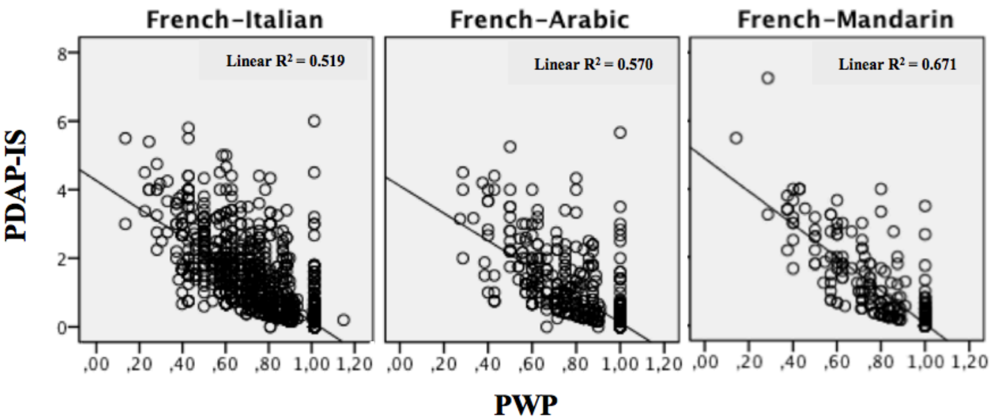

Figure 79: Correlation between PDAP-IS and PWPs for all linguistic groups.

Then, a high negative correlation is also found between PCC and PDAP-IS for all three groups, whereas only a moderate (for the French-Arabic participants) or low (for the French-Italian and French-Mandarin participants) negative correlation is found between PVC and PDAP-IS. This means that the two measures of segmental accuracy decrease as the PDAP-IS increases, however to much different degrees. Indeed, the relation between consonant accuracy and the distance to target word-forms (as measured by the PDAP-IS) is much stronger. Thus, even if the PDAP-IS is computed based on both types of segments and does not give more weight to consonants than to vowels, it is still more correlated to the consonant accuracy measure than to the vowel accuracy measure. This probably results from the fact that vowels are more accurately produced by children or, should it be said, are perceived as such.

Finally, a negligible positive correlation is found between PVC and both PWP and PCC for the French-Italian and French-Mandarin participants, meaning that the relation between these measures is very weak, especially for French-Mandarin bilinguals. The correlation between PVC and PCC is also negligible for French-Arabic participants, while there is a low positive correlation between PVC and PWP in that group. Global PVC is thus slightly more correlated to the other measures for the French-Arabic participants. In other words, PVC evolves more concomitantly with both PCC and PWP in that group than in the other two groups. Figure 80 allows to visualize this more clearly. Indeed, PVC follows a similar evolution pattern than PCC and PWP in the French-Arabic group: a decline from S1 to S2 and an increase during the two subsequent sessions. This is not the case for the two other groups in which a similar evolution pattern can be observed for both PCC and PWP but not for PVC, especially for the French-Mandarin participants.

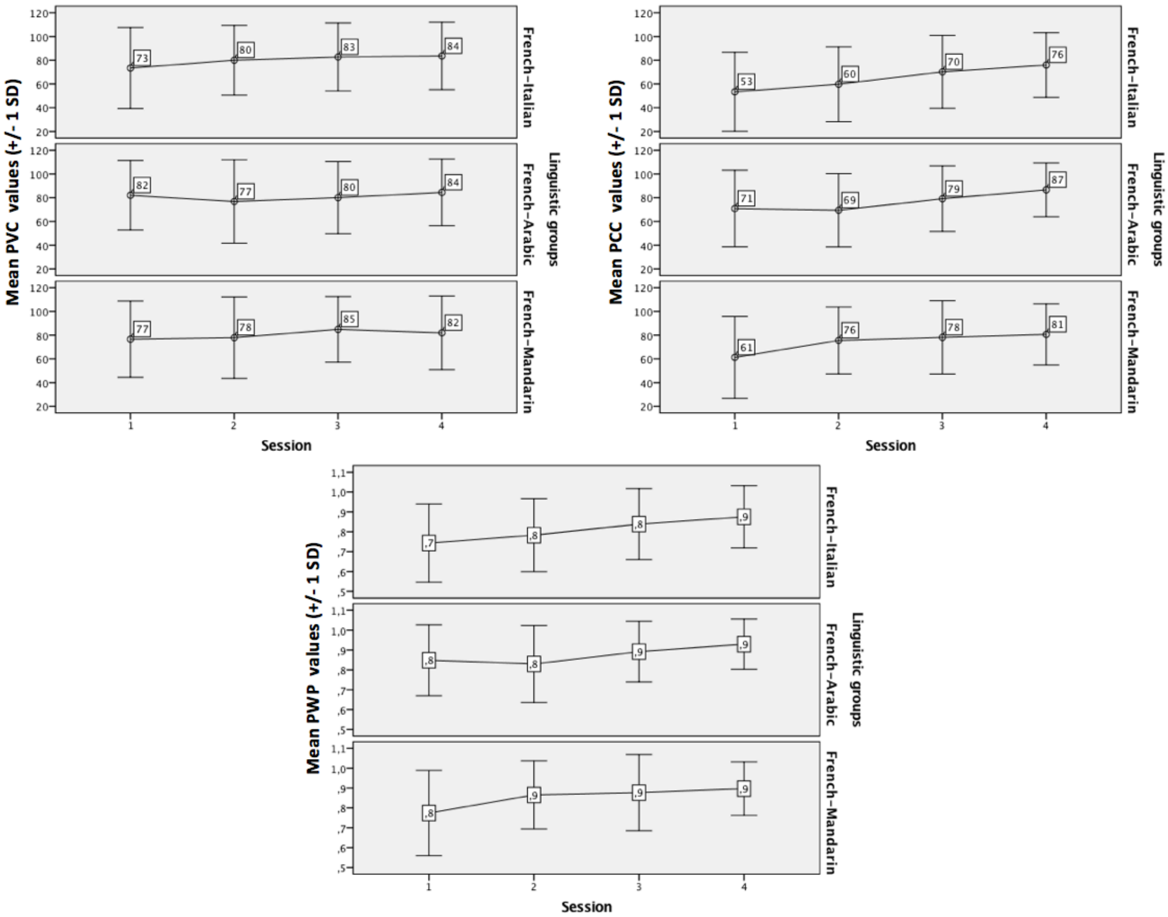

Figure 80: Evolution of PVC (left), PCC (right) and PWP (below) values over the four sessions for the three linguistic groups.

Chapter IV:

General discussion

IV GENERAL DISCUSSION

We now discuss the results obtained for all measures taken on the different structures investigated (i.e., vowels, consonants and whole-word forms) and for the correlations calculated between the item-based measures (i.e., global PVC and PCC, PWP and PDAP-IS) in a global perspective. This general discussion will be organized in the following manner: first, we expose the similar and different development patterns observed in the three linguistic groups; therefore, both developmental variables of session and chronological age are discussed in that sub-section. Then, we review the impact of the series of independent variables considered in our analyses.

IV.1 SIMILARITIES AND DIFFERENCES IN DEVELOPMENTAL PATTERNS ACROSS LINGUISTIC GROUPS

Several similarities in developmental patterns have been found in the three linguistic groups. Both developmental variables of session and chronological age significantly impacted a large part of the measures for the three linguistic groups and the direction of the effect found was always the same: children gain in organization (for vowels) and segmental precision as they grew older. In other words, the children's phonetic and phonological skills improved with time. Then, we globally observed a more limited evolution of vowel production accuracy in comparison to consonants, which accuracy evolved much more from session to session. As hypothesized earlier, this might be due to the fact that children may already have been more advanced in terms of vowel production, the development of which could be momentarily overshadowed by consonant acquisition. Besides, the acoustic measures indexing the size and organization of the vocalic system (i.e., VSA and PHI values) uncovered a large amount of inter- and intra-individual variability for all three types of bilinguals. In contrast, a rather linear increase of consonant accuracy occurred from session to session in the three linguistic groups. Correlations between segmental accuracy measures (i.e., global PVC and PCC) and measures of whole-word forms' distance to targets (i.e., PWP and PDAP-IS) yielded rather similar outcomes for all three groups, indicating a comparable relation between the different measures. More precisely, the highest correlations were found between PCC and both PWP and PDAP-IS and the lowest between PVC and both PCC and PWP. If the weak relation between PVC and PWP could certainly be anticipated, the near absence of link between vowel and consonant accuracy was not necessarily awaited. This can be explained by the fact that global PVC values were initially already high for most participants and did not evolve as much as PCC values did across the four sessions. Besides, this confirms that in all three groups the consistent decrease in whole-word distance to target over time is mainly related to an improvement in terms of consonant accuracy, and that consonant and vowel accuracy developed quite independently in our participants over the four recording sessions.

Still, the three linguistic groups also demonstrated different developmental trends with regard to consonant development. French-Arabic bilinguals globally showed a faster consonantal acquisition, as they outperformed the two other groups on all measures focused on consonants (i.e., global PCC and all nuanced PCCs) as well as on measures of whole-word forms distance to targets. As already argued, this acceleration phenomenon might result from cross-linguistic interaction between the children's two phonological systems. More particularly, these children might have benefited from: (1) the richer Arabic consonant inventory involving sounds which are more challenging from an articulatory point of view, and (2) the presence of complex consonant sequences occurring in both word-initial (albeit only in surface realizations) and word-final positions in Arabic.

In addition, the performances of the French-Arabic participants are the closest to that of age-matched French-speaking monolinguals (based on data from MacLeod et al., 2011). Interestingly, correlations between global PVC and the other measures (i.e., global PCC, PWP and PDAP-IS) are slightly stronger in that group. This could indicate a more parallel development of vowels and consonants in French-Arabic bilinguals. Indeed, no particular discrepancy was observed in the development of these two types of segments for those children, since when a regression occurred in vowel production at a particular session, it also occurred in consonant production at the very same session.

French-Italian bilinguals displayed a slower consonant acquisition than children from the other two groups, both globally and for all targeted syllabic constituents as well as for fricatives. This is reflected by greater distances to targets in whole-word forms. This deceleration phenomenon cannot readily be explained in terms of cross-linguistic interaction. Although we presumed a slower development in comparison to French-Arabic bilinguals for global consonant and word-final singleton codas accuracy (and, eventually, for fricatives), we did not expect French-Italian bilinguals to be lagged behind French-Mandarin bilinguals. On the contrary, the French-Italian participants were expected to benefit from their exposure to the syllabic structure of Italian, which is much less restricted compared to that of Mandarin. Still, our limited sample of French-Mandarin participants might not be considered as representative of the general population as is the case of French-Italian (and French-Arabic) children. In addition, the two French-Mandarin participants presented very contrasted developmental trajectories, as the older participant (i.e., B15) displayed relatively high PCC values (for all structures investigated) at all sessions while the other participant showed a strong improvement from the first to the last session. Besides, correlations between global PVC and the other measures (i.e., global PCC, PWP and PDAP-IS) were the weakest in that group. This suggests a rather non-parallel development of vowels and consonants, as was indeed indicated by the evolution curves of the two segmental accuracy measures.

At this point, a word should be said about the methodological choice to give a predominant position to the session in our analyses. Indeed, the children's developmental patterns have been mainly considered according to this developmental variable as it enabled us to analyse the same amount of data for each child for each point of comparison. This decision certainly has had an impact on the results' direction. Considering chronological age as the main developmental variable would probably have given rise to similar global tendencies but more specifically, it might have allowed us to observe other interesting phenomena. If our sample would have permitted it, we may have chosen chronological age as the main developmental variable but unfortunately, only but a limited number of comparisons between age-matched children of the three linguistic groups would have been possible in the current study. In addition, the children compared would have been at a different session. There was thus no perfect approach to capture the effect of time on the children's speech development. Albeit to a lesser extent, we also examined the evolution of children's performances according to chronological age in our investigation of individual evolution curves. Besides, chronological age was also included in our analyses focused on the different independent variables.

Finally, comparisons with age-matched monolinguals did not show a bilingual advantage, as was previously demonstrated in several studies (Goldstein & Bunta, 2012; Kehoe & Havy, 2019). On the contrary, it indicated a temporary delay in bilingual children from all three linguistic groups, which was then almost completely recovered around the age of 42 months. In fact, it might be assumed that bilingual toddlers follow specific developmental trajectories, similar but not identical to those of monolinguals, and that the challenge of simultaneously acquiring two systems might protract the development of certain structures. Besides, the gap between bilinguals and monolinguals observed for the proportion of whole-word proximity (i.e., PWP) appeared to be smaller than the one observed for mean PCC values and this, for all three groups. This could imply that, despite differences in terms of segmental accuracy, a fair degree of proximity to the target is maintained by the bilingual children. As stated by Bunta et al. (2009), "phonological acquisition may not be driven just by a need to increase word complexity, but also by a need to maintain a constant relationship between the child's productions and their targets" (Bunta et al., 2009: 74). This could, in turn, be related to the fact that language acquisition is driven by the need to communicate and to learn form-meaning associations and that phonological development might be structured by "whole-word" representations as put forward by whole-word-templatic phonology.

IV.2 IMPACT OF SUBJECT-RELATED AND ITEM-RELATED VARIABLES

In this study, we have considered a number of independent variables in order to examine their impact on the children's phonetic and phonological development. More precisely, we have investigated the influence of both subject-related and item-related variables.

Our results have shown a wide-ranging effect of the two developmental variables of session and chronological age, of both vocabulary scores and of item-related variables of elicitation, phonological complexity and lexical frequency. Linguistic dominance, gender and siblings - which have been tested to a more limited extent due to the specificities of our participant's sample - were found to only marginally influence speech production. As the effect of both developmental variables of session and chronological age has just been discussed in relation to the linguistic group, this issue will not be returned to in the following sub-sections.

IV.2.1 WIDE-RANGING EFFECTS

IV.2.1.1 Impact of the lexical development in French and in both languages

Both vocabulary scores (i.e., in French and in both languages combined) turned out to have a significant effect on all measures – that is, global vowel and consonant accuracy, consonant accuracy in all targeted syllabic constituents, fricatives' accuracy and whole-word forms' distance to targets – in the French-Italian and French-Arabic groups. Moreover, the effect found for the two vocabulary scores was the same for all tested measures: children's performances improve as the vocabulary scores increase. In other words, a more advanced lexical development – either in French or in both languages – benefits speech production. These results are not surprising, given that children are acquiring their phonological system while simultaneously building a lexicon in which phonological representations of words are stored. Our results thus indicate that both language-specific and global lexical competence are predictive of phonological proficiency. These results are partly in line with findings from studies about bilingual speech acquisition. Indeed, an effect of language-specific lexical skills on phonological development was evidenced by Scarpino's investigation (2011) which did not examine the impact of the children's global lexical competence. In contrast, phonological development has been shown to be impacted by the total vocabulary score for both languages combined but not by the French vocabulary score in the study led by Kehoe and Havy (2019).

Still, a different pattern was found for the French-Mandarin participants for whom the total vocabulary score did not emerge as a significant factor neither for the production of consonants in the targeted syllabic constituents (except for word-final codas), nor for the production of the targeted fricatives. This absence of effect of total vocabulary score for the French-Mandarin participants more particularly resulted from the fact that the child who had higher total vocabulary scores also had lower values for all nuanced PCC measures, possibly due to her more reduced exposure to French. It is conceivable that lexical knowledge in Mandarin might no benefit phonological development in French given that the two languages share only a few phonological properties, as pointed out by Kehoe and Havy (2019). But in that case, a stronger effect of the total vocabulary score should have been observed for the French-Italian group given the larger amount of shared phonological properties between French and Italian. Considering the vocabulary score in each L1 separately might have helped to better understand the link between lexical development in both languages and phonological development in French. Indeed, if the link between vocabulary size and phonological skills is probably bidirectional in monolinguals, as pointed out by several studies (Metsala & Walley, 1998; Beckman, Munson & Edwards, 2007; Stoel-Gammon; 2011), the relation becomes more complex in a bilingual child who concomitantly develops two lexicons as well as two phonological systems.

IV.2.1.2 Impact of the elicitation technique

The elicitation technique emerged as a significant variable for all measures for the French-Arabic group and for all measures except consonant accuracy in word-final complex codas for the French-Italian group. The impact of the variable was less pronounced for the French-Mandarin participants, for whom elicitation turned out to significantly affect global vowel and consonant accuracy, accuracy of word-final codas and whole-word forms' distance to targets. Overall, results show that children are more accurate when they spontaneously name a word than when they repeat it, and that they are the least accurate when they repeat a spoken model for a word they do not know yet. It remains unclear why this variable has a smaller impact for the French-Mandarin participants. Besides, the qualitative difference between naming and repetition of unknown words is more marked in the French-Arabic group, as children from that group are particularly more precise when they spontaneously name words. Given that the French-Arabic participants outperform children from the two other groups on nearly all measures, it might be assumed that they can rely on more stable phonological representations when naming words.

Our findings thus conflict with the idea that the children's productions would gain in precision in the presence of a spoken model, and that the inclusion of repetitions in a speech assessment could result in an over-estimation of the children's phonetic-phonological skills. On the contrary, findings from our study indicate that children are not advantaged when they are provided with an oral target, in line with several studies previously mentioned (Goldstein & Fabiano-Smith, 2004; Grandon, 2016). Still, a qualitative difference was robustly observed between named and unknown repeated words and, to a lesser extent between known and unknown repeated words. As already argued, children's lower performances in cases of repetition of unknown repeated word is most likely attributable to the fact that, when repeating words that are not yet part of their lexicon, children are faced with an additional process of word learning. As they do not have stored representations for such words yet, their productions are subjected to more truncations or substitutions. More akin to verbal imitation, such repetitions should thus ideally not be placed on the same level as naming and repetitions of known words when analysing speech production skills in children.

IV.2.1.3 Impact of phonological complexity and lexical frequency

Item-related variables of phonological complexity and lexical frequency were found to significantly impact global vowel and consonant accuracy as well as the distance of whole-word forms to targets in the three linguistic groups. More specifically, the children's productions were more accurate in less complex and more frequent words than in more complex and less frequent words. Assessing French segmental acquisition in cochlear-implanted *vs.* normally-hearing children, Grandon (2016) did observe a significant impact of the word's complexity, but only on the production of stops, not of vowels and fricatives, which led her to postulate that children already had stable representations for these sounds. Given that our participant sample involved much younger children than those included in her study (aged between 5;6 and 10;6 years), it is not surprising that both variables turned out to be significant factors in our results. Indeed, children were still in the process of building their phonological system and phonemic categories. Characterized by a high degree of variation, their speech productions were not stable yet and therefore, more subjected to the influence of complexity and frequency variables.

With regard to phonological complexity, it should be recalled that this variable was not included in the analyses for the different syllabic constituents and fricatives as the limited number of items preclude the inclusion of all three levels of complexity for each targeted structure. Concerning lexical frequency, it was not found as a significant factor for consonant accuracy in the different targeted syllabic constituents in any of the three linguistic groups. We have postulated that the articulatory challenges posed by the production of consonant clusters could have taken precedence over the frequency variable. The effect of the variable might also not have emerged due to the fact that only a restricted subset of items (i.e., the words containing word-final codas, word-initial branching onsets and word-final complex codas) were considered in the analyses. But then, it does not explain why the effect of lexical frequency did stand out for fricatives accuracy. It would have been interesting to examine whether an effect of phonological complexity emerges in cases where lexical frequency does not (i.e., for consonant accuracy in the different syllabic constituents). Assessing the influence of complexity might also have allowed us to further validate the Complexity Index developed in the frame of our word-naming task and based on which the items' phonological complexity was calculated.

IV.2.2 Marginal effects

The impact of linguistic dominance and gender was tested for the French-Italian and French-Arabic groups only, given that the French-Mandarin group only included two participants (who both had siblings). In addition, the influence of the presence of siblings was not assessed for the French-Arabic group since the only French-Arabic participant who had no siblings was the oldest child, who performed almost at ceiling for all accuracy measures.

IV.2.2.1 Linguistic dominance

Contrary to expectations, results showed a rather limited impact of linguistic dominance on the different structures under investigation. Indeed, linguistic dominance had no impact on none of the measures focused on vowels and with regard to consonants and whole-word forms, an effect of this variable only emerged for the French-Arabic group. Also, the observed effects often differed from what was expected.

More precisely, the French-Arabic participants characterized by a balanced bilingualism displayed lower rates of global consonant accuracy than Arabic dominant children. Arabic-dominant children were also found to outperform both balanced bilinguals and French-dominant children in the production of fricatives. These results are quite surprising, as one would not expect to observe more accurate productions in French for children who are less exposed to French. Rather, one would assume that the more a child gets exposed to one language, the more accurate his/her speech productions should be in that specific language, as was observed in several bilingual studies (Gildersleeve-Neumann et al., 2008). This pattern was actually observed in the same group of bilinguals for whole-word forms' distance to targets. In that case, the French-dominant children displayed the highest performances (i.e., the lowest PDAP-IS values), as expected. The effect of linguistic dominance can thus take different directions within the same linguistic group, depending on the particular phonological structure investigated.

Such varied outcomes make it difficult to provide a clear interpretation of the actual impact of this variable. It might be assumed that such results are not due to linguistic dominance only, but that one or several other factors could come into play. In fact, results from other bilingual studies could similarly not be explained by invoking the degree of exposure to languages (Almeida, 2011; Kehoe & Havy, 2019). Similarly, the greater exposure to French did not prove to be profitable for any of the phonological measures in the French-Italian group. As already pointed out, the absence of effect of language exposure for that group might be due to the older age of the non-French (Italian) dominant children. Going back to the French-Arabic group, the two eldest children in that group were characterized by different profiles, as one had been more exposed to French (i.e., participant B11) while the other had been equally exposed to both languages (i.e., participant B04). In consequence, the mixed results can not be attributed to chronological age for the French-Arabic group. We postulate that the more accurate production of fricatives by non-French dominant children could actually result from their greater exposure to Arabic and its richer fricative inventory or, in other words, that the cross-linguistic influence observed for fricatives could effectively originate from the children's linguistic dominance, only not French-dominance in this case.

IV.2.2.2 Gender and siblings

Gender only emerged as a significant factor for: (1) global consonant accuracy in the French-Italian and French-Arabic groups, (2) consonant accuracy in word-initial branching onsets for the French-Italian participants, and (3) for whole-word forms' distance to targets in the French-Arabic group. Girls outperformed boys for all measures in the French-Italian group whereas the opposite tendency was observed for the French-Arabic participants. As previously noted, the lower rates of consonant accuracy observed for girls in the French-Arabic group might be attributable to chronological age rather than to gender, as the youngest participant (i.e., participant B14) - who globally displayed the lowest performances - is a girl and conversely, the oldest participant (i.e., participant B11) - who globally displayed the highest performances - is a boy. Interestingly, the effect observed in the French-Italian group are consistent with previous findings according to which better performances are observed in girls (Dodd et al., 2003; Kehoe & Havy, 2019). It is likely that the outcomes observed in the largest group of participants (i.e., the French-Italian group) might be more representative than those observed in the more reduced French-Arabic sample. Still, other language areas such as grammatical and lexical competence might also be more impacted by gender than phonetic and phonological skills.

Finally, the presence of siblings turned out to be a significant factor only for global consonant accuracy, accuracy of word-final complex codas and for whole-word forms' distance to targets in the French-Italian group. In line with the effect observed in the literature (Bridges & Hoff, 2014), children with older siblings displayed higher performances than those without siblings. Given that the impact of siblings was only assessed for the French-Italian bilingual children, it is not possible to know whether this variable would also have emerged only marginally as a significant factor for the children exposed to the other language pairs.

IV.3 Individual trajectories

If similarities and differences have been observed in the developmental patterns of the three linguistic groups, our results also highlighted a large amount of individual variability. Globally, all children demonstrated improvement from the first to the last session but contrasted developmental profiles also emerged from the data, reflecting different learning styles and speech production strategies. Two types of profiles seem relevant to mention here: children displaying a rather fast and linear phonological development and, in contrast, children characterized by a slower and potentially delayed development.

A particularly rapid development was observed in a couple of children belonging to different linguistic groups, such as the French-Italian participants B10 and B12 and the French-Arabic participants B05 and B06. Initially aged between 21 and 25 months, these children make significant progress for all structures investigated, from segments to whole-word forms. It appears that these participants share several characteristics: they are all boys with older siblings and all of them but one (i.e., B06) have a linguistic dominance in French. Given the marginal effect globally observed for both the presence of older siblings and linguistic dominance (see previous points, IV.2.2.1 and IV.2.2.2.), this suggests that the impact of these variables might indeed have been diminished under the influence of other factors. In addition, these four children all display *No-risk index* values between 22 and 26 which, as previously explained (see section II.2), would probably indicate a typical language development. The index values are thus in line with the developmental trajectories observed in these children.

In contrast, other participants presented a much slower phonological acquisition, characterized by low and/or not much evolving performances for the different structures investigated. Two children from the French-Italian group are worth mentioning: the participant B02, initially aged 25 months, and the participant B07, initially aged 33 months. These two participants are boys with no siblings, one of whom is characterized by a linguistic dominance in Italian and the other by a balanced bilingualism. Interestingly, B02 and B07 both present low *No-risk index* values of respectively 19 and 17. An index value below 17 would probably indicate an atypical development and a value between 18 and 20 would suggest a non-typical development that requires monitoring. Again the index values appear to correspond to the developmental patterns observed.

This suggests that the *No-risk index* could be a reliable tool to detect children at-risk for a delay or a potential language/speech impairment. Still, the index was only calculated once, at the very beginning of the longitudinal follow-up and was not actualized on the subsequent recording sessions. No regression was observed in these two participants. Both children did progress – albeit slowly – from the first to the last session, especially B07 who finally caught up with children of the same age at the end of the study. Rather than a speech impairment, one should rather speak of an initially delayed development for these two children which could be attributed to two factors for B07: recurrent hearing infections in his infancy and a linguistic dominance in Italian, or a combination of both. The cause of the delay is less clear for B02. One might argue that his reduced exposition to French (in comparison to age-matched participants B10 and B12) could be one of the factors in play. In this specific case, it might also have been related to a particularly withdrawn behaviour displayed by that child. Indeed, the parents expressed their preoccupation about their child's behaviour pattern when filling the questionnaire's section about parental concern (see section II.2.). As the child entered nursery school (a little before the last session), this pattern progressively disappeared and, concomitantly, his language skills began to improve.

These contrasted individual cases once again highlight the fact that a wide range of factors are susceptible to impact language development in bilingual children and that individual characteristics should not be neglected. Besides, it also shows that the use of parental questionnaires and resulting calculated indexes proves to be highly relevant when assessing speech development in bilingual toddlers.

Chapter V:

Conclusion and perspectives

V CONCLUSION AND PERSPECTIVES

In the last decades, a growing number of studies have been conducted about bilingual speech production development, focusing on the comparison between bilingual and monolingual toddlers. Findings have shown that, although phonetic and phonological development of bilingual children presents similarities with that of monolinguals, it definitely has its own unique characteristics. Indeed, bilingual toddlers are faced with the challenge of simultaneously acquiring two phonological systems which results in specific developmental paths. Discrepancies observed between bilingual and monolingual children have been explained in terms of cross-linguistic effects due to the interaction between the two languages in contact. Still, the mechanisms underlying bilingual acquisition are not yet well understood given the large number of interlinked explanatory factors related to both the properties of the two languages and the exposure patterns.

Aimed at providing new insights about bilingual speech acquisition, our research proposed a different approach and attempted to address several methodological shortcomings of previous works. Rather than assessing bilinguals in relation to monolinguals, our study focused on the comparison between bilingual children exposed to different language pairs, namely French-Italian, French-Arabic and French-Mandarin. There is, to our knowledge, only one study (Kehoe and Havy, 2019) about bilingual speech acquisition that has involved more than one language pair. Our particular objective was to study the specific impact that each linguistic combination would have on French phonetic and phonological development. The differences between the linguistic groups under study as well as the high individual variability observed within the groups have once again stressed the complexity of the bilingual development and the necessity to control as much as possible the different factors susceptible to impact phonetic and phonological development in bilingual toddlers.

In addition to focusing on language pairs rarely studied before, the current study involved the implementation of an original and adapted protocol in order to assess the evolution of the children's speech productions. Indeed, children were recorded longitudinally at regular four-months intervals and their speech productions, elicited via a self-developed word-naming task, have been subjected to complementary analyses based on both acoustic measures and phonetic transcriptions. To our knowledge, no bilingual production study has yet combined these two types of analyses. Furthermore, only a few investigations have involved acoustic analyses (Khattab, 2002; Kehoe, 2002; Kehoe, Lleó & Rakow, 2004; Fabiano-Smith & Bunta, 2012; Yang et al., 2015) and none of them have focused on fricatives. Another innovative aspect of this research is the inclusion of new measures used for the first time with a child population, namely the PHI index (Huet & Harmegnies, 2000) and the PDAP-IS (Ghio et al., 2018). Our protocol also included parental questionnaires allowing us to characterize each participant's linguistic profile via quantification indexes (i.e., *No-risk index* and *Index of linguistic dominance*) as well as to document the lexical development in French and in both languages. This multi-tool protocol has enabled us to examine the impact of a series of factors, some of which insufficiently investigated (i.e., lexical development, gender, siblings), on the development of phonological skills.

Still, our work also presents several limitations resulting from methodological issues. Indeed, the nature of the participant's sample imposed several constraints on the analyses conducted. First, the reduced sample size and the heterogeneity of the groups restricted the types of statistical analyses that could be conducted on data. This was especially the case for the French-Mandarin group, for which several subject-related independent variables were confounded with the subject and therefore, potentially found effects were rather attributable to the subject him/herself than to the variable of interest. Then, and as previously mentioned (see section IV.1), it also compelled us to consider the session as the main developmental variable, whereas chronological age might have brought other developmental patterns into light within the three groups.

The perspectives opened up by this study are multiple. The current work consisted in an exploratory study in which we attempted to bring innovative methodological aspects as well as to consider a number of variables that may affect bilingual phonological development. On this basis, our prospect is to conduct future studies to more particularly investigate the relations between these different variables. Indeed, some of them have been found to have a unilateral effect on all measures (i.e., session, chronological age, vocabulary scores), whereas others only marginally impacted children's performances (i.e., linguistic dominance, gender and siblings). Our objective would thus be to test the interaction between different variables – such as the relation between linguistic dominance and the language's structural properties or between chronological age and gender – in order to better understand the individual developmental patterns and to evolve towards a more hypothetico-deductive approach. In parallel, several aspects of the children's speech productions could also be more thoroughly investigated. Indeed, assuming that the corpus and/or the data points would be extensive enough, the acoustic analyses could extend to all French vowels and consonants, which could be systematically assessed according to their manner and/or place of articulation, both globally and in the different syllabic constituents. In line with this, phonological processes could be examined in more details, as a function of the position of the consonant within the syllable and the word.

To conclude, the present study also points out the fact that reporting bilingual performances to that of monolinguals is most probably not the most appropriate approach to best assess - and understand the specificities of - bilingual development, especially considering the greater variability that could be expected from the wide ranges of bilingual experiences. In fact, comparisons between different types of bilinguals and between bilinguals and monolinguals are both needed in order to get a more complete and nuanced picture of bilingual acquisition. Referring exclusively to monolingual norms could lead to diagnosis errors, whether of under- and over-diagnosis. Indeed, numerous speech therapists and developmental psychologists regret that bilingual children do not benefit from a clinical follow-up similar in quality to that set up for monolingual children. More precisely, they recommend that language assessment tools as well as specific intervention strategies be developed for bilingual toddlers. Henceforth, an underlying objective of our research was to contribute, albeit modestly, to making the objective of defining bilingual developmental norms a reality in the near future. Such norms will allow building adapted instruments in order to ensure early diagnostic and quality treatment for bilingual populations.

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VII APPENDICES
Appendix 1

Consent form

UMONS
Université de Mons

FORMULAIRE D'INFORMATION ET DE CONSENTEMENT

Ce formulaire a pour but de vous informer de notre démarche. Avant que vous n'acceptiez de participer à cette étude, vous devez connaître clairement nos objectifs, les procédures qui seront mises en place ainsi que vos droits quant à la recherche, afin de prendre une décision informée. C'est ce qu'on appelle un formulaire de consentement éclairé.

Veuillez lire attentivement ce document et poser toutes les questions que vous souhaitez à l'investigateur.

Présentation de l'étude

L'étude que nous menons dans le cadre de notre mémoire de Master de spécialisation en Sciences du langage et de notre doctorat en Psychologie et Sciences de l'Education, effectués conjointement à l'Université de Mons, porte sur l'impact d'une expérience bilingue précoce sur le développement du langage oral.

L'objectif de notre recherche est d'observer le développement phonologique et phonétique d'enfants bilingues ayant différentes combinaisons linguistiques, afin de contribuer à une meilleure compréhension des spécificités du développement langagier bilingue.

Plus concrètement, le/les parent(s) participant à l'étude est/sont amené(s) à remplir deux types de questionnaires lors d'un entretien se déroulant à son/leur domicile. Ensuite, plusieurs séances seront programmées avec l'enfant participant à l'étude. Ces séances consisteront en une observation de la manière dont l'enfant s'exprime lors d'un jeu impliquant un livre avec des images représentant des objets ou des animaux familiers. L'ensemble de ces séances d'observation feront l'objet d'enregistrements audio et se dérouleront au domicile des familles en présence d'un/des parent(s). Les séances auront lieu à intervalles réguliers, tous les quatre mois, durant une période d'un an et demi et leur durée sera comprise entre trente minutes et une heure.

L'ensemble des données récoltées feront l'objet d'analyses ultérieures menées à des fins scientifiques, en relation directe avec les objectifs de la recherche mentionnés ci-dessus.

Respect de la vie privée

Cette étude se soumet aux règles éthiques et déontologiques de la Fédération Belge des Psychologues. L'ensemble des données récoltées et les résultats des analyses seront anonymes et nous nous engageons à ce qu'ils soient diffusés uniquement dans le cadre de notre étude en respectant les règles déontologiques de la communauté scientifique.

Conditions de participation

La participation à cette recherche est volontaire et vous êtes libre d'accepter ou de refuser de participer à cette étude. Plus précisément, vous êtes libre de décider de remplir les questionnaires demandés complètement ou pas, et de consentir à ce que votre enfant participe aux différentes séances d'observation ou non.

Vous pouvez abandonner votre participation et celle de votre enfant à cette étude à tout moment, sans qu'il soit nécessaire de justifier votre décision. En outre, vous pouvez, à tout moment et sans devoir avancer aucune raison, demander la consultation des différentes données collectées, ainsi que leur rectification ou leur suppression de la base de données sans aucun frais. Enfin, vous pouvez également demander à ce que les résultats des analyses vous soient communiqués.

Coordonnées de l'investigateur

- Nom et prénom : Philippart de Foy Marie (étudiante-doctorante à l'Université de Mons)

- Adresse e-mail : marie.philippartdefoy@umons.ac.be

- Téléphone : +32(0)476/91.11.51

Participant

- Je, soussigné(e), ..., parent de ...., déclare avoir lu le formulaire d'information et consens de mon plein gré à ce que mon enfant participe aux séances d'observation dans le cadre du mémoire et de la thèse de doctorat de Marie Philippart de Foy.

- Je déclare avoir reçu une explication sur la nature, le but et la durée de l'étude et j'ai eté informé(e) sur ce que l'on attend de la part du/des parent(s) et de l'enfant participant à l'étude.

- J'ai reçu une copie de ce formulaire d'information et de consentement, datée et signée.

- J'ai compris que je suis libre de participer ou non, de remplir les questionnaires, complètement ou non, et d'abandonner ma participation et celle de mon enfant à l'étude à tout moment, sans devoir justifier ma décision.

- J'ai compris que des données concernant ma famille et mon enfant seront récoltées et que l'investigateur se porte garant de la confidentialité de ces données. Je suis conscient(e) que je peux à tout moment demander la consultation, rectification ou suppression des données sans devoir avancer de raison et sans aucun frais.

- J'accepte que les données récoltées fassent l'objet d'analyses ultérieures à des fins scientifiques et, si je le souhaite, je peux etre informé(e) des résultats de ces analyses à tout moment.

- J'accepte que les résultats, anonymes et confidentiels, soient diffusés à des fins scientifiques en respectant les règles déontologiques de la communauté scientifique.

______________________________________ __________________________

NOM ET PRENOM **DATE**

____

SIGNATURE (précédée de la mention « lu et approuvé »)

<u>Investigateur</u>

Je, soussignée, ..., déclare avoir fourni oralement les informations nécessaires sur l'étude, avoir répondu à toutes les questions du participant et lui avoir donné un exemplaire de ce document.

Je confirme qu'aucune pression n'a été exercée sur le participant pour qu'il/elle accepte de prendre part à l'étude et je suis prête à répondre à toutes les questions supplémentaires, le cas échéant.

______________________________________ __________________________

NOM ET PRENOM **DATE**

____

SIGNATURE (précédée de la mention « lu et approuvé »)

Appendix 2

Parental questionnaire

QUESTIONNAIRE DEVELOPPEMENT ET LANGAGE DESTINE AUX PARENTS D'ENFANTS BILINGUES D'AGE PRESCOLAIRE

Ce questionnaire est basé sur différents questionnaires existants : le questionnaire *Alberta Language Environnement* – ALEQ (Paradis, 2011) et son adaptation française (Laloi, 2015), le questionnaire *Alberta Language and Development* – ALDeQ (Paradis, 2010) et le questionnaire *Questionaire for parents of bilingual children for infants and toddlers* – PaBiQ-IT (Tuller, 2015).

Nom de l'enfant :

Age actuel de l'enfant (années et mois) : Fille / garçon (entourez)

Date de l'entretien :

Personne avec laquelle l'entretien a été réalisé (ex : mère/père de l'enfant) :

Personne menant l'entretien (ex : étudiante(e), chercheur) :

Si le questionnaire n'a été pas complété dans le cadre d'un entretien, précisez la personne ayant répondu aux questions (ex : mère/père de l'enfant) :

SECTION A – QUESTIONS SUR L'ENFANT

1 – Informations générales sur l'enfant

1.1. Date et lieu (ville et pays) de naissance :

1.2. Lieu de résidence actuelle (ville et pays) :

1.3. Si le lieu de naissance (ville et/ou pays) est différent du lieu de résidence actuelle, précisez la date d'arrivée dans le lieu de résidence actuelle :

1.4. Si l'enfant a des frères et sœurs, précisez l'ordre de naissance de l'enfant (entourez) :

1$^{er/ère}$ né(e) 2ème né(e) 3ème né(e) 4ème né(e) 5ème né(e) 6ème né(e)

Fratrie (détails)

Ordre de naissance	Prénom	Date de naissance	Sexe
1 - ainé(e)			

2			
3			
4			

2 - Histoire précoce : premiers jalons développementaux

2.1. Vers quel âge (en mois) votre enfant a-t-il/elle produit son premier mot ?

Age : .... et précisez la/les langue(s) : ....

2.2. Votre enfant a-t-il/elle déjà commencé à combiner des mots et/ou à faire des petites phrases (même si elles ne sont pas correctes, exemple : *encore pain* ; *a plus gâteau*, etc.) ? Si oui, à quel âge (en mois) ?

Age : .... et précisez la/les langue(s) : ....

2.3. Avez-vous ou avez-vous déjà eu une quelconque inquiétude au sujet du langage de votre enfant ?

OUI ou NON ; si oui, précisez la/les langues (entourez): Français - Langue (précisez) : ....

Et expliquez brièvement : ....

....

....

2.4. Lorsque vous pensez à d'autres enfants du même âge que vous connaissez, pensez-vous que votre enfant est différent(e) au niveau de l'émergence du langage (entourez la réponse correspondante) ?

Pas différent(e) du tout – Un petit peu différent(e) – Assez différent(e) – Très différent(e)

Si votre enfant est différent(e), pouvez-vous expliquer en quoi ?
....
....

2.5. Est-ce que votre enfant a ou a eu des problèmes d'audition ou des otites fréquentes ?

OUI ou NON

<u>INSTRUCTION</u> : les réponses aux questions 2.1 à 2.3 ET 2.5 sont à reporter dans le tableau au point 1. *Indice de non-risque*, p. 13.

2.6. De manière générale, à quel degré votre enfant a-t-il/elle été en contact avec/exposé(e) aux différentes langues (cochez les cases correspondantes) :

	0 **Jamais**	1 **Rarement/de temps en temps**	2 **La moitié du temps**	3 **Souvent**	4 **Toujours**
Français					
Langue (précisez) :					
Autre :					

2.7. Dans quel(s) contexte(s) et à partir de quel âge (en mois) votre enfant a-t-il/elle été exposé(e) aux différentes langues ?

Votre enfant a été exposé(e) à ... → avec/via ... ↑		Français		Langue (précisez) :		Autre :	
		Oui/non	Age	Oui/non	Age	Oui/non	Age
a. la mère	Oui - non	Oui - non		Oui - non		Oui - non	
b. le père	Oui - non	Oui - non		Oui - non		Oui - non	
c. les frères et sœurs	Oui - non	Oui - non		Oui - non		Oui - non	
d. les grands-parents maternels	Oui - non	Oui - non		Oui - non		Oui - non	
e. les grands-parents paternels	Oui - non	Oui - non		Oui - non		Oui - non	
f. la nounou/gardienne	Oui - non	Oui - non		Oui - non		Oui - non	
g. d'autres adultes :	Oui - non	Oui - non		Oui - non		Oui - non	
h. le personnel de la crèche	Oui - non	Oui - non		Oui - non		Oui - non	
i. des comptines/des chansons/des histoires	Oui - non	Oui - non		Oui - non		Oui - non	
j. la télévision	Oui - non	Oui - non		Oui - non		Oui - non	
Age du 1er contact							

Total oui/non	**T**	**A**		**B**		**C**	
Taux d'exposition à chaque langue : Nombre de contextes dans une langue (A, B, C) sur nombre de contextes total (T)		**A/T**		**B/T**		**C/T**	

<u>INSTRUCTION</u> : les réponses aux questions 2.6. et 2.7. sont à reporter dans le tableau au point n° 2. *Exposition précoce pour chaque langue – quantité et qualité*, p. 14.

2.8 A quel âge votre enfant a-t-il/elle commencé à être exposé(e) de façon <u>importante et régulière</u> à chacune des langues ?

<u>Remarque</u> : *de façon importante et régulière* = au moins-minimum 3 jours complets/24h par semaine

	Age d'exposition (en mois)
Français	
Langue (précisez) :	
Autre :	

<u>INSTRUCTION</u> : les réponses à la question 2.8. sont à reporter dans le tableau au point n° 3. *Durée d'exposition pour chaque langue*, p. 14.

3 - Capacités actuelles

3.1. Dans quelle(s) langue(s) votre enfant parle-t-il/elle ou produit-il/elle actuellement des mots isolés ?

....

Selon vous, dans quelle langue se sent-il/elle le plus à l'aise ? ....

3.2. Dans le tableau ci-dessous, estimez les capacités actuelles de votre enfant pour chaque langue :
Vous pouvez choisir d'évaluer votre enfant par rapport à d'autres enfants monolingues ou bilingues <u>OU</u> les deux, selon les points de comparaison dont vous disposez dans votre entourage.
<u>INSTRUCTION</u> : les réponses à la question 3.2. sont à reporter dans le tableau au point 4. *Capacités actuelles*, p. 14.

	Français	Langue (précisez)	Autre : ....

		....	
<u>Au moyen de l'échelle suivante</u> : *0 = pas très bien, 1 = un peu moins bien, 2 = pareil, 3 = très bien, mieux* Comparé à d'autres enfants *monolingues* du même âge, comment pensez-vous que votre enfant a. s'exprime en ? b. prononce les mots en ?			
<u>Au moyen de l'échelle suivante</u> : *0 = pas très bien, 1 = un peu moins bien, 2 = pareil, 3 = très bien, mieux* Comparé à d'autres enfants *bilingues* du même âge, comment pensez-vous que votre enfant a. s'exprime en ? b. prononce les mots en ?			
<u>Au moyen de l'échelle suivante</u> : *0 = pas autant, 1 = un peu moins, 2 = autant, 3 = plus* c. Comparé à d'autres enfants *monolingues* du même âge, pensez-vous que votre enfant connaît autant de mots en ?			
<u>Au moyen de l'échelle suivante</u> : *0 = pas autant, 1 = un peu moins, 2 = autant, 3 = plus* d. Comparé à d'autres enfants *bilingues* du même âge, pensez-vous que votre enfant connaît autant de mots en ?			
<u>Au moyen de l'échelle suivante</u> : *0 = beaucoup de difficultés, 1 = quelques difficultés, 2 = pareil, 3 = pas de difficulté/mieux* e. Comparé à d'autres enfants monolingues du même âge, pensez-vous que votre enfant a des difficultés à mettre des mots ensemble pour faire			

des petites phrases (même incorrectes) ?			
<u>Au moyen de l'échelle suivante</u> : *0 = beaucoup de difficultés, 1 = quelques difficultés, 2 = pareil, 3 = pas de difficulté/mieux* f. Comparé à d'autres enfants bilingues du même âge, pensez-vous que votre enfant a des difficultés à mettre des mots ensemble pour faire des petites phrases (même incorrectes) ?			
<u>Au moyen de l'échelle suivante</u> : *0= pas du tout/très peu satisfait(e), 1 = moyennement satisfait(e), 2 = assez satisfait(e), 3 = très satisfait(e)* g. Etes-vous satisfait(e) des capacités de votre enfant à comprendre en ?			
h. Etes-vous satisfait(e) des capacités de votre enfants à s'exprimer en ?			

3.3. Comment définiriez-vous globalement le langage de votre enfant ?
(Veuillez ne remplir qu'une seule case par langue)

	Français	Langue (précisez) :	Autre :
Il/elle ne comprend pas et ne parle pas :			
Il/elle comprend un peu et parle difficilement :			
Il/elle comprend bien mais parle difficilement :			
Il/elle comprend et parle facilement :			

3.4. Vous a-t-on déjà conseillé de ne parler qu'une seule langue avec votre enfant ?

OUI ou NON ; si oui, pourquoi ?...

4 – Utilisation des langues au sein de la famille

<u>Remarque</u> : *dans les différents tableaux qui suivent, veillez à ce que les proportions d'utilisation des différentes langues soient cohérentes les unes par rapport aux autres, ex : ne pas cocher la case « Toujours » pour plusieurs langues.*

4.1. Avec les parents

Quelle(s) langue(s) utilise la mère avec l'enfant ?

Quelle(s) langue(s) utilise l'enfant avec sa mère ?

	Mère => Enfant					Enfant => Mère				
	0 Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours	**0** Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours
Français										
Langue (précisez)										
Autre :										

Quelle(s) langue(s) utilise le père avec l'enfant ?

Quelle(s) langue(s) utilise l'enfant avec son père ?

Père => Enfant						Enfant => Père				
	0 Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours	**0** Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours
Français										
Langue (précisez)										
Autre :										

4.2. Y a-t-il un autre adulte qui prend soin de votre enfant à la maison (ex : grands-parents, nounou, etc.) ? OUI ou NON ; si oui, **précisez qui** :...

(Utilisez les tableaux additionnels en annexe p.12 si d'autres adultes s'occupent régulièrement de l'enfant.)

Quelle(s) langue(s) utilise l'autre adulte avec l'enfant ? Quelle(s) langue(s) utilise l'enfant avec l'autre adulte ?

Autre adulte => Enfant						Enfant => Autre adulte				
	0 Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours	**0** Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours
Français										
Langue (précisez)										
Autre :										

4.3. Avec les frères et sœurs ; indiquez les frères et sœurs par ordre décroissant d'âge (du plus âgé - Frère/sœur 1 => au plus jeune Frère/sœur 3).

(Utilisez les tableaux additionnels en annexe p.12 si l'enfant a plus de trois frères/sœurs).

Quelle(s) langue(s) utilise le frère/sœur 1 avec l'enfant ? Quelle(s) langue(s) utilise l'enfant avec le frère/sœur 1 ?

	Frère/sœur 1 => Enfant					Enfant => Frère/sœur 1				
	0 Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours	**0** Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours
Français										
Langue (précisez)										
Autre :										

Quelle(s) langue(s) utilise le frère/sœur 2 avec l'enfant ? Quelle(s) langue(s) utilise l'enfant avec le frère/sœur 2 ?

	Frère/sœur 2 => Enfant					Enfant => Frère/sœur 2				
	0 Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours	**0** Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours
Français										
Langue (précisez)										
Autre :										

Quelle(s) langue(s) utilise le frère/sœur 3 avec l'enfant ? Quelle(s) langue(s) utilise l'enfant avec le frère/sœur 3 ?

	Frère/sœur 3 => Enfant					Enfant => Frère/sœur 3				
	0 Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours	**0** Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours
Français										

Langue (précisez)										
Autre :										

4.4. Entre les parents

Quelle(s) langue(s) utilise la mère avec le père ? Quelle(s) langue(s) utilise le père avec la mère ?

	Mère => Père					Père => Mère				
	0 Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours	**0** Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours
Français										
Langue (précisez)										
Autre :										

<u>INSTRUCTION</u> : les réponses aux questions 4.1. à 4.4. sont à reporter dans le tableau au point 5. *Score d'utilisation de chacune des langues au sein de la famille*, p. 15.

5 - Utilisation des langues dans d'autres contextes

5.1. Quelle(s) langue(s) parle votre enfant avec les autres enfants avec lesquels il/elle joue régulièrement ? (*Veillez à ce que les proportions des différentes langues soient cohérentes les unes par rapport aux autres)*

5.1.1. *Avec les autres enfants de la famille* (ex : cousins/cousines) :

	0 Jamais	**1** Rarement	**2** Parfois	**3** Souvent	**4** Toujours
Français					
Langue (précisez) :					
Autre :					

5.1.2. *Avec les enfants d'amis* :

	0 Jamais	**1** Rarement	**2** Parfois	**3** Souvent	**4** Toujours
Français					
Langue (précisez) :					
Autre :					

5.1.3. *Avec les enfants de la crèche* :

	0 Jamais	**1** Rarement	**2** Parfois	**3** Souvent	**4** Toujours
Français					
Langue (précisez) :					
Autre :					

5.2. Les amis de la famille (personnes adultes) qui viennent régulièrement chez vous utilisent quelle(s) langue(s) ?

	0 Jamais	**1** Rarement	**2** Parfois	**3** Souvent	**4** Toujours
Français					
Langue (précisez) :					
Autre :					

5.3. Si votre enfant va à la crèche, quelle(s) langue(s) utilise le personnel de la crèche ?

	0 Jamais	**1** Rarement	**2** Parfois	**3** Souvent	**4** Toujours
Français					

Langue (précisez) :					
Autre :					

5.4. Quelles activités l'enfant fait-il/elle actuellement chaque semaine et dans quelle(s) langue(s) ? Remarque : la lecture = lecture faite à l'enfant, activité de regarder un livre avec lui/elle ou de le lui raconter.

	Français			Langue (précisez) :			Autre :		
Activités	**2** Tous les jours	**1** Au moins une fois par semaine	**0** Presque jamais ou jamais	**2** Tous les jours	**1** Au moins une fois par semaine	**0** Presque jamais ou jamais	**2** Tous les jours	**1** Au moins une fois par semaine	**0** Presque jamais ou jamais
a. Lecture/histoires									
b.Télévision et/ou dessins animés									
c. Chansons/ comptines									
Total (par colonne)									
Total (par langue)	**/6**			**/6**			**/6**		

INSTRUCTION : les réponses aux questions 5.1. à 5.3. sont à reporter dans le tableau au point 6. *Score d'utilisation de chacune des langues dans d'autres contextes* (Richesse linguistique), p. 15.

SECTION B – QUESTIONS SUR LES PARENTS

6 - Informations sur la mère

6.1. Dans quel pays êtes-vous née ?

6.2. Depuis combien d'années êtes-vous en Belgique ?

6.3. Travaillez-vous/ou étudiez-vous actuellement en dehors de la maison ? Si oui, quelle est votre profession/quelles sont vos études ?

6.4. Quelle(s) langue(s) utilisez-vous sur votre lieu de travail/d'études ?

	0 Jamais	**1** Rarement	**2** Parfois	**3** Souvent	**4** Toujours
Français					
Langue (précisez) :					
Autre :					

6.5. Combien d'années d'études/formation avez-vous fait (dans le pays d'origine et/ou en Belgique) ?

		Nombre d'années	**Informations supplémentaires**
Ecole primaire	Oui / non		
Ecole secondaire	Oui / non		
Enseignement supérieur/université	Oui / non		
Formation professionnelle	Oui / non		

6.6. Quel est votre niveau dans les langues suivantes

	0 Maximum quelques mots (Pas de maîtrise)	**1** Pratique limitée (Faible)	**2** Se débrouille, pratique presque courante (Moyen)	**3** Est à l'aise, pratique courante (Bon)	**4** Pratique totalement courante (Excellent)
Français					
Langue (précisez) :					
Autre :					

7 - Informations sur le père

7.1. Dans quel pays êtes-vous né ?

7.2. Depuis combien d'années êtes-vous en Belgique ?

7.3. Travaillez-vous/ou étudiez-vous actuellement en dehors de la maison ? Si oui, quelle est votre profession/quelles sont vos études ?

7.4. Quelle(s) langue(s) utilisez-vous sur votre lieu de travail/d'études ?

	0 Jamais	**1** Rarement	**2** Parfois	**3** Souvent	**4** Toujours
Français					
Langue (précisez) :					
Autre :					

7.5. Combien d'années d'études/formation avez-vous fait (dans le pays d'origine et/ou en Belgique) ?

		Nombre d'années	**Informations supplémentaires**
Ecole primaire	Oui / non		
Ecole secondaire	Oui / non		
Enseignement supérieur/université	Oui / non		
Formation professionnelle	Oui / non		

7.6. Quel est votre niveau dans les langues suivantes

	0 Maximum quelques mots (Pas de maîtrise)	**1** Pratique limitée (Faible)	**2** Se débrouille, pratique presque courante (Moyen)	**3** Est à l'aise, pratique courante (Bon)	**4** Pratique totalement courante (Excellent)
Français					
Langue (précisez) :					

Autre :					

8 – Histoire familiale – difficultés langagières

8.1. Pour chaque case, indiquez OUI (1 point) ou NON (0 point) :

Membre(s) de la famille / **Difficultés**	Frère(s)/ sœur(s)	Mère	Père
Difficultés au niveau de la lecture et/ou de l'orthographe (dans votre langue maternelle).	**1**	**1**	**1**
Difficultés à comprendre les autres quand ils parlent (dans votre langue maternelle).	**1**	**1**	**1**
Difficultés à s'exprimer à l'oral : problèmes de prononciation/bégaiement, difficultés à trouver ses mots (problème de vocabulaire) et/ou à former des phrases, etc. (dans votre langue maternelle).	**1**	**1**	**1**
Total	**/3**	**/3**	**/3**
Total difficultés pour toute la famille	**/9**		

Pour l'expression orale, précisez le type de difficultés : ....

Si d'autres types de difficultés langagières sont présentes, précisez : ....

<u>INSTRUCTION</u> : les réponses à la question 8.1. sont à reporter dans le tableau au point 1. *Indice de non risque*, p. 13.

SYSTEME DE NOTATION – INDICE ET SCORES

1. Indice de non-risque

Questions		Réponse	Attribution points	Points
s	1er mot	15 mois ou plus jeune	**6 points**	**/6**
		16-24 mois	**4 points**	
		25 mois ou plus vieux	**0 point**	
2.2	1ères combinaisons de mots	24 mois ou plus jeune	**6 points**	**/6**
		24-30	**4 points**	
		31 mois ou plus vieux	**0 point**	
2.3	Inquiétude parentale	Non	**2 points**	**/2**
		Oui	**0 point**	
2.5	Otites fréquentes	Non	**3 points**	**/3**
		Oui	**0 point**	
Total développement précoce (*additionner les points ci-dessus*)				**/17**
8.1	Difficultés familiales	Soustraction : **9 – [total des difficultés familiales**] => au moins il y a eu de difficultés, au plus l'indice sera élevé.		**/9**
INDICE DE NON RISQUE (additionner total développement précoce /17 et difficultés familiales /9)				**/26**

2. Exposition précoce pour chaque langue – quantité et qualité

Questions		Français	Langue (précisez)	Autre
2.6	Fréquence d'exposition *Reporter fréquence pour chaque langue*			
2.7	Age du premier contact *Reporter l'âge le plus jeune pour chaque langue*	mois	mois	mois
2.7	**Variété de contextes d'exposition**			

	Reporter nombre total de contextes pour chaque langue			
2.7	**Taux d'exposition** ***Convertir en % (ex : (A/T) x 100)***	**%**	**%**	**%**

3. Durée d'exposition pour chaque langue (question 2.8.)

	Age du début de l'exposition importante et régulière	**Nombre de mois d'exposition** (1) convertir l'Age d'exposition en mois (2) convertir l'Age au test en mois (3) soustraire Age au test – Age d'exposition
Français		
Langue (précisez)		
Autre		

4. Capacités actuelles

=> *Le total peut être de /18 ou de /30, en fonction de la façon dont les parents répondent : soit ils comparent leur enfant à d'autres enfants monolingues ou bilingues (total = 18), ou aux deux (total = 30).*

Questions		**Français**	**Langue (précisez) ....**	**Autre**
3.2	Total des capacités actuelles pour chaque langue *Reporter total par langue sur total de 18 ou de 30*	**/18 ou /30**	**/18 ou /30**	**/18 ou /30**

5. Score d'utilisation de chacune des langues au sein de la famille

Situation	Score			Situation	Score		
	Français	**Langue (précisez) ....**	**Autre**		**Français**	**Langue (précisez) ....**	**Autre**
Mère => enfant *(Question 4.1)*	Ex : 1			Enfant => Mère *(Question 4.1)*	Ex : 3		
Père => enfant *(Question 4.1)*	Ex : 1			Enfant => Père *(Question 4.1)*	Ex : 3		
Autre adulte => enfant *(Question 4.2)*	/			Enfant => Autre adulte *(Question 4.2)*	/		
Frère/sœur 1 => enfant *(Question 4.3)*	Ex : 3			Enfant => Frère/sœur 1 *(Question 4.3)*	Ex : 4		
Frère/sœur 2 => enfant *(Question 4.3)*	Ex : 3			Enfant => Frère/sœur 2 *(Question 4.3)*	Ex : 4		
Frère/sœur 3 => enfant *(Question 4.3)*	/			Enfant=> Frère/sœur 3 *(Question 4.3)*	/		
Mère => Père *(Question 4.4)*	Ex : 1			Père => Mère *(Question 4.4)*	Ex : 1		
Total : Total des scores / Nombre de score * 4	9/5x4				15/5x4		
Grand total d'utilisation	***Additionnez les totaux et divisez pour obtenir un score de proportion*** Ex : calcul du score pour le français => *9/20 + 15/20 = 24/40 = 0,6*						

6. Score d'utilisation de chacune des langues dans d'autres contextes (Richesse linguistique)

Questions		Français	Langue (précisez)	Autre
5.1.1.	Avec les autres enfants de la famille	**/4**	**/4**	**/4**
5.1.2.	Avec les enfants d'amis	**/4**	**/4**	**/4**
5.1.3.	Avec les enfants de la crèche	**/4**	**/4**	**/4**
5.2.	Les amis de la famille	**/4**	**/4**	**/4**
5.3.	Le personnel de la crèche	**/4**	**/4**	**/4**
5.4.	Activités chaque semaine	**/8**	**/8**	**/8**
Total utilisation de chaque langue		**/28**	**/28**	**/28**

ANNEXES

	Autre adulte => Enfant					Enfant => Autre adulte				
	0 Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours	**0** Jamais	**1** Rarement	**2** 50 %	**3** Souvent	**4** Toujours
Français										
Langue (précisez)										
Autre :										

Appendix 3

French adaptation of MBCDI

Questionnaire Mots et Phrases

16-30 mois

Date de passation: .... ☐ ☐

Nom: .... Prénom: ....

Date de naissance: .... Âge (mois): ....

Nombre et âge (mois) des frères et sœurs: ....

Profession et diplôme le plus élevé de la mère: ....

Profession et diplôme le plus élevé du père: ....

Langues parlées à la maison: ....

Vocabulaire

Noircir ☐ si votre enfant dit ces mots:

#1 Cris d'animaux et sons

☐ aïe	☐ allô	☐ bêê bêê	☐ cocorico
☐ meuh	☐ miaou	☐ oh oh	☐ ouaf-ouaf
☐ coin-coin	☐ grrrr	☐ miam-miam	☐ tchou-tchou
☐ vroum			

#2 Jeux et routines

☐ ainsi font font	☐ au revoir	☐ bain	☐ bonjour
☐ chut	☐ coucou	☐ coup de fil	☐ déjeuner
☐ sieste	☐ merci	☐ ne fais pas	☐ non
☐ je vais t'attraper	☐ s'il te plaît	☐ top là	☐ tourne-toi
☐ bonne nuit	☐ bravo	☐ ce petit cochon	☐ dîner
☐ goûter	☐ faire les courses	☐ oui	☐ salut
☐ petit déjeuner	☐ va sur le pot		

#3 Noms d'animaux (vrais ou jouets)

☐ abeille	☐ agneau	☐ âne	☐ animal
☐ chien	☐ biche	☐ canard	☐ chat

#3 (suite) Noms d'animaux (vrais ou jouets)

☐ cochon	☐ coq	☐ crocodile	☐ dindon
☐ girafe	☐ grenouille	☐ hibou	☐ lapin
☐ nounours	☐ oie	☐ oiseau	☐ ours
☐ poisson	☐ poney	☐ poule	☐ renne
☐ tortue	☐ vache	☐ zèbre	☐ bébé chat
☐ bébé chien	☐ tigre	☐ cheval	☐ chèvre
☐ chien	☐ écureuil	☐ éléphant	☐ fourmi
☐ lion	☐ loup	☐ mouton	☐ papillon
☐ petite bête	☐ pingouin	☐ singe	☐ souris

#4 Jouets

☐ balle	☐ ballon	☐ bulles	☐ cadeau
☐ cube	☐ feutre	☐ histoire	☐ jeu
☐ poupée	☐ puzzle	☐ raquette	☐ stylo
☐ colle	☐ craie	☐ crayon	☐ jouet
☐ livre	☐ pâte à modeler		

#5 Vêtements

☐ basket	☐ bavoir/bavette	☐ body	☐ bottes
☐ chaussettes	☐ chapeau	☐ chaussure	☐ chemise
☐ couche	☐ culotte/slip	☐ écharpe	☐ gants
☐ moufles	☐ pantalon	☐ perles	☐ pull
☐ short	☐ sweat	☐ tee-shirt	☐ veste
☐ boutons	☐ ceinture	☐ chausson/pantoufle	☐ collants
☐ collier	☐ combinaison de ski	☐ grenouillère	☐ jeans
☐ manteau	☐ pyjama	☐ robe	☐ salopette

#6 Objets d'extérieur

☐ arbre	☐ arrosoir	☐ bac à sable	☐ balançoire
☐ ciel	☐ drapeau	☐ eau	☐ échelle
☐ jardin	☐ lune	☐ neige	☐ nuage
☐ pluie	☐ rocher	☐ rue/route	☐ soleil
☐ trottoir	☐ tuyau	☐ vent	☐ bâton
☐ piscine	☐ caillou	☐ étoile	☐ fleur
☐ herbe	☐ pelle	☐ pierre	☐ bonhomme de neige
☐ toboggan	☐ toit	☐ tondeuse à gazon	

#7 Endroits où aller

☐ campagne	☐ camping	☐ centre-ville	☐ cinéma
☐ dehors	☐ école	☐ église	☐ ferme
☐ magasin	☐ maison	☐ parc	☐ pique-nique
☐ travail	☐ zoo	☐ cirque	☐ cour
☐ crèche	☐ fête	☐ forêt	☐ garderie
☐ plage	☐ station-service	☐ terrain de jeux	

#8 Petits objets ménagers

☐ appareil photo	☐ argent	☐ aspirateur	☐ assiette
☐ bol	☐ bouteille	☐ brosse	☐ brosse à dent
☐ clou	☐ coussins	☐ couteau	☐ couverture
☐ horloge	☐ lampe	☐ lumière	☐ lunettes
☐ mouchoir	☐ musique	☐ ordures	☐ oreiller
☐ photo	☐ plante	☐ plat	☐ plateau
☐ radio	☐ savon	☐ seau	☐ serpillière
☐ sous/pièces	☐ sucette	☐ tasse	☐ verre
☐ balai	☐ biberon	☐ boîte	☐ cassette
☐ cuillère	☐ ciseaux	☐ clefs	☐ pot
☐ marteau	☐ feuille	☐ fourchette	☐ sirop
☐ panier	☐ montre	☐ médicaments	☐ trotteur
☐ poubelle	☐ papier	☐ peigne	☐ serviette
☐ porte-monnaie	☐ serviette de table	☐ télécommande	☐ téléphone

#9 Meubles et pièces

☐ baignoire	☐ banc	☐ berceau	☐ canapé
☐ chambre	☐ cuisine	☐ cuisinière	☐ douche
☐ évier	☐ fauteuil	☐ fenêtre	☐ four
☐ lit	☐ lavabo	☐ parc	☐ pièce
☐ salon	☐ table	☐ télé	☐ tiroir
☐ cave	☐ chaise	☐ chaise haute	☐ entrée
☐ escalier	☐ étendage	☐ frigo	☐ garage
☐ machine à laver	☐ porte	☐ pot	☐ salle de bain
☐ wc			

#10 Parties du corps

☐ aïe bobo	☐ bouche	☐ bras	☐ cheveux
☐ doigt de pied	☐ doigt	☐ fesses	☐ figure/visage
☐ langue	☐ lèvre	☐ main	☐ menton
☐ pénis/zizi…	☐ pied	☐ pouce	☐ tête
☐ cheville	☐ cœur	☐ dent	☐ genou
☐ jambe	☐ joue	☐ nez	☐ nombril
☐ oreille	☐ yeux	☐ ventre	☐ vagin/zezette…

#11 Nourriture et boissons

☐ baguette	☐ banane	☐ beignet	☐ beurre
☐ café	☐ carotte	☐ céréales	☐ eau
☐ coca	☐ compote	☐ confiture	☐ cornflakes
☐ esquimau	☐ flan	☐ fraise	☐ frites
☐ pizza	☐ gâteaux apéro	☐ poisson	☐ glace
☐ hamburger	☐ pop-corn	☐ haricot	☐ poulet
☐ raisin	☐ kiwi	☐ raisins secs	☐ lait
☐ madeleine	☐ sel	☐ maïs	☐ soupe

#11 (suite) Nourriture et boissons

- ☐ sucette
- ☐ œuf
- ☐ yaourt
- ☐ bonbons
- ☐ clémentine
- ☐ fromage
- ☐ glaçon
- ☐ jus de fruit
- ☐ mayonnaise
- ☐ nutella
- ☐ pâtes
- ☐ noisettes
- ☐ vanille
- ☐ petits pois
- ☐ bretzel
- ☐ courge
- ☐ petits pots
- ☐ pomme de terre
- ☐ sandwich
- ☐ spaghetti
- ☐ thon
- ☐ sucre
- ☐ orange
- ☐ petits gâteaux
- ☐ chips
- ☐ crêpe
- ☐ gâteau
- ☐ haricots verts
- ☐ limonade
- ☐ melon
- ☐ pain
- ☐ nourriture
- ☐ viande
- ☐ boisson
- ☐ chocolat
- ☐ chewing-gum
- ☐ pomme
- ☐ purée
- ☐ sauce
- ☐ tartine
- ☐ vitamines

#12 Véhicules

- ☐ avion
- ☐ poussette
- ☐ camion
- ☐ vélo
- ☐ bateau
- ☐ tracteur
- ☐ voiture
- ☐ hélicoptère
- ☐ bus
- ☐ train
- ☐ camion de pompier
- ☐ moto
- ☐ traîneau
- ☐ tricycle

#13 Personnes

- ☐ bébé
- ☐ fille
- ☐ maître/sse
- ☐ oncle
- ☐ docteur
- ☐ grand-père
- ☐ nom de l'animal
- ☐ clown
- ☐ frère
- ☐ maman
- ☐ papa
- ☐ enfant
- ☐ nom de l'enfant
- ☐ pompier
- ☐ copain/ine
- ☐ garçon
- ☐ monsieur
- ☐ personne
- ☐ facteur
- ☐ nounou
- ☐ sœur
- ☐ dame
- ☐ gens
- ☐ tante
- ☐ police
- ☐ grand-mère
- ☐ infirmière
- ☐ nom de la nounou

#14 Mots descriptifs

- ☐ attention
- ☐ blanc/he
- ☐ coincé
- ☐ dur
- ☐ gentil/le
- ☐ lourd/e
- ☐ mouillé
- ☐ plein/ne
- ☐ tendre
- ☐ vilain/e
- ☐ bien
- ☐ bruyant/e
- ☐ dégoûtant/e
- ☐ fort/e
- ☐ joli
- ☐ mieux
- ☐ parti
- ☐ avoir faim
- ☐ blessé
- ☐ collant/e
- ☐ endormi
- ☐ grand/e
- ☐ malade
- ☐ neuf/ve
- ☐ premier/ère
- ☐ tranquille
- ☐ vite
- ☐ beau/belle
- ☐ cassé
- ☐ dernier/e
- ☐ fou/folle
- ☐ lent/e
- ☐ mignon/ne
- ☐ avoir peur
- ☐ bleu
- ☐ content/te
- ☐ être réveillé
- ☐ haut/e
- ☐ marron
- ☐ noir
- ☐ propre
- ☐ triste
- ☐ avoir sommeil
- ☐ chaud/e
- ☐ doux/ce
- ☐ froid
- ☐ long/ue
- ☐ minuscule
- ☐ petit/e
- ☐ avoir soif
- ☐ bon/ne
- ☐ coquin/e
- ☐ fatigué
- ☐ jaune
- ☐ méchant/e
- ☐ orange
- ☐ rouge
- ☐ venteux
- ☐ sale
- ☐ vert/e
- ☐ sec/che
- ☐ vide
- ☐ vieux/vieille
- ☐ sombre
- ☐ pas bon

#15 Mots d'action

☐ acheter	☐ aider	☐ aimer	☐ aimer bien
☐ arracher	☐ arrêter	☐ attendre	☐ attraper
☐ boire	☐ cacher	☐ casser	☐ chanter
☐ couper	☐ courir	☐ courir après	☐ couvrir
☐ déposer	☐ dessiner	☐ détester	☐ dire
☐ éclabousser	☐ écouter	☐ écrire	☐ entendre
☐ faire bravo	☐ faire	☐ parler	☐ dormir
☐ finir	☐ mettre	☐ glisser	☐ goûter
☐ jouer	☐ laver	☐ lécher	☐ lire
☐ montrer	☐ mordre	☐ nager	☐ nettoyer
☐ partager	☐ penser	☐ pleurer	☐ porter
☐ ramasser	☐ recevoir	☐ regarder	☐ renverser
☐ sauter	☐ se cogner	☐ se dépêcher	☐ se réveiller
☐ souhaiter	☐ sourire	☐ taper	☐ tenir
☐ travailler	☐ trouver	☐ verser	☐ voir
☐ aller	☐ aller bien avec	☐ apporter	☐ réparer
☐ avoir	☐ balancer	☐ balayer	☐ sécher
☐ chatouiller	☐ conduire	☐ construire	☐ tirer
☐ cuisiner	☐ danser	☐ donner un coup	☐ rester
☐ donner	☐ déchirer	☐ faire du vélo/moto	☐ secouer
☐ essuyer	☐ être debout	☐ faire de la peinture	☐ tomber
☐ jeter	☐ fermer	☐ faire un bisou	☐ s'asseoir
☐ goutter	☐ grimper	☐ faire semblant	☐ souffler
☐ manger	☐ marcher	☐ frapper à la porte	☐ toucher
☐ nourrir	☐ ouvrir	☐ faire du patin	☐ prendre
☐ pousser	☐ prendre dans ses bras		

#16 Mots sur le temps

☐ après	☐ aujourd'hui	☐ avant	☐ ce soir
☐ jour	☐ maintenant	☐ matin	☐ nuit
☐ demain	☐ heure	☐ hier	

#17 Pronoms

☐ à elle/sa	☐ à lui/son	☐ à moi	☐ ça
☐ eux	☐ il	☐ ils/elles	☐ je
☐ moi	☐ moi-même	☐ notre	☐ nous
☐ votre/ta/ton	☐ vous/tu	☐ ces	☐ ceux
☐ elle	☐ leur	☐ on	☐ lui
☐ ma/mon/mes	☐ ses	☐ toi-même	

#18 Quantificateurs et articles

☐ aucun/e	☐ aussi	☐ autre	☐ chaque
☐ le/la/les	☐ pas	☐ un/une	☐ tous/tout
☐ du/de la/des	☐ encore	☐ le/la même	☐ un autre
☐ un peu	☐ plein/beaucoup		

#19 Auxiliaires

- ☐ a fait
- ☐ était
- ☐ pourrait
- ☐ devoir faire
- ☐ avoir besoin de
- ☐ aller
- ☐ être
- ☐ sont
- ☐ laisse-moi
- ☐ essayer de
- ☐ vouloir
- ☐ faire
- ☐ suis
- ☐ peux
- ☐ est
- ☐ fait
- ☐ avoir à faire
- ☐ ne pas

#20 Prépositions et localisations

- ☐ à
- ☐ avec
- ☐ en bas
- ☐ pour
- ☐ au loin
- ☐ de
- ☐ là-bas
- ☐ à côté de
- ☐ autour de
- ☐ en haut
- ☐ près de
- ☐ par dessus
- ☐ dehors
- ☐ loin
- ☐ derrière
- ☐ chez
- ☐ ici
- ☐ sous
- ☐ au sujet de
- ☐ à l'intérieur de
- ☐ vers
- ☐ dans
- ☐ là
- ☐ sur
- ☐ au dessus de
- ☐ au sommet de

#21 Connecteurs

- ☐ et
- ☐ si
- ☐ mais
- ☐ alors
- ☐ donc
- ☐ parce que

#22 Interrogatifs

- ☐ comment
- ☐ quand
- ☐ qui
- ☐ quoi
- ☐ où
- ☐ le/la/les/quel(les)
- ☐ pourquoi

#23 Votre enfant...

☐ parle d'événements passés ou de personnes absentes (par exemple un enfant qui a vu un défilé la semaine précédente peut dire plus tard «défilé», «orchestre», «musiciens»)

#24 Votre enfant...

☐ parle de choses qui vont se produire dans le futur (par exemple, dire «tchou tchou» ou «avion» avant de quitter la maison pour voyager ou dire «balançoire» quand vous allez au parc)

#25 Votre enfant...

☐ parle d'objets qui ne sont pas présents comme d'un jouet manquant ou absent, se réfère à un animal domestique hors de vue, ou pose des questions à propos d'une personne absente

#26 Votre enfant...

☐ comprend si vous lui demandez quelque chose qui n'est pas dans la pièce (par exemple, il va dans la chambre à coucher chercher son ours en peluche si vous lui dites «où est l'ours?»)

Grammaire

Noircir ☐ pour la phrase la plus fréquemment utilisée par votre enfant en ce moment pour dire:

#27 Les chiens sont là
- ☐ les chiens est là
- ☐ les chiens sont là

#28 Aller à l'école
- ☐ aller école
- ☐ aller à école

#29 Je vais t'attaquer
- ☐ je vais s'attaquer
- ☐ je vais t'attaquer

#30 C'est dans la valise
- ☐ c'est dedans la valise
- ☐ c'est dans la valise

#31 Le robot de Grégoire (en parlant de lui-même)
- ☐ robot Grégoire
- ☐ robot à Grégoire
- ☐ robot à moi
- ☐ mon robot à moi
- ☐ mon robot

#32 Je ne joue pas
- ☐ jouer pas
- ☐ pas jouer
- ☐ non jouer
- ☐ non pas jouer
- ☐ je joue pas

#33 Je veux la chaise
- ☐ veux la chaise
- ☐ veux la chaise Grégoire
- ☐ moi veux la chaise
- ☐ moi je veux la chaise
- ☐ je veux la chaise

#34 Est-ce que c'est un chien?
- ☐ chien?
- ☐ ça chien?
- ☐ est chien?
- ☐ c'est un chien?
- ☐ est-ce que c'est un chien?

#35 La chaussure de maman
- ☐ chaussure maman
- ☐ chaussure (d)e maman
- ☐ chaussure à maman
- ☐ chaussure de maman

#36 Une chaise ou un frigidaire
- ☐ chaise/frigidaire
- ☐ (l)a chaise/(l)e frigidaire
- ☐ la chaise/le frigidaire
- ☐ une chaise/un frigidaire

#37 Je veux de la confiture/du chocolat
- ☐ confiture/chocolat
- ☐ je veux de la confiture/du chocolat

#38 Elle monte sur la chaise
- ☐ elle monte chaise
- ☐ elle monte sur la chaise

#39 Je veux descendre
- ☐ descendre
- ☐ veux descendre
- ☐ je veux descendre

#40 Il est beau
- ☐ «yé» beau
- ☐ l'est beau
- ☐ il est beau

#41 C'est une voiture
- ☐ ça voiture
- ☐ ça c'est voiture
- ☐ c'est une voiture

#42 Il/elle cherche
- ☐ cherche
- ☐ é cherche
- ☐ il/elle cherche

#43 Noircir ☐ et donnez des exemples si votre enfant utilise des verbes…

☐ au présent (prends)
ex : ....

☐ à l'impératif (prends !)
ex : ....

☐ à l'infinitif (prendre)
ex : ....

☐ au passé composé (ai pris)
ex : ....

☐ au futur (prendrai)
ex : ....

☐ à l'imparfait (prenais)
ex : ....

#44 Donnez les trois phrases les plus longues que votre enfant produit en ce moment :

....

....

....

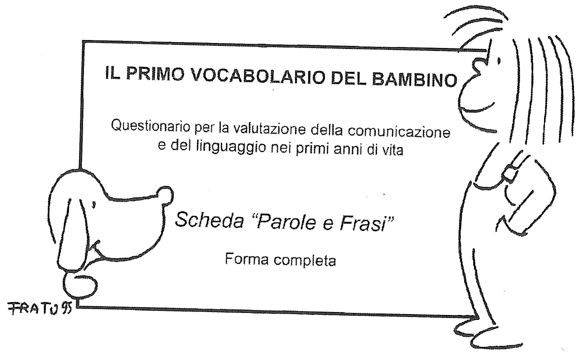
Appendix 4

Italian adaptation of MBCDI

The MacArthur - Bates

Communicative Development Inventory - MB-CDI

Nome e Cognome del bambino ______ Sesso ______
Data di nascita del bambino ______ Data di compilazione ______ Età ______
Indirizzo ______ Città ______



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PARTE I - LISTA DI PAROLE

In questa parte dell'intervista desideriamo raccogliere informazioni dettagliate sulle parole usate dai bambini. Scorrete la lista e segnate una crocetta nella colonna DICE a fianco delle parole che il vostro bambino effettivamente usa. Se il vostro bambino usa una parola diversa da quella indicata nella lista per un identico significato (ad esempio "bumba" al posto di "acqua"), o una diversa pronuncia (ad esempio "pappe" al posto di "scarpe"), segnate con una crocetta la parola e scrivete accanto la forma usata da vostro figlio. Abbiamo messo molte parole nella lista ma non è detto che esse siano tutte presenti nel vocabolario del vostro bambino.

1. SUONI E VOCI DELLA NATURA

	Dice		Dice		Dice
Bau Bau	O	Clop Clop	O	Coccodè	O
Beh Beh	O	Ih Oh	O	Grr	O
Brum Brum	O	Miao	O	Muh	O
Cip Cip	O	Qua Qua	O	Tuttù	O

2. ANIMALI (veri o giocattoli)

	Dice		Dice		Dice
Agnello	O	Gallina	O	Pesciolino	O
Animale	O	Gallo	O	Pinguino	O
Ape	O	Gatto	O	Pulcino	O
Asino	O	Giraffa	O	Rana	O
Cane	O	Gufo	O	Scimmia	O
Capra	O	Ippopotamo	O	Scoiattolo	O
Cavallo	O	Leone	O	Tacchino	O
Cerbiatto	O	Lupo	O	Tartaruga	O
Coccodrillo	O	Maiale	O	Tigre	O
Coniglio	O	Mosca	O	Topo	O
Cucciolo	O	Mucca	O	Uccellino	O
Elefante	O	Oca	O	Zanzara	O
Farfalla	O	Orso	O	Zebra	O
Foca	O	Papera	O		
Formica	O	Pecora	O		

3. VEICOLI (veri o giocattoli)

	Dice		Dice		Dice
Aereo	O	Camion	O	Passeggino	O
Autobus	O	Elicottero	O	Slitta	O
Automobile	O	Gru	O	Trattore	O
Barca	O	Jeep	O	Treno	O
Bicicletta	O	Motocicletta	O		

4. GIOCATTOLI

	Dice		Dice		Dice
Bambola	O	Giocattolo	O	Secchiello	O
Birilli	O	Paletta	O	Soldatini	O
Casetta	O	Palla	O	Tamburo	O
Costruzioni	O	Palloncino	O	Tromba	O
Cubi	O	Pistola	O	Pongo/Didò	O
Favola/Storia	O	Pupazzi	O	Trottola	O

5. CIBO E BEVANDE

	Dice		Dice		Dice
Acqua	O	Caramella	O	Fagiolini	O
Arancia	O	Carne	O	Formaggio	O
Aranciata	O	Carote	O	Fragola	O
Banana	O	Ciliege	O	Gelato	O
Biscotti	O	Cioccolata	O	Ghiaccio	O
Budino	O	Coca - Cola	O	Gomma da masticare	O
Burro	O	Cocomero/Anguria	O	Kiwi	O
Cacao	O	Cracker	O	Latte	O
Caffè	O	Crema	O	Leccalecca	O
Camomilla	O	Fagioli	O		

	Dice		Dice		Dice
Mandarino	O	Patate	O	Succo di Frutta	O
Marmellata	O	Patatine	O	Sugo	O
Mela	O	Pera	O	The	O
Melone	O	Pesca	O	Tonno	O
Miele	O	Piselli	O	Torta	O
Minestrone/Brodo	O	Pizza	O	Tortellini	O
Noccioline	O	Pollo	O	Uovo	O
Olio	O	Polpette	O	Uva	O
Pane	O	Pomodori	O	Verdura	O
Panino	O	Riso	O	Vino	O
Panna	O	Sale	O	Yogurt	O
Pappa	O	Spaghetti	O	Zucchero	O
Pasta	O	Spinaci	O	Zucchine	O

6. ABBIGLIAMENTO

	Dice		Dice		Dice
Bavaglino	O	Collana	O	Pantaloni	O
Borsa	O	Giacca	O	Pantofole	O
Bottone	O	Gonna	O	Pigiama	O
Bretelle	O	Grembiule	O	Scarpe	O
Calze	O	Guanti	O	Sciarpa	O
Calzettoni	O	Jeans	O	Stivali	O
Camicia	O	Maglione	O	Tuta	O
Cappello	O	Mutande	O	Vestito	O
Cappotto	O	Occhiali	O		
Cinta	O	Pannolino	O		

7. PARTI DEL CORPO

	Dice		Dice		Dice
Bocca	O	Gola	O	Organo genitale femm.	O
Braccio	O	Guance	O	Organo genitale masc.	O
Capelli	O	Labbra	O	Pancia	O
Caviglia	O	Lingua	O	Piede	O
Denti	O	Mano	O	Sederino	O
Dito	O	Naso	O	Seno	O
Faccia	O	Occhio	O	Spalla	O
Gambe	O	Ombelico	O	Testa	O
Ginocchio	O	Orecchio	O	Unghie	O

8. OGGETTI D'USO FAMIGLIARE

	Dice		Dice		Dice
Asciugamano	O	Fazzoletto	O	Sacchetto	O
Aspirapolvere	O	Forbici	O	Sapone	O
Biberon	O	Forchetta	O	Scatola	O
Bicchiere	O	Fotografia	O	Scopa	O
Bottiglia	O	Giornale	O	Secchio	O
Candeline	O	Luce	O	Shampoo	O
Cestino	O	Libro	O	Soldi	O
Chiave	O	Martello	O	Spazzolino da denti	O
Ciuccio	O	Matita/Penna	O	Specchio	O
Colori	O	Medicina	O	Straccio	O
Coltello	O	Musica	O	Tappo	O
Coperchio	O	Ombrello	O	Tazza	O
Coperta	O	Orologio	O	Telefono	O
Cucchiaio	O	Pentola	O	Termometro	O
Cuscino	O	Pettine	O	Termosifone	O
Dentifricio	O	Pianta	O	Vasino	O
Disegno	O	Piatto	O		

9. MOBILI STANZE E OGGETTI DELLA CASA

	Dice		Dice		Dice
Armadio	O	Finestra	O	Radio	O
Bagno	O	Fon	O	Registratore	O
Bidè	O	Forno	O	Salotto	O
Camera	O	Frigorifero	O	Scala	O
Cantina	O	Lavandino	O	Sedia	O
Cassetto	O	Lavatrice	O	Seggiolone	O
Cucina	O	Letto	O	Tappeto	O
Culla	O	Muro	O	Tavolo	O
Divano	O	Poltrona	O	Televisione/TV	O
Doccia	O	Porta	O	Terrazza	O
Ferro da stiro	O	Quadro	O	Vasca da bagno	O

10. ALL'APERTO

	Dice		Dice		Dice
Albero	O	Fumo	O	Scivolo	O
Altalena	O	Garage	O	Sole	O
Ascensore	O	Luna	O	Stella	O
Bandiera	O	Nebbia	O	Strada	O
Benzina	O	Neve	O	Terra	O
Campana	O	Nuvola	O	Tetto	O
Cielo	O	Pioggia	O	Torre	O
Erba	O	Piscina	O	Tubo	O
Fiore	O	Pompa	O	Vento	O
Foglia	O	Prato	O		
Fontana	O	Sasso	O		

11. POSTI DOVE ANDARE

	Dice		Dice		Dice
Asilo	O	Festa	O	Ospedale	O
Bar	O	Giardino	O	Parco giochi	O
Bosco	O	Giostra	O	Scuola	O
Campagna	O	Lavoro	O	Spiaggia	O
Casa	O	Mare	O	Supermercato	O
Chiesa	O	Mercato	O	Zoo	O
Circo	O	Montagna	O		
Città	O	Negozio	O		

12. PERSONE

	Dice		Dice		Dice		Dice
Amico/a	O	Fratello	O	Parrucchiere	O	Sorella	O
Babysitter/Tata	O	"Il suo nome"	O	Pediatra	O	Uomo	O
Bambino/a	O	Maestro/a	O	Persone	O	Vigile	O
Barbiere	O	Mamma	O	Poliziotto	O	Zia	O
Bimbi	O	Nonna	O	Portiere	O	Zio	O
Cugino/a	O	Nonno	O	Ragazzo/a	O		
Donna	O	Panettiere	O	Signore/a	O		
Dottore	O	Papà	O	Soldato	O		

13. ROUTINES

	Dice		Dice		Dice
Auguri	O	Dare le Tottò	O	Per favore/Per piacere	O
Basta	O	Fare il bagno	O	Pronto, chi è? (al telef.)	O
Bravo	O	Fare la pipì	O	Sì	O
Bua	O	Fare la popò	O	Un, due, tre	O
Bum (cade)	O	Giro-girotondo	O	Via	O
Buonanotte/Buongiorno	O	Grazie/Prego	O	Voler bene	O
Ciao	O	Nanna	O	Zitto/Sch	O
Che rumore/Chiasso	O	No	O		
Cuccù-settete	O	Non c'è più/Più	O		

14. VERBI							
	Dice		Dice		Dice		Dice
Abbracciare	O	Conoscere	O	Levare/Togliere	O	Scappare	O
Accendere	O	Coprire	O	Litigare	O	Scendere	O
Acchiappare	O	Correre	O	Mangiare	O	Scrivere	O
Aggiustare	O	Costruire	O	Mettere	O	Sedersi	O
Aiutare	O	Cucinare	O	Mordere	O	Sentire	O
Alzarsi	O	Cullare	O	Nascondere/si	O	Soffiare	O
Andare	O	Dare	O	Nuotare	O	Spazzare	O
Aprire	O	Dare un calcio	O	Parlare	O	Spegnere	O
Arrampicarsi	O	Dire	O	Passeggiare	O	Spingere	O
Asciugare	O	Disegnare	O	Pettinare	O	Sporcarsi	O
Aspettare	O	Dondolare	O	Piacere	O	Sputare	O
Aver fame	O	Dormire	O	Piangere	O	Stare	O
Aver sete	O	Entrare	O	Portare	O	Strappare	O
Aver sonno	O	Fare	O	Prendere	O	Svegliarsi	O
Baciare	O	Fermarsi	O	Provare	O	Tagliare	O
Ballare	O	Finire	O	Pulire	O	Telefonare	O
Bere	O	Giocare	O	Raccontare	O	Tenere	O
Bussare	O	Girare	O	Regalare	O	Tirare	O
Buttare	O	Gridare/Urlare	O	Restare	O	Toccare	O
Cadere	O	Guardare	O	Ridere	O	Trovare	O
Camminare	O	Guidare	O	Rispondere	O	Uscire	O
Cantare	O	Lanciare	O	Rompere	O	Vedere	O
Cercare	O	Lavare	O	Rovesciare	O	Venire	O
Chiudere	O	Lavorare	O	Saltare	O	Versare	O
Colorare	O	Leccare	O	Salutare	O	Volare	O
Comprare	O	Leggere	O	Sbrigarsi	O		

15. AGGETTIVI E QUALITA'					
	Dice		Dice		Dice
Addormentato	O	Dolce	O	Piccolo	O
Alto	O	Duro	O	Pieno	O
Amaro	O	Felice	O	Povero	O
Arancione	O	Ferito	O	Pulito	O
Arrabbiato	O	Finito	O	Rosso	O
Asciutto	O	Forte	O	Rotto	O
Attento	O	Freddo	O	Salato	O
Bagnato	O	Gentile	O	Sbagliato	O
Bello	O	Giallo	O	Schifoso	O
Bianco	O	Grande/Grosso	O	Sciocco/Stupido	O
Blu	O	Leggero	O	Spaventato	O
Brutto	O	Lento	O	Sporco	O
Buio	O	Lungo	O	Stanco	O
Buono	O	Malato	O	Stretto	O
Caldo	O	Marrone	O	Sveglio	O
Calmo/Tranquillo	O	Morbido	O	Triste	O
Carino	O	Nero	O	Ultimo	O
Cattivo	O	Nuovo	O	Vecchio	O
Contento	O	Pazzo/Matto	O	Veloce/Svelto	O
Corto	O	Pesante	O	Verde	O
Disubbidiente	O	Piano	O	Vuoto	O

16. AVVERBI - ESPRESSIONI DI TEMPO					
	Dice		Dice		Dice
Adesso/Ora	O	Ieri	O	Pomeriggio	O
Domani	O	Mattina	O	Presto	O
Dopo/Poi	O	Notte	O	Sera	O
Giorno	O	Oggi	O	Tardi	O

17. PRONOMI

Es.: **Ci** vado; **Si** sente; **Gli** parlo; Prendil**o/a**; **Li**/le voglio

	Dice		Dice		Dice
Io	O	Tuo/a	O	Si	O
Tu	O	Suo/a	O	Che	O
Lui	O	Nostro/a	O	Quello/a	O
Lei	O	Vostro/a	O	Questo/a	O
Noi	O	Me/Mi	O	Gli	O
Voi	O	Te/Ti	O	Lo/a	O
Loro	O	Ci	O	Li/e	O
Mio/a	O	Vi	O		

18. INTERROGATIVI

	Dice		Dice		Dice		Dice
Che/Che cosa?	O	Come?	O	Perchè?	O	Quando?	O
Chi?	O	Dove?	O	Quale?	O		

19. PREPOSIZIONI

Es.: Occhiali **di** nonna; Andiamo **da** papà; Il gatto è **sul** letto

	Dice		Dice		Dice
Di	O	Giù	O	Fuori	O
A	O	Per	O	Lontano	O
Da	O	Fra/Tra	O	Vicino	O
In	O	Sopra	O	Davanti	O
Con	O	Sotto	O	Dietro	O
Su	O	Dentro	O		

20. ARTICOLI E QUANTIFICATORI

Es.: **Lo** Zucchero; **Un/a** Bimbo/a; Dammi **del** pane

	Dice		Dice		Dice
Il	O	Gli	O	Dei/Delle	O
Lo	O	Le	O	Altro/Un altro	O
La	O	Un/Uno/Una	O		
I	O	Del/Della	O		

21. VERBI AUSILIARI E MODALI

	Dice		Dice		Dice		Dice		Dice
Essere:	O	**Avere:**	O	**Potere:**	O	**Volere:**	O	**Dovere:**	O
Sono	O	Ho	O	Posso	O	Voglio	O	Devo	O
Sei	O	Hai	O	Puoi	O	Vuoi	O	Devi	O
E'	O	Ha	O	Può	O	Vuole	O	Deve	O

22. CONGIUNZIONI

	Dice		Dice		Dice
Così	O	Ma	O	Quindi/Allora	O
E	O	Perchè	O	Se	O

23. AVVERBI - ESPRESSIONI DI LUOGO E QUANTITA'

	Dice		Dice		Dice
Anche/Pure	O	Molto	O	Tanto	O
Ancora	O	Nessuno	O	Troppo	O
Di più	O	Niente	O	Tutto	O
Ecco	O	Poco	O	Un pò	O
Lì/Là	O	Qui/Qua	O		

COME I BAMBINI COMPRENDONO E USANO LE PAROLE

	Non ancora	A Volte	Spesso
1. Il bambino capisce se gli chiedete di andare a prendere qualcosa che non è presente nella stanza in cui siete? (es.: Va a prendere il bicchiere dopo che glielo avete chiesto)	O	O	O
2. Il bambino mostra di capire quando gli parlate di situazioni o eventi passati? (es.: "Ti ricordi quando siamo andati allo zoo?" e lui dice "Orso")	O	O	O
3. Il bambino capisce quando gli parlate di cose, persone o eventi che stanno per succedere? (es.: Prende il suo golfino dopo che gli avete detto: "Tra poco usciamo")	O	O	O

segue COME I BAMBINI COMPRENDONO E USANO LE PAROLE	Non ancora	A Volte	Spesso
4. Il bambino parla di cose o persone non presenti?	O	O	O
5. Il bambino parla di situazioni o eventi passati?	O	O	O
6. Il bambino parla di cose, persone o eventi che stanno per succedere? (es.: dice "Bimbi" quando sta per andare al parco con la mamma)	O	O	O

PARTE II - COME I BAMBINI USANO LA GRAMMATICA

1. IL BAMBINO USA SIA IL SINGOLARE CHE IL PLURALE DI UNO STESSO NOME?					
Biscotto/i; Gioco/hi; Gatto/i;	O	Bimba/e; Casa/e; Palla/e;	O	Fiore/i; Cane/i; Bicchiere/i;	O

2. IL BAMBINO USA VARIE FORME DI UNO STESSO AGGETTIVO?					
Piccolo/Piccola/Piccoli/Piccole	O	Buono/Buona/Buoni/Buone	O	Caldo/Calda/Caldi/Calde	O

3. IL BAMBINO USA VARIE FORME DI UNO STESSO VERBO?					
Mangio	O	Bevo	O	Dormo	O
Mangi	O	Bevi	O	Dormi	O
Mangia	O	Beve	O	Dorme	O
Mangiamo	O	Beviamo	O	Dormiamo	O
Mangiate	O	Bevete	O	Dormite	O
Mangiano	O	Bevono	O	Dormono	O

PARTE III - COME I BAMBINI USANO LE FRASI

	Non ancora	A Volte	Spesso
Il vostro bambino ha già iniziato a formare frasi di più parole?	O	O	O

SE AVETE RISPOSTO "NON ANCORA", GRAZIE, POTETE FERMARVI QUI. SE AVETE RISPOSTO DIFFERENTEMENTE, PER FAVORE CONTINUATE

ESEMPI: Riportate tre esempi delle frasi più lunghe che il vostro bambino ha detto in questo periodo

1. ______________________________

2. ______________________________

3. ______________________________

COMPLESSITA'

In ciascuna delle seguenti coppie di frasi, segnate quella che vi "suona" più simile a ciò che il vostro bambino direbbe, in questo periodo. Se il vostro bambino dice già frasi più lunghe o più complicate, segnate ugualmente la seconda.Abbiamo messo degli esempi che non possono corrispondere esattamente a quello che il vostro bambino dice. Vi preghiamo comunque di segnare ciò che assomiglia di più al suo modo di parlare.

1. a Scotta pappa	O	10. a Orso letto	O	19. a Scrivo penna	O
b Scotta la pappa	O	b Metto l'orso a letto	O	b Scrivo con la penna	O
2. a Scarpe mamma	O	11. a Papà via brum brum	O	20. a Prendi cappello cappotto	O
b Le scarpe di mamma	O	b Papà è andato via con la macchina	O	b Prendi il cappello e il cappotto	O
3. a Bau bau nanna	O	12. a Bimbo più	O	21. a Lavo pupa, metto nanna	O
b Il cane dorme	O	b Il bimbo non c'è più	O	b Lavo la bambola e la metto a nanna	O
4. a Mamma bella	O	13. a Adesso vene nonna	O	22. a Metto pappe via	O
b Mamma è bella	O	b Adesso viene nonna	O	b Mi metto le scarpe e vado via	O
5. a Bimbo cade	O	14. a Medicina no	O	23. a Vojo banana, no mela	O
b Il bimbo cade per terra	O	b Non voglio la medicina	O	b Voglio la banana, non voglio la mela	O
6. a Papà più	O	15. a Domani bimbi	O	24. a Apro libro, leggo	O
b Papà è andato via	O	b Domani vado dai bimbi	O	b Apro il libro e lo leggo	O
7. a Io pappa	O	16. a Via treno rosso nonno	O	25. a Andiamo nonna, no asilo	O
b Io mangio la pappa	O	b Sono andato sul treno rosso col nonno	O	b Andiamo dalla nonna non all'asilo	O
8. a Butta palla	O	17. a Taglia torta coltello	O	26 a Bevo latte, nanna	O
b Nonna butta la palla	O	b Mamma taglia la torta col coltello	O	b Bevo il latte e dopo vado a nanna	O
9. a Mella bimba	O	18. a Dà palla rossa	O	27. a Lavo mani, denti	O
b Do la caramella alla bimba	O	b Dammi la palla rossa	O	b Mi lavo le mani e i denti	O

segue COMPLESSITA'

28. a Butto palla, mamma prende ○	32. a Vado zia, micio ○	36. a Bimbo detto no camion a me ○
b Io butto la palla e mamma la prende ○	b Vado dalla zia a vedere il micio ○	b Il bimbo ha detto che non mi dà il camion ○
29. a Papà, lo sai Simona fatto bua oggi ○	33. a Soffio pappa, scotta ○	37. a Lavo mani, sporche! ○
b Papà lo sai che Simona mi ha fatto la bua oggi ○	b Soffio sulla pappa perchè scotta ○	b Mi lavo le mani, perchè sono sporche ○
30. a Bimbo piange, caduto ○	34. a Papà detto no mangia mella ○	
b Il bimbo piange perchè è caduto ○	b Papà ha detto che non si mangia la caramella ○	
31. a Mamma, vedi bimbo abbiato! ○	35. a Più pappa, no piace ○	
b Mamma, vedi che il bimbo si è arrabbiato ○	b Non voglio più la pappa perchè non mi piace ○	

MODI DI ESPRIMERSI

I bambini spesso parlano delle stesse cose in maniera un pò diversa dagli adulti. Segnate nelle coppie di frasi che seguono quelle che assomigliano di più al modo di esprimersi del vostro bambino. Abbiamo usato, in alcune frasi, il nome "Luca" solo come esempio: quando lo leggete pensate al nome del vostro bambino.

1. a Mio camion ○	5. a Sei bella tu ○	9. a La apro io la porta ○
b Luca camion ○	b Bella mamma ○	b Apro io la porta ○
2. a Io sono sporco ○	6. a Tu mi leggi il libro! ○	10. a Non lo voglio più ○
b Luca è sporco ○	b Mamma legge il libro! ○	b Non voglio più ○
3. a Mi porti alle giostre? ○	7. a Dammi la palla ○	11. a Scotta quello! ○
b Porti Luca alle giostre? ○	b A Luca palla ○	b Scotta il latte ○
4. a Voglio il succo, io ○	8. a Lui dorme ○	12. a Metto questo qui ○
b Vuole il succo, Luca ○	b Bau Bau dorme ○	b Metto l'orso sul letto ○

SCHEDA INFORMATIVA

DATI SUL BAMBINO E NOTIZIE SULLA SUA SALUTE

Ordine di nascita del bambino 1° ○ 2° ○ | Altro (specificare)________________ | Numero di bambini totali presenti in famiglia________

Il bambino è figlio adottivo? SI ○ NO ○ | Il bambino è gemello? SI ○ NO ○ | Il bambino è nato a termine? SI ○ NO ○

Se NO in quale settimana di gestazione è nato? __________ Peso alla nascita __________

Il bambino ha avuto o ha qualche rilevante problema di salute e/o di linguaggio? SI ○ NO ○ | Se SI, per favore descrivetelo ________________

Il bambino soffre o ha sofferto di otiti (più di 4 volte in un anno)? SI ○ NO ○

Avete qualche preoccupazione sulle abilità comunicative e linguistiche del bambino? SI ○ NO ○ | Se SI, per favore descrivetelo ________________

Uno o più componenti della vostra famiglia (voi genitori, zii, nonni) ha avuto problemi di udito, linguaggio e /o apprendimento SI ○ NO ○ | Se SI quali?

Nome del pediatra di famiglia ________________

Il bambino frequenta il nido? SI ○ NO ○ | Se SI: per quante ore al giorno? ________ | A quanti mesi è stato inserito al nido?________________

Con chi passa il maggior numero di ore durante il giorno quando non è al nido?________________

CONTATTO CON ALTRE LINGUE

Il bambino è esposto ad altre lingue oltre all'Italiano? SI ○ NO ○ | Se SI: A quale lingua?________________

Chi la usa?________________ | Da che età (in mesi)________ Per quanti giorni a settimana (numero)?_____

Per quante ore al giorno (numero)? ________________ | Da che età (in mesi) il bambino è esposto all'Italiano?________________

Da che età (in mesi) il bambino è esposto all'altra lingua?__________

DATI SUI GENITORI

MADRE: Nazionalità________________Occupazione________________ | **PADRE:** Nazionalità________________Occupazione________________

Scolarità: Per favore cerchia gli anni di studio completati (8= licenza media; 13=liceo/diploma; 18= laurea; >18= post lauream)

MADRE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	> 18
PADRE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	> 18

Chi compila il questionario? MADRE ○ PADRE ○ | Contatti: email________________ tel________

CONSENSO INFORMATO e AUTORIZZAZIONE AL TRATTAMENTO DEI DATI

Le informazioni qui riportate saranno usate in forma anonima ai sensi del decreto legislativo n. 196/2003 nel rispetto dei suoi diritti e della riservatezza dei dati personali

Data________________ Firma per consenso informato e autorizzazione________________

Appendix 5

Mandarin adaptation of MBCDI

□–□ –□ –□□ –□ – □□

孩子的姓名：________ 性别：________

填表日期：________ 出生日期：________ 实际年龄：________

汉语沟通发展量表
（普通话版）：词汇及句子

请用铅笔填写

正确填写	不正确填写
●	⊘⊗⊙⊘

第一部份

这是了解幼儿词汇量的表。如果您的孩子还不会说该词或者只是重复别人，请填“不能说”（涂黑第一个圆圈）；如果您的孩子会说该词而不是马上重复别人说过的词，请填“能说”（可涂黑第二个圆圈）。假如您的孩子对该词的发音不准（例如：火车说成“火些”）或他的说法有所不同（例一：葡萄说成“萄”；例二：老鼠说成“耗子”），也算能说。当遇到“面/面条”这种中间划有“/”的词汇时，对会说“/”两侧中的一个词即为“会说”。这个词汇表示用于不同年龄的孩子，完全有可能您的孩子现在只知道这个词表中较少的词，甚至根本不知道，也属于正常范围，请不要为孩子究竟知道其中多少个词而担心。

1

143

□-□-□-□□-□-□□

1. 象声和感叹词（12）

	不会说	会说		不会说	会说		不会说	会说
喂?	○	○	哎哟	○	○	嘎嘎达（鸡叫）	○	○
旺旺（狗叫）	○	○	呀	○	○	梆梆（打枪）	○	○
喵（猫叫）	○	○	咩咩（羊叫声）	○	○	喳喳（鸟叫）	○	○
嘀嘀（汽车声）	○	○	嘎嘎（鸭子叫）	○	○	嗷（狮子叫）	○	○

2. 人名（32）

	不会说	会说		不会说	会说		不会说	会说
妈妈	○	○	伯伯/大大	○	○	男孩	○	○
爸爸	○	○	舅舅	○	○	男人	○	○
奶奶	○	○	姐姐	○	○	老师	○	○
姥姥	○	○	妹妹	○	○	警察	○	○
爷爷	○	○	哥哥	○	○	医生/大夫	○	○
姥爷	○	○	弟弟	○	○	唐老鸭	○	○
宝宝	○	○	小朋友的名字	○	○	米老鼠	○	○
自己的名字	○	○	大妈	○	○	孙悟空	○	○
阿姨	○	○	人	○	○	猪八戒	○	○
姑姑	○	○	孩子/小孩/小朋友	○	○	朋友	○	○
叔叔	○	○	女孩	○	○			

3. 游戏和常做的事（28）

	不会说	会说		不会说	会说		不会说	会说
要	○	○	打（电话）	○	○	是	○	○
不要	○	○	藏猫猫	○	○	对了	○	○
再见/Byebye	○	○	抓（逮）住了!	○	○	不行	○	○
谢谢	○	○	你拍一，我拍一	○	○	快点	○	○
撒尿/尿尿	○	○	你好	○	○	等等	○	○
拉屎/拉臭臭	○	○	（某某某）好	○	○	轻点	○	○
吃饭	○	○	请	○	○	听话	○	○
洗澡	○	○	（真）棒!	○	○	上学	○	○
休息/歇会儿	○	○	好吧	○	○	一岁/两岁	○	○
买（东西）	○	○						

4. 动词（194）

	不会说	会说		不会说	会说		不会说	会说
抱	○	○	尿	○	○	要	○	○
拿（过来）	○	○	上	○	○	有	○	○
来	○	○	下	○	○	睡觉	○	○
走	○	○	喝	○	○	盖上	○	○
坐	○	○	吃	○	○	玩	○	○
站	○	○	喂	○	○	开（门）	○	○
蹲	○	○	爬	○	○	关	○	○

2

□—□ —□ —□□ —□ — □□

	不会说	会说		不会说	会说		不会说	会说
画画	○	○	追	○	○	搬	○	○
打	○	○	摔	○	○	端	○	○
背	○	○	是（什么）	○	○	揉	○	○
戴	○	○	想	○	○	转	○	○
洗	○	○	知道	○	○	爱	○	○
擦	○	○	梳	○	○	乐（一个）	○	○
亲（一个）	○	○	刷	○	○	数数	○	○
飞	○	○	唱	○	○	磕	○	○
亮了	○	○	听	○	○	翻	○	○
打开	○	○	听见	○	○	夹	○	○
起来	○	○	扎	○	○	闻	○	○
剥	○	○	推	○	○	尝	○	○
叫	○	○	捡	○	○	咽	○	○
看	○	○	找	○	○	做饭	○	○
跑	○	○	倒了	○	○	跳舞	○	○
跳	○	○	进去	○	○	换	○	○
踢	○	○	出去	○	○	抹（油等）	○	○
倒（水）	○	○	过	○	○	装	○	○
买	○	○	回来	○	○	摘（揪）	○	○
摸	○	○	踩	○	○	让	○	○
穿	○	○	藏	○	○	修	○	○
给	○	○	拉/拽	○	○	使劲	○	○
送	○	○	讲	○	○	举	○	○
掉	○	○	握（手）	○	○	挂	○	○
笑	○	○	敲	○	○	滚	○	○
哭	○	○	闭（眼、嘴）	○	○	挖	○	○
拍	○	○	丢	○	○	扶	○	○
会	○	○	喜欢	○	○	学	○	○
写	○	○	动	○	○	记（得）	○	○
躺	○	○	等	○	○	打破/打碎	○	○
趴	○	○	醒	○	○	扭	○	○
骑	○	○	滑	○	○	停	○	○
开（车）	○	○	切（菜）	○	○	压	○	○
蹦	○	○	剪	○	○	撞	○	○
扫（地）	○	○	撕	○	○	插	○	○
去	○	○	洒	○	○	搂	○	○
放	○	○	撒	○	○	带	○	○
咬	○	○	响	○	○	搭	○	○
扔	○	○	接	○	○	跟着	○	○
吐	○	○	碰	○	○	拨（电话）	○	○
说	○	○	蹬	○	○	逗	○	○
吹	○	○	抓	○	○	排（队）	○	○

	不会说	会说		不会说	会说		不会说	会说
干（什么）	○	○	套	○	○	绑	○	○
用	○	○	拆	○	○	搅	○	○
舔	○	○	读	○	○	绕	○	○
嚼	○	○	搁	○	○	摁/按	○	○
拐（弯）	○	○	瞅	○	○	做梦	○	○
弯	○	○	逮（坏蛋）	○	○	工作	○	○
抢	○	○	躲	○	○	试	○	○
眨（眼）	○	○	待（一会儿）	○	○	卖	○	○
拧	○	○	嚷	○	○	掸掸	○	○
叫唤	○	○	问	○	○	收拾	○	○
瞧	○	○	告诉	○	○	忘记	○	○
弄	○	○	捋/挽（袖子）	○	○	假装	○	○
游泳	○	○	冲	○	○	希望	○	○
贴	○	○	帮助/帮忙	○	○	抖搂	○	○
拔（草）	○	○	拖	○	○	蹭	○	○
长（大）	○	○	悠	○	○			

5. 吃和喝的（69）

	不会说	会说		不会说	会说		不会说	会说
水	○	○	肝儿(猪肝、鸡肝)	○	○	西瓜	○	○
牛奶	○	○	菜	○	○	草莓	○	○
粥	○	○	豆子	○	○	梨	○	○
汤	○	○	扁豆	○	○	糖	○	○
酸奶	○	○	豆芽	○	○	饼	○	○
乐百氏	○	○	瓜	○	○	饼干	○	○
果汁	○	○	白菜	○	○	面包	○	○
可乐	○	○	菠菜	○	○	蛋糕	○	○
汽水	○	○	萝卜	○	○	果冻	○	○
茶	○	○	土豆	○	○	瓜子	○	○
饮料	○	○	西红柿	○	○	花生	○	○
饭	○	○	黄瓜	○	○	核桃	○	○
米	○	○	玉米	○	○	巧克力	○	○
饺子	○	○	豆腐	○	○	薯条	○	○
面条	○	○	葱	○	○	冰棍儿	○	○
包子	○	○	蘑菇	○	○	糖葫芦	○	○
馒头	○	○	木耳	○	○	冰淇淋	○	○
馄饨	○	○	水果	○	○	油条	○	○
肉	○	○	苹果	○	○	面/面粉	○	○
鱼	○	○	香蕉	○	○	辣椒	○	○
蛋	○	○	橘子	○	○	盐	○	○
虾	○	○	橙子	○	○	醋	○	○
鸡肉	○	○	葡萄	○	○	酱油	○	○

□—□ —□ —□□ —□ — □□

6. 身体的部分（27）

	不会说	会说		不会说	会说		不会说	会说
头	○	○	嘴（口）	○	○	手指头	○	○
脑袋	○	○	嘴唇	○	○	大拇指	○	○
头发	○	○	牙	○	○	肚子	○	○
脸	○	○	舌头	○	○	肚脐眼	○	○
眼睛	○	○	下巴	○	○	屁股	○	○
眉毛	○	○	脖子	○	○	腿	○	○
脸蛋	○	○	肩膀	○	○	脚/脚丫丫	○	○
耳朵	○	○	胳膊	○	○	膝盖	○	○
鼻子	○	○	手	○	○	脚腕	○	○

7. 动物（真的或玩具的均可）(49)

	不会说	会说		不会说	会说		不会说	会说
猫	○	○	斑马	○	○	猫头鹰	○	○
小白兔/兔子	○	○	长颈鹿	○	○	鱼	○	○
马	○	○	骆驼	○	○	虫子	○	○
羊	○	○	刺猬	○	○	乌龟	○	○
狗	○	○	动物	○	○	青蛙	○	○
猴子	○	○	鸭子	○	○	蚂蚁	○	○
老虎	○	○	鸟	○	○	龙	○	○
牛	○	○	小鸡	○	○	蝴蝶	○	○
熊	○	○	燕子	○	○	蜻蜓	○	○
猪	○	○	鸽子	○	○	蚊子	○	○
大象	○	○	鹅	○	○	苍蝇	○	○
熊猫	○	○	企鹅	○	○	蛇	○	○
狮子	○	○	喜鹊	○	○	鳄鱼	○	○
老鼠	○	○	孔雀	○	○	蛐蛐	○	○
猩猩	○	○	乌鸦	○	○	恐龙	○	○
鹿	○	○	老鹰	○	○	蟑螂	○	○
狼	○	○						

8. 形容词和副词（66）

	不会说	会说		不会说	会说		不会说	会说
没了	○	○	冷	○	○	害怕	○	○
大	○	○	饱	○	○	疼	○	○
小	○	○	饿	○	○	乖	○	○
好	○	○	渴	○	○	坏了	○	○
坏	○	○	甜	○	○	破了	○	○
香	○	○	辣	○	○	淘气/调皮	○	○
臭	○	○	酸	○	○	讨厌	○	○
烫	○	○	咸	○	○	快	○	○
热	○	○	脏	○	○	慢/慢点	○	○
凉	○	○	干净	○	○	可爱/好玩儿	○	○

□—□—□—□□—□—□□

	不会说	会说		不会说	会说		不会说	会说
可怜	○	○	湿	○	○	不错	○	○
累	○	○	干	○	○	粘糊	○	○
困了	○	○	响	○	○	卡了	○	○
病	○	○	长	○	○	白	○	○
高	○	○	硬	○	○	黑	○	○
漂亮/美	○	○	软	○	○	红（色）	○	○
喜欢	○	○	完了	○	○	绿	○	○
新	○	○	够了	○	○	黄	○	○
老	○	○	空	○	○	蓝（色）	○	○
高兴/乐/开心	○	○	满	○	○	黑乎乎	○	○
生气	○	○	重	○	○	第一	○	○
委屈	○	○	小心	○	○	最后	○	○

9. 家里的小东西（56）

	不会说	会说		不会说	会说		不会说	会说
碗	○	○	音响	○	○	包	○	○
杯子	○	○	VCD 机	○	○	书包	○	○
瓶子	○	○	被子	○	○	钱包	○	○
勺	○	○	枕头	○	○	口袋	○	○
筷子	○	○	药	○	○	扇子	○	○
盘	○	○	梳子/拢子	○	○	(抹）布	○	○
锅	○	○	盆	○	○	盒子	○	○
刀	○	○	肥皂/香皂	○	○	篮子	○	○
茶杯	○	○	牙刷	○	○	桶	○	○
灯	○	○	毛巾	○	○	刷子	○	○
钟/表	○	○	手纸	○	○	笤帚	○	○
电话	○	○	画	○	○	托把/墩布	○	○
电扇	○	○	纸	○	○	垃圾	○	○
电池	○	○	剪刀	○	○	簸箕	○	○
手表	○	○	绳	○	○	锤子	○	○
收音机	○	○	眼镜	○	○	钉子	○	○
照相机	○	○	报纸	○	○	木头	○	○
(钢）琴	○	○	钥匙	○	○	东西	○	○
录音机	○	○	钱	○	○			

10. 玩具和娱乐用品（18）

	不会说	会说		不会说	会说		不会说	会说
球	○	○	汽球	○	○	故事	○	○
书	○	○	枪	○	○	风筝	○	○
小娃娃	○	○	积木	○	○	歌	○	○
笔	○	○	玩具	○	○	铃铛	○	○

6

□—□ —□ —□□ —□ — □□

	不会说	会说		不会说	会说		不会说	会说
铅笔	○	○	车轮/轱辘	○	○	棋子	○	○
蜡笔	○	○	游戏	○	○	礼物	○	○

11. 衣服（28）

	不会说	会说		不会说	会说		不会说	会说
帽子	○	○	毛衣	○	○	裙子	○	○
手套	○	○	背心	○	○	皮带	○	○
围巾	○	○	上衣	○	○	袜子	○	○
手绢	○	○	（裤）兜	○	○	鞋	○	○
围嘴	○	○	扣子	○	○	拖鞋	○	○
项链	○	○	拉锁	○	○	皮鞋	○	○
衣服/衣裳	○	○	袖子	○	○	凉鞋	○	○
大衣/外套	○	○	裤子	○	○	球鞋/旅游鞋	○	○
棉袄	○	○	毛裤	○	○			
夹克	○	○	裤衩	○	○			

12. 家具、屋子（29）

	不会说	会说		不会说	会说		不会说	会说
楼梯	○	○	茶几	○	○	水池子	○	○
门	○	○	电视	○	○	水龙头/水管	○	○
窗户	○	○	冰箱	○	○	厨房	○	○
床	○	○	炉子/灶	○	○	暖水瓶/暖壶	○	○
桌子/饭桌	○	○	洗衣机	○	○	煤气	○	○
尿盆	○	○	屋子	○	○	空调	○	○
镜子	○	○	柜子	○	○	微波炉	○	○
凳子	○	○	抽屉	○	○	阳台	○	○
椅子	○	○	澡盆	○	○	电梯	○	○
沙发	○	○	厕所	○	○			

13. 外面的东西（32）

	不会说	会说		不会说	会说		不会说	会说
花	○	○	山	○	○	星星	○	○
树	○	○	棍子	○	○	天（空）	○	○
叶子/树叶	○	○	沙子	○	○	云彩	○	○
树枝	○	○	铲子	○	○	房顶	○	○
草	○	○	梯子	○	○	街（道）/大街	○	○
土	○	○	滑梯	○	○	路	○	○
水	○	○	转椅	○	○	红绿灯	○	○
雨	○	○	秋千	○	○	（雨）伞	○	○
雪	○	○	蹦蹦床	○	○	雪人	○	○
风	○	○	太阳	○	○	游泳池	○	○
石头	○	○	月亮	○	○			

□—□—□—□□—□—□□

14. 车（真的或玩具的均可）(14)

	不会说	会说		不会说	会说		不会说	会说
车	○	○	小轿车	○	○	老吊车	○	○
飞机	○	○	自行车	○	○	三轮车	○	○
火车	○	○	公共汽车	○	○	吉普车	○	○
船	○	○	卡车	○	○	救护车	○	○
摩托车	○	○	出租车/的	○	○			

15. 外面的地方（17）

	不会说	会说		不会说	会说		不会说	会说
家	○	○	动物园	○	○	学校	○	○
外头/外面/外外	○	○	花园	○	○	天安门	○	○
班儿/单位	○	○	麦当劳/肯德基	○	○	中国	○	○
房子	○	○	医院	○	○	游乐园	○	○
楼房	○	○	商店	○	○	超市	○	○
公园	○	○	幼儿园/托儿所	○	○			

16. 方向词（21）

	不会说	会说		不会说	会说		不会说	会说
这边/这儿	○	○	底下	○	○	边上	○	○
那边/那儿	○	○	前面	○	○	跟	○	○
上（面）	○	○	后面	○	○	到	○	○
下（面）	○	○	中间	○	○	往	○	○
外面	○	○	旁边	○	○	朝	○	○
里面	○	○	挨着	○	○	向	○	○
在	○	○	一边	○	○	上（哪儿去）	○	○

17. 数量词（9）

	不会说	会说		不会说	会说		不会说	会说
一	○	○	一样	○	○	全部	○	○
二	○	○	多	○	○	所有	○	○
三	○	○	有的	○	○	另外	○	○

18. 代词（24）

	不会说	会说		不会说	会说		不会说	会说
我	○	○	这个	○	○	他们	○	○
我的	○	○	那个	○	○	我们的	○	○
自己	○	○	那些	○	○	咱们的	○	○
自己的	○	○	这些	○	○	你们的	○	○
你	○	○	别的	○	○	他们的	○	○
你的	○	○	我们	○	○	人家	○	○
他（她、它）	○	○	咱们	○	○	其它	○	○
他的	○	○	你们	○	○	别人	○	○

□—□ —□ —□□ —□ — □□

19. 量词（20）

	不会说	会说		不会说	会说		不会说	会说
个	○	○	点	○	○	粒	○	○
口	○	○	块	○	○	头	○	○
只	○	○	件	○	○	匹	○	○
辆	○	○	次	○	○	位	○	○
张	○	○	步	○	○	眼	○	○
本	○	○	层	○	○	些	○	○
条	○	○	堆	○	○			

20. 疑问词（12）

	不会说	会说		不会说	会说		不会说	会说
干嘛？	○	○	几点	○	○	几个	○	○
什么	○	○	哪个	○	○	多少	○	○
谁	○	○	为什么	○	○	（行、好）吗？	○	○
在哪里/哪儿呢？	○	○	怎么	○	○	（还有）呢？	○	○

21. 句尾虚词（6）

	不会说	会说		不会说	会说		不会说	会说
啊/呀	○	○	啦	○	○	呢	○	○
了	○	○	嘛	○	○	噢	○	○

22. 时间词（15）

	不会说	会说		不会说	会说		不会说	会说
早上	○	○	后天	○	○	以后	○	○
晚上	○	○	天	○	○	晚（一点）	○	○
今天	○	○	先	○	○	现在	○	○
明天	○	○	已经	○	○	早（一点）	○	○
昨天	○	○	以前	○	○	时间	○	○

23. 助词（12）

	不会说	会说		不会说	会说		不会说	会说
爱（听）	○	○	肯	○	○	该（走啦！）/应该	○	○
能	○	○	想	○	○	得（你得去）	○	○
会	○	○	不许	○	○	把（××放…）	○	○
可以（做）	○	○	愿意	○	○	舍不得	○	○

24. 连词（9）

	不会说	会说		不会说	会说		不会说	会说
和	○	○	就	○	○	要是	○	○
跟	○	○	可是	○	○	所以	○	○
因为	○	○	如果	○	○	那么	○	○

9

□—□ —□ —□□ —□ — □□

第二部份

A. 小孩怎么使用词			
注："有时"即指孩子用过一次以上；"经常"即指需要用的时候大部分会用到			
	还没有	有时会	经常会
1. 如果您提及一个不在眼前的东西，他会不会明白？（例：您说"小狗熊在哪里"？假如在另外一间屋的话，他会不会去找？）	○	○	○
2. 您的孩子有没有指或拿起人家的东西并说出那人的名字或名称？（例：指一指妈妈的鞋，说"妈妈"）	○	○	○
3. 您的孩子有没有讲过有关不在眼前的玩具或动物？	○	○	○
4. 您的孩子有没有讲过有关过去发生的事或见过的人？（例：昨天去姥姥家，第二天说"姥姥"）	○	○	○
5. 您的孩子有没有讲过有关将要发生的事？（例：您要上外地时，孩子自己说"飞机"、"火车"等）	○	○	○

B. 句子与语句			
	还没有	有时会	经常会
1. 您的孩子有没有开始组合几个动词在一起？（例："出去"，"上来"，"走上去"）	○	○	○
2. 当讲起人们的东西或身体部分的时候，您的孩子有没有开始使用"的"表示所属。（例："我的！"）	○	○	○
3. 当讲起名词的时候，您的孩子有没有开始使用量词？（例：个、辆等。注：不需要很准，只要他开始用了）	○	○	○
4. 当讲过去发生的事时，您的孩子有没有开始使用"过"或"了"字？（例："去过"，"吃了"）	○	○	○

	还没有	有时会	经常会
C. 您的孩子有没有开始把几个字组合在一起？（例："妈妈车"、"吃饼干"）	○	○	○
＊如果您 C 部分答的是"还没有"，请在此停。如果您答的是"有时会"或"经常会"，请继续填。＊			
您的孩子组合的例子			
请列出您孩子最近说过的三个最长的句子			
1			
2			
3			
			10

□—□—□—□□—□—□□

D. 复杂性

下面每一组里面，请选出最象您孩子现在讲话的样子。如果他讲的话比最后的选择还要复杂，请选最后的一项。如果他讲的话比第一个选择还要简单，请填号码边的圈。

○ 1.（表示某东西不见了）
- 没 ○
- 没了 ○
- 车没（有）了 ○

○ 2.（讲想要的东西）
- 球 ○
- 要 ○
- 要球 ○

○ 3.（表示愿望） ○
- 去外外 ○
- 出去 ○
- 要出去 ○
- 我要出去 ○

○ 4. 宝宝车 ○
- 宝宝的车 ○
- 我的车 ○

○ 5.（表示愿望）
- 喝水 ○
- 我喝水 ○
- 要喝水 ○
- 我要喝水 ○

○ 6.（表示所属）
- 妈妈车 ○
- 妈妈的车 ○

○ 7.（讲将要发生的事）
- 球掉 ○
- 球要掉 ○

○ 8.（如果不能做某事）
- 不 ○
- 不拿 ○
- 不拿起来 ○
- 拿不起来 ○

○ 9.（如果要人为他做某事）
- 讲 ○
- 妈妈讲 ○
- 妈妈讲故事 ○
- 讲故事宝宝 ○
- 妈妈给宝宝讲故事 ○

○ 10.（表示是自己的东西）
- 我的 ○
- 那我的 ○
- 那是我的 ○

○ 11.（讲想要的东西）
- 宝宝要 ○
- 宝宝要球 ○
- 宝宝想要球 ○

○ 12.（如果要再做某件事）
- 吃点 ○
- 再吃点 ○

○ 13.（讲过去发生的事）
- 哥哥摔 ○
- 哥哥摔跤 ○
- 哥哥摔了 ○
- 哥哥摔跤了 ○

○ 14.（讲正在发生的事）
- 娃娃哭 ○
- 娃娃哭了 ○

○ 15.（如果不想有某事发生）
- 不动 ○
- 不许/不能动 ○
- 别动 ○

○ 16.（讲发生过的事）
- 哥哥打 ○
- 哥哥打我 ○
- 哥哥打我了 ○

○ 17.（如果又发生某事）
- 他要 ○
- 他还要 ○

○ 18.（如不想让他人做某事）
- 不要看书 ○
- 你不要看书 ○
- 我不要你看书 ○

○ 19.（如果不希望某事发生）
- 不洗小娃娃 ○
- 不能洗小娃娃 ○

○ 20.（如果又发生某事）
- 他来了 ○
- 他又来 ○
- 他又来了 ○

○ 21.（讲正在发生的事）
- 我吃饭 ○
- 我吃饭呢！ ○
- 我正吃饭呢！ ○

○ 22.（提问）
- 这？ ○
- 这（个）呢？ ○
- 什么？ ○
- 这是什么？ ○

○ 23.（讲数量词）
- 一人 ○
- 一个人 ○

□—□ —□ —□□ —□ — □□

○ 24.（讲量词）		○ 26.（如果做不了某件事）		○ 27.（提问）	
一个车	○	不	○	玩?	○
一辆车	○	不会	○	能玩?	○
○ 25.（讲以前发生过的事）		我不会	○	能玩吗?	○
我做	○	我不会做	○		
我做过	○	我做不了	○		

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Appendix 6

Vocabulary checklists for Moroccan and Standard Arabic.

MOROCCAN ARABIC

1. Sons d'animaux

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
bêê bêê	(تَيْبَعْبَعْ) بَاعْ بَاعْ	[ba:ʔˤba:ʔˤ]	/	
tchou tchou	تْصْفَارْ	tsˤfa:r	tsfar	
cocorico	تْتْقَاقِي	ttqaqj	tkaki (?)	
grr	الزْئِيرْ	alzʔj:r	alz'ir	
miaou	تْتْعُوكْ	ttʔˤwk	/	
meuh	ك/ تْتْمُوكْ	ttmwk	/	
aie	آحْ آحْ	ah ah	/	
coin-coin	وَاكْ وَاكْ	wak wak	/	
oh-oh	يَاهْ /أحْلِيلِي	aʔhljlj / jah	/	
vroum	تْفْغْنِنْ / فْغْنْ غْنْ	fɣn ɣn / tfɣnjn	/	
ouaf-ouaf	الْكَلْبْ نْبَاحْ	nbah alklb	/	
miam-miam	أمنمنمنمْ	aʔmnmnmnm	/	

2. Noms d'animaux

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
animal	البهيمة / الْوَحْشْ	alwhʃ /albhjmt	hayawan	
ours	دُبْ	dub	dob/debb	
abeille	نَحلة	nahla	n'hla	
oiseau	حْمَامة	hmama	/	
insecte/petite bête	حَشَرَة	haʃara	/	
lapin	قْنِيَة	qnja	qniyya	
papillon	فَرْطْوطو	frtˤowtˤow	farâsha	
chat	مَشَة / مَشْ	moʃa / moʃ	mesh	
poulet	دْجَاجة	dʒaʒa	djâja, djaaj	
vache	بَقْرَة (قاف =جيم مصري)	baqara	bagra	
cerf/biche	غْزَالة	ɣazala	/	
chien	كَلْبْ / قَانُوعْ	kalb / qanwuʔˤ	kelb	
âne	كِيدَارْ / حْمَارْ	himar/ kjdar	/	
canard	بَطَّة	batˤa	btta, wazza	
éléphant	فِيلْ	fjjl	fil	
poisson	حُوتْ	hut	hout	
mouche	ذْبَّانَة	dbana	debbana	

grenouille	جْـرَانَة	ʒarana	j'râna	
girafe	زرَافـة	zarafa		
oie	وَزّة	waza	/	
cheval	عَاوْدْ	ʔˤawd	aawd	
lion	السْـبَـعْ	səbaʔˤ	sbaa	
singe	لْقَرْدْ	lqard	qard	
souris	لْفَـارْ	lfar	far	
hibou	مُوكا	moqa	/	
pingouin	مصري جيم / لْبانجوان	lbanʒowan	/	
mouton	كَـبْـشْ /حَوْلي	hawlj /kbʃ	hawli/kbir/k'b'sh	
serpent	حَنْشْ	hnɛʃ	hanach/h'n'sh, lfaa	
araignée	عَنْكْـبُـوت	ʔˤankabowt	ankabuwt ['ankabūt], rtila	
écureuil	نَمْسْ	nmsə	nims	
tigre	النْمَر	alnmr	namir, n'mer	
dinde	بـيبـي	bjbj	bibi	
tortue	فـكَرُونْ	fakron	fakroun	

3. Véhicules

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
avion	طَيّارَة	tˤaja:ra	**tiyyâra**	
vélo/bicylette	بـيشْكْلِيطَا	bjʃkljtˤa	/	
bateau	لْبـاطُو	lbatˤo	bâto	
bus	طُوبـيسْ	tˤowbjs	/	
voiture	طوموبـيلْ	tˤowmowbjl	tomobila, siyara	
camion pompier	بـومْبـيا	bowmbja	/	
moto	مُوطورْ	mowtˤowr	/	
poussette	كَـرُّوسَة	karowsa	/	
tracteur	تْرَاكْتـور	tˤraktowr	/	
train	تْرَانْ	tˤran	trin	
camion	يُونكَـام	kamjow	/	

4. Jouets

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
balle	كورة	kowra	/	
ballon	نَفَّاخَة	nofaxa	koura	

cube	طوبات	t^{ʕ}owbat	**mokhahab**	
livre	كتاب	kutab	ktab	
bulle	فقاعات	foqaʔ^{ʕ}at	/	
poupée	منيكا	monjka	/	
stylo	ستيلو	stjlow	stilou	
jouet	لعبة	loʔ^{ʕ}ba	/	
nounours	ونوسن	nownows	/	

5. Nourriture et boissons

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
pomme	تفاح	tofah	tffah	
banane	بنان	banan	banân	
biscuit	بيسكوي	bjskwj	/	
pain	خبز	xobz	khobz	
beurre	زبدة	zobda	zebda	
gâteau	كيكة	kjka	kik, helwa	
carotte(s)	خيزو	xjzo	khizzou	
céréale	الزرع	alzraɣ	/	
cheerios	فليكس كورن	kowrn fljks	/	
fromage	جبن	ʒobn	formaj	
chips	شيبس	ʃjbs	/	
chocolat	شكلاط	ʃoklat^{ʕ}	/	
café	لقهوة	lqahwa	qahwa	
cookie/biscuit	كعك	kaʔ^{ʕ}k	kik, bakout	
oeuf	بيضة	bajda	bida	
nourriture/aliment(s)	ماكلة	makla	makla	
glace	كلاص لا	la glas	glâss	
confiture	كوفيتير	kofjtjr	/	
jus	عصير	ʔ^{ʕ}as^{ʕ}jr	aasir	
viande	اللحم	alhm	l'ham	
lait	لحليب	alhaljb	lahlib	
nouilles	شعرية	ʃaʔ^{ʕ}rja	/	
orange	الليمون	ljmown	limon	
(petits) pois	جلبانا	ʒjlbana	j'l'bâna	
pizza	بيتزا	bjtza	/	
patate	بطاطا	bat^{ʕ}at^{ʕ}a	btâta	
raisin	زبيب	zbjbə	ainab	
sandwich	كروط كاس	kas krowt^{ʕ}	/	

saucisses	صُصيطْ	sˤosˤjtˤ	marquiz	
spaghetti	مقارُونية	maqarownja	/	
bonbons	حلْوَى	halwa	/	
thé	أتَاي	ataj	atay	
eau	الْمَا	lma	ma	
yaourt	الرّايْب	rajb	/	
		lahwajʒ / lbas		

6. Vêtements

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
cordons	خرز	xarɛz	/	
bavoir/bavette	ريّاقة	rajaga	/	
bottes	سباط	sabatˤ	bôtiyyô	
bouton	صْدَايْف	sˤadajf	**s'dâfa, h'boûba**	
cardigan/gilet	فَوْقِيَة / جَلّابة	ʒalaba / fowqja	/	
lange/couche	ليكُوشْ	ljkowʃ	/	
robe	كَسْوة	kswa	//	
lunettes	نَظّارات	nadarat	**n'dâder**	
chapeau	طّاقية	tˤagja	trbôsh	
veste	جاكيت	ʒakjt	jâkêta	
jeans	دْجين	dʒjn	/	
collier	عُقْدْ	ʔˤoqd	/	
pyjamas	بيجامة	bjʒama	pijama	
pantalon	سَرْوالْ	sarwal	serwâl	
écharpe	كُولْ كَاشْ	kaʃ kol	/	
chemise	تْرِيكُو	trjko	qamija	
short	شُورط	ʃortˤ	short	
chausette(s)	تْقاشَرْ	tqaʃar	sbbât	
tirette/braguette	السّلْسْلَة	lslsla	/	

7. Parties du corps

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
bras	ذْراعْ	draʔˤ	draa	
dos	ظْهَرْ	zˤhar	d'har	
ventre	كَرْشْ	karʃ	kersh	
nombril	صُرّة	sora	/	

derrière/fesses	مَكْعَد	magʔˤad	/	
joue	خَدْ	xad	hank	
oreille	لُوذْنِينْ	lwodnjn	loudin, w'den	
oeil	عِينْ	xajn	aayn	
visage/figure	لوجَهْ	loʒah	loujih, w'jeh	
doigt	صْبَعْ	sˤboʒ	/	
cheveux	شْعَرْ	ʃxar	chaar	
main	إيدْ	ʔjd	yedd	
tête	رَاسْ	ras	râss	
genou	رَكْبَة	rokba	rekba	
jambe	رْجَلْ	raʒol	/	
lèvres	شْوارَبْ	ʃowarb	شَفة	
bouche	فَمْ	fom	fam	
ongle	ضْفَارْ	dˤfar	dfar	
nez	مْنَخَارْ	manxar	nîf	
bobo	جرح	ʒorh	/	
langue	لْسَانْ	ljsan	lsân (lisshaan)	
dent	سْنَانْ	snan	snna	

8. Meubles et pièces

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
bain/baignoire	بَانْيُو	banjo	/	
salle de bain	طْوَالِيتْ	tˤwaljt	/	
lit	نَامُوسِيًا	namowsja	**nâmoûssiyya**	
chambre	بيتْ النْعَاس	bjt nxas	**baiyt**	
chaise	كُرْسَي	korsj	koursi	
cuisinière	بوطًا	botˤa	/	
berceau	كَامًا	kama	/	
divan/canapé	فُوطويْ	fowtˤøj	/	
porte	بَابْ	bab	/	
en bas/au rez de chaussée	السفْلي	səflj	/	
tiroir	دْرُوجْ	dorwʒ	/	
garage	كَرَاجْ	garaʒ	/	
chaise haute	كرسي عالي	korsj xalj	/	
cuisine	كُزِينَا	kozjna	**cousîna**	
salle à manger	بيت الْمَاكْلة	bjt lmakla	bait = salle	
stylo à jeu (?)	رُوضْ	rowdˤ	/	
pot	حمام للأطفال	hamam adfal	/	

réfrigérateur	ثَلَاجَة	θalaʒa	/	
chaise à bascule	كُرْسِي كَيْهَزْهَزْ	korsj kjhzhz	/	
évier	حَوْض	hawdˁ	/	
escaliers	سْلُوم	salom	**droûj**	
table	طَابْلَة / مِيدَة	tˁabla / mjda	**tâbla/maida**	
TV/télé	تَلْفَزَة / تِلِفِزْيُون	tjlfjzjwn / talfaza	/	
toilette	كَابِينَة / طْوَالِيط	kabina / tˁwalɛtˁ	**kabîna/toilêt**	
en haut/à l'étage	الْفُوقِي	lfoqj	/	
fenêtre	سَرْجَم	sarʒm	**sh'rjem**	

9. Objets ménagers (d'intérieur)

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
sac	بَالِيزَة	baljza		
couverture	بَطَّانِيَة	bətˁanja	**baṭṭāniyya**	
bouteille	قَرْعَة	qarxa	**qar'a**	
bol	زْلَافَة	zlafa	/	
boite	صُنْدُوقْ	sˁandoq	/	
balai	شَطَّابَة	ʃatˁaba	/	
brosse	شِيتَا	ʃjta	**shîta**	
seau	دْلُو	dlu	stal	
horloge/montre	مَكَانَة	magana	/	
peigne	مَشْطَة	maʃtˁa	machta	
ordinateur	كُمْبْيُوتَرْ / بِ سِ	kombjwtr / bese	/	
vaisselle	طْبْسِيلْ	təbsjl	/	
fourchette	فُرْشِيطَة	forʃjtˁa	**fershiita**	
verre	غُرَافْ	ɣoraf	**kâss**	
marteau	مْطَرْقَة	mtˁaraqa	**mterqa**	
cruche/carafe	بْرَادْ	brəd	**kharraf**	
clé	سَارُوت	sarot	**sârout**	
lampe	بُولَة	bola	**missbah**	
lumière	ضُو	dˁuw	**douw**	
médicament	دْوَا	dwa	/	
argent	فْلُوسْ	flus	**nouqra = matériau**	
papier	وَرْقَة	warqa	**awraq**	
centimes/pièces	رْيَالَات	rajat	**ssarf = monnaie**	
photo	صُورَة	sˁowra	**taswir**	
oreiller	مْخَدَّة / وَسَادَة	mxada / wosada	**lamkhadda, w'sâda**	
plante	نَبَات	nabat	/	

porte-monnaie radio déchets ciseaux savon cuillère téléphone brosse à dent essui/serviette	بزطام راديو زبل مقص صابون معلقة تلفون سنان د شيتة فوطة	bztˤam radjo zbl mqasˤ sabun mxalqa tjljfun ʃjta dsnɛn fotˤa	/ / / mkass / **m'ilqa, mhourfa** tilifoun **chita dial snan**	

10. Objets d'extérieur et endroits où aller

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
cour/arrière-cour	اللورانية جردة	jarda loraniya	wast dar (cour intérieure)	
plage	لابلاج	laplage	bhar (mer)	
église	كنيسة	kanissa	/	
fleur	وردة	warda	/	
jardin	جردة	jarda	/	
maison	الدار	dar	/	
lune	كمرة /قمرة	gamra	/	
fête	فيشطا /حفلة	hafla	/	
piscine	بيسين	piscine	masbah	
pluie	شتا	chta	/	
route	طريق	trig	/	
pierre	صخرة	sakhra	hajra	
école	مدرسة	madrassa	/	
magasin	محل	mahal	hanout	
ciel	سما	sma	/	
toboggan	زليقة	zalliga	/	
neige	تلج	talj	/	
pelle	الاب	bala	/	
étoile	نجمة	najma	/	
magasin	خزين	Khzine (=entrepôt)	/	
soleil	شمس	chams	/	
balançoire	زعلولة	zaaloula	tahrayjouya	
arbre	شجرة	chajra	/	
mur	حيط	hit	/	
travail	خدمة	khadma	/	
zoo	الحيوان حديقة	hadikat lhayawan (=jardin d'animaux)	/	

11. Personnes

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
tante	خَالْتِي / عَمْتِي	amti (maternelle) / khalti (paternelle)	/	
bébé	/التْرْبِيَة	trabya	weld sghir (= petit enfant)	
baby-sitter	دَادَة	dada	/	
nom de la baby-sitter	الْحَاضْنَة	alhadna	/	
garçon	وَلْدْ	wald	/	
frère	خُو	khou	/	
enfant	طْفَلْ / الْوْلِيّدْ	wliyed / tfal	/	
papa	أبَا	ba	/	
docteur	دُكْتُورْ / طْبِيبْ	tbib / doctor	/	
ami	صَاحْبِي	sahbi	/	
fille	طْفْلَة / بَنْتْ	bent	/	
grand-mère	جَدّة	jadda	/	
grand-père	جَدْ	jad	/	
dame	لَلَا	lalla	Mra (= dame)	
homme	رَاجَلْ	rajel	/	
maman	ما ما/ مْيَا	mi / mama	/	
gens	نَاسْ	nas	/	
personne	الْمْرَا /الرّجل وَاحَدْ	wahed rajel/ wahed mra => bnadem (fils d'adam)	/	
policier	بُولِسِي	boulissi	/	
soeur	اخْتِي	khti (= ma sœur) neutre = oukht	/	
professeur	الْمْعَلّمْ /الْسْتَاذْ	oustad, mouallim	/	
oncle	خَالِي / عَمّي	aami (maternel) / khali (paternel)	/	

12. Jeux et routines

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
petit-déjeuner	فْطُور	ftour	/	
au revoir	السّلَامَة مْعَ بَايْ بَايْ	bay bay / maa slama	/	
coup de fil	التّلِيفُون فْ دَاوِي	dawi f tilifoun (parler au tel)	/	
tape dans les mains	الرّشْ كَيْضْرَبْ	kaydrab rach	/	
dîner	عْشَا	acha	/	

ne fais pas	مَا دِّيرْهَاشْ	ma dirhach	/	
bonjour	أَهْلًا مَرْحْبًا	ahlan/marhba	/	
déjeuner/dîner	لَغْدَا	larda	/	
musique	لْمُوسِيقَى	moussika	/	
sieste	لَا سْيِيسْتْ / الْقَايْلَةْ	kayla	/	
bonne nuit	تْصْبَحْ عْلَى خِيرْ	tasbah ala khir (= formule : j'espère que demain)		
non	لَا	la		
oups	عَفْواً / إيَّهْ	afwan		
s'il te plait	إلَا سْمَحْتْ	lla smaht		
chut	هَوَسْ	hawas	skout	
pardon	سَامْحْنِي	samahni		
merci	شُكْراً	chokran		
attends	تْسَنَّى	tsana	sayen	
je veux	بْغِيتْ	brit		
oui	إيَّهْ	éh	naam	

13. Mots d'action

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
mordre	كَيْعَضْ	kayad	yad	
souffler	تَتْوْهَبْ	tatwhab	(t)whab	
casser	تَيْهَرَّسْ	tayharas	hrrs	
apporter	كَيْجَاوَبْ	kayjaweb	jâb	
cogner	تَيْدْفَعْ	taydfa	(y)dfa	
appeler	كَيْعَيَّطْ	kayaat	ayyt	
porter	كَيْهَزّْ	kayhaz	haz	
attraper	كَيْشَدّْ	kaychad	(y)chad	
chasser/poursuivre	كَيْطْرَدْ	kayatrad	atrad	
nettoyer	كَيْنَظّفْ	kaynadaf	nadaf, nqqâ	
fermer	كَيْسَدّْ	kaysad	sedd	
venir/arriver	كَيْجِي /كَيْحْضَرْ		ghad, jâ	
pleurer	كَيْبْكِي		bka	
câliner	كَيْعَنَّقْ		/	
couper	كَيْقْطَعْ		qta'	
danser	كَيْشْطَحْ		chtih	
dessiner	كَيْرْسَمْ		r'sam	
boire	كضيشْرْبْ		shrb	
conduire	كَيْسُوقْ		sog	

faire tomber	كَيْطِيحْ		tâh	
manger	كَيَاكُلْ		koull	
nourrir	لْكَيَكَا		mouqawwi	
trouver	كَيْلْقَى		jbar, l'qâ	
finir	كَيْفَضِّي / كَيْسَالِي		**kmmal, sâlî**	
recevoir/obetnir	عْلَى تَيْحْصَلْ		/	
donner	تَيْعْطِي		ata	
aller	تَيْمْشِي		sir	
avoir	تَيْمْلَكْ / عَنْدْ		hanid	
entendre	تَيْسْمَعْ		smaa	
aider	تَيْعَاوَنْ		3âwn	
frapper	تَيْضْرَبْ		drab	
dépêcher	تَيْجَرِّي		/	
sauter	تَيْنْقَزْ		**n'qqez**	
embrasser	تَيْبُوسْ		bous	
savoir	تَيْعْرَفْ		/	
regarder	تَيْشُوفْ		chouf	
aimer	تَيْحَبْ		**ahhab, bgha**	
faire	تَيْخْدَمْ		dir	
ouvrir	تَيْحَلْ		fath, hell	
jouer	تَيْلْعَبْ		**alaab**	
tirer	بَدْتَيْجْ / تَيْجَرْ		**taghrij**	
pousser	تَيْدْفَعْ		**dfa'**	
mettre	تَيْنْزَلْ / تَيْحَطْ		/	
lire	تَيْقْرَا		**qra**	
monter	تَيْرْكَبْ		**r'keb, t'la'**	
courir	تَيْجْرِي		**jrâ**	
dire	تَيْقُولْ		**goul, qoul**	
gratter	تَيْخَرْبَشْ		**hakk**	
voir	تَيْشُوفْ		**chouf, shâf**	
montrer	تَيْبَيَّنْ		**warri**	
chanter	تَيْغَنِّي		/	
dormir	تَيْنْعَسْ		**n'aass**	
sentir	تَيْشَمْ		**cham**	
sourire	تَيْتْبَسَّمْ		/	
éclabousser	تَيْرَشْ		/	
arrêter	تَيْوْقَفْ		ouqaf	
nager	تَيْعُومْ		oum	
balancer	تَيْتْرَعْلَلْ		/	
prendre	تَيَاخْذْ		kh'dâ, khoud	
dire/raconter	رْتَيْخْبْ / تَيْعْلَمْ		qâl	

jeter	تَيْلُوحْ / تَيْرْمِي		r'mi, loûh	
chatouiller	تَيْتْمَشْخَرْ / تَيْمْزَرْ		/	
toucher	تَيْقِيسْ / تَيْمَسْ		m'ass, qîss	
laver	تَيْغْسَلْ		gh'sel	
regarder	تَيْتْفَرَّجْ		qâbl	
écrire	تَيْكْتَبْ		ktb	

14. Mots sur le temps

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
jour	نْهَارْ	nhar	/	
plus tard	بَعْدْ مَنْ	man baad	/	
matin	الصْبَاحْ	sbah	/	
nuit	اللَّيْلْ	lil	/	
maintenant	دْرُكَا	dorka	/	
aujourd'hui	الْيُومَ	youm	/	
demain	غَدًا	radda	/	
ce soir	اللَّيْلَة هَادْ	had lila	/	

15. Mots descriptifs (adjectifs)

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
mauvais	خَايَبْ	khayab	/	
grand	كْبِيرْ	kbir	/	
bleu	زْرَقْ	zrag	/	
cassé	مْهَرَّسْ	mharras	/	
soigneux	حَاضِي / الْبَالْ رَدْ	rad lbal	/	
propre	نْظِيفْ / نْقِي	nki / ndif	/	
froid	بَارْدْ	bared	/	
mignon	جَدَّابْ	jaddab	zwin	
sombre	مْظَلَّمْ	mdallam	/	
sale	مْوَسَّخْ	mwassakh	/	
sec	نَاشَفْ	nachef	/	
vide	خَاوِي	khawi	/	
rapide	زَرْبَانْ/ سْرِيعْ	sriaa, zarban	/	
fin/beau	زْوِينْ	zwin	/	
vert	خْضَرْ	khdar	/	
content	فَرْحَانْ / نَاشَطْ	nachat	/	

dur	وَاعَرْ	waaer	/	
chaud	حَامِي / سْخُونْ	skhoun / hami	/	
faim	جِيعَانْ	jiaan	/	
blessé	مْغَيْدَدْ / مَفْقُوسْ	mafkous / mraydad (blessé sentimentalement)	majrouh	
petit	قْلِيلْ	Klil (= peu)	sghir	
vilain/méchant	مَنْحُوسْ /مَتْعُوسْ	mataous / manhous (= poisseux)	chki	
vieux	شَارَفْ	charaf	/	
beau/joli	غْزَالْ / زْوِينْ	zwin / ghzal	/	
rouge	حْمَرْ	hmar	/	
triste	زَعْفَانْ / مْقَلَّقْ	mkallak / zaafan	/	
effrayé	خَايَفْ	khayef	/	
malade	مْرِيضْ / عَيَّانْ	ayyan/ mrid	/	
endormi	نَاعَسْ	naas	/	
doux	مْلَسْ / رْطَبْ	rtab / mlas	/	
soif	عَطْشَانْ	atchan	/	
fatigué	مَنْهُوكْ	manhouk	/	
mouillé	فَازَكْ	fazag	/	
jaune	صْفَرْ	sfar	/	
dégoutant	مَنْبُوذْ / مْكْرُوهْ	makrouh / manboud	/	

16. Pronoms

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
il	هُوَ	houwa	/	
sa/à elle	دْيَالْهَا	dyalha	/	
son/à lui	يْاَلُد	dyalou	/	
je	أنَا	ana	/	
mon	لِيَ/ دْيَالِي	dyali / li	/	
elle	هِيَ	hiya	/	
cela, ça, ce-là	لْهِيهْ هَدَاكْ	hadak lhih	/	
ceci, ce, ce-ci	هْنَا هَدَا	hada hna	/	
tu	أنْتَ	nta	/	
ton/ta/tes	أنْتَ لِكْ / دْيَالَكْ	dyalek/ lik nta	lik tna = à toi	

17. Interrogatifs

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
comment	كِيفَاشْ	kifach		
quel	أَشْنُو	achnou	quoi	
quand	وَقْتَاشْ / إِمْتَى	lmta		
où	فِينْ	fine		
qui	شْكُونْ	chkoun		
pourquoi	عْلَاشْ	alach		

18. Prépositions et localisations

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
loin	ابَرَ عْلَى	ala barra	baid	
de derrière	وْرَا	wra	/	
en bas	تَحْتْ	taht	/	
dans	فِي	fi	/	
sur	عْلَى	ala	/	
là	هْنَاكْ	Hnak (= là-bas)	/	
à/pour	لْ / حَتَّى	Hâta (= jusqu'à)	/	
en haut	فُوقْ	fouk	/	

19. Quantificateurs

Français	Arabe marocain	Transcription	Autre transcription ou traduction	Cocher si l'enfant dit le mot
encore	الجّاوْجَة لْمَرَّة / تَانْيَة مَرَّة	marra taniya/ mara zawja	/	
tout	كُلُّه	koullou	/	
un autre	لَاخُرْ	lakhor	/	
plus	كْتَرْ	ktar	/	
aucun	كَايْنْشْ مَا	ma kayench	/	
pas	مَاشِي	machi	/	
même	نَفْسْ	nafs	/	
quelques/un peu	شْوِيَّة	chwiya	/	

1. Sons d'animaux

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
bêê bêê	الخروف صوت	
tchou tchou	القطار صوت	
cocorico	الدجاجة صوت	
grr	الأسد صوت	
miaou	القطة صوت	
meuh	البقرة صوت	
aie	الألم عن للتعبير صوت	
coin-coin	البطة صوت	
oh-oh	الدهشة عن للتعبير	
vroum	السيارة صوت	
ouaf-ouaf	الكلب صوت	
miam-miam	الطعام تناول في الرغبة	

2. Noms d'animaux

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
animal	حيوان	
ours	دب	
abeille	نحلة	
oiseau	طائر	
insecte/petite bête	خنفساء /بق /حشرة	
lapin	أرنب	
papillon	فراشة	
chat	قطة	
poulet	دجاجة	
vache	بقرة	
cerf/biche	غزال	
chien	كلب	
âne	حمار	
canard	بطة	
éléphant	فيل	
poisson	سمكة	
mouche	ذبابة	
grenouille	ضفدعة	
girafe	زرافة	
oie	أوزة	

cheval	حصان	
lion	أسد	
singe	قرد	
souris	فأر	
hibou	بومة	
pingouin	بطريق	
mouton	خروف	
serpent	ثعبان	
araignée	عنكبوت	
écureuil	سنجاب	
tigre	نمر	
dinde	ديك رومي	
tortue	سلحفاة	

3. Véhicules

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
avion	طائرة	
vélo/bicylette	دراجة	
bateau	مركب	
bus	حافلة	
voiture	سيارة	
camion pompier	طفاية حريق	
moto	موتوسيكل	
poussette	كرسي أطفال	
tracteur	جرار	
train	قطار	
camion	شاحنة	

4. Jouets

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
balle	كرة	
ballon	بالون	
cube	مكعبات	
livre	كتاب	
bulle	فقاعة	
poupée	دومية	
stylo	قلم	

jouet	لعبة	
nounours	دمية دب	

5. Nourriture et boissons

Français	Arabe classique/standard	Cocher si l’enfant dit le mot
pomme	تفاحة	
banane	موز	
biscuit	بسكويت	
pain	خبز	
beurre	زبد	
gâteau	كعكة	
carotte(s)	جزر	
céréale	حبوب	
cheerios	تشيريوس	
fromage	جبن	
chips	شيبسى	
chocolat	تشيكولا	
café	قهوة	
cookie/biscuit	كعكة	
oeuf	بيضة	
nourriture/aliment(s)	طعام	
glace	كريم أيس	
confiture	مربى	
jus	عصير	
viande	لحم	
lait	حليب	
nouilles	شعرية	
orange	برتقال	
(petits) pois	بازلاء	
pizza	بيتزا	
patate	بطاطس	
raisin	زبيب	
sandwich	ساندوتش	
saucisses	سجق	
spaghetti	معكرونة	
bonbons	حلوى	
thé	شاي	
eau	ماء	

yaourt	زبادي	

6. Vêtements

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
cordons	خرز	
bavoir/bavette	مريلة	
bottes	حذاء	
bouton	زر	
cardigan/gilet	ثوب /سترة	
lange/couche	حفاضة	
robe	فستان	
lunettes	نظارة	
chapeau	قبعة	
veste	جاكيت	
jeans	جينز	
collier	عقد	
pyjamas	بيجامة	
pantalon	بنطلون	
écharpe	ايشارب	
chemise	قميص	
short	شورت	
chausette(s)	جوارب	
tirette/braguette	سوسته	

7. Parties du corps

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
bras	ذراع	
dos	ظهر	
ventre	بطن	
nombril	صرة	
derrière/fesses	مؤخرة	
joue	خد	
oreille	أذن	
oeil	عين	
visage/figure	وجه	
doigt	اصبع	

cheveux	شعر	
main	يد	
tête	رأس	
genou	ركبة	
jambe	رجل	
lèvres	شفاه	
bouche	فم	
ongle	ظفر	
nez	أنف	
bobo	جرح	
langue	لسان	
dent	سن	

8. Meubles et pièces

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
bain/baignoire	استحمام حوض	
salle de bain	حمام	
lit	فراش	
chambre	نوم حجرة	
chaise	كرسي	
cuisinière	بوتوجاز	
berceau	طفل سرير	
divan/canapé	أريكة	
porte	باب	
en bas/au rez de chaussée	الأسفل الطابق	
tiroir	درج	
garage	جراج	
chaise haute	عالي كرسي	
cuisine	مطبخ	
salle à manger	المعيشة حجرة	
stylo à jeu (?)	أطفال روضة	
pot	بوتي	
réfrigérateur	ثلاجة	
chaise à bascule	هزاز كرسي	
évier	حوض	
escaliers	سلالم	
table	منضدة	

TV/télé	تلفزيون	
toilette	مياه دورة /مرحاض	
en haut/à l'étage	العلوى الدور	
fenêtre	شباك	

9. Objets ménagers (d'intérieur)

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
sac	حقيبة	
couverture	بطانية	
bouteille	زجاجة	
bol	وعاء	
boite	صندوق	
balai	مقشة	
brosse	فرشاه	
seau	دلو	
horloge/montre	حائط ساعة	
peigne	مشط	
ordinateur	كمبيوتر /كمبيوتر شخصى	
vaisselle	طبق	
fourchette	شوكة	
verre	كوب	
marteau	مطرقة	
cruche/carafe	ابريق	
clé	مفتاح	
lampe	مصباح	
lumière	ضوء	
médicament	دواء	
argent	نقود	
papier	ورقة	
centimes/pièces	(قرش) صغيرة عملة	
photo	صورة	
oreiller	وسادة	
plante	نبات	
porte-monnaie	محفظة	
radio	راديو	
déchets	قمامة	
ciseaux	مقص	

savon	صابون	
cuillère	ملعقة	
téléphone	هاتف	
brosse à dent	فرشاة أسنان	
essui/serviette	منشفة	

10. Objets d'extérieur et endroits où aller

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
cour/arrière-cour	الفناء الخلفي	
plage	ساحل	
église	كنيسة	
fleur	زهرة	
jardin	حديقة	
maison	منزل	
lune	قمر	
fête	حفلة	
piscine	حمام سباحة	
pluie	مطر	
route	طريق	
pierre	صخرة	
école	مدرسة	
magasin	محل	
ciel	سماء	
toboggan	زحليقة	
neige	ثلج	
pelle	مجرفة/مسحاة	
étoile	نجم	
magasin	مخزن	
soleil	شمس	
balançoire	أرجوحة	
arbre	شجرة	
mur	حائط	
travail	عمل	
zoo	حديقة حيوان	

11. Personnes

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
tante	خالة / عمة	
bébé	مولود	
baby-sitter	جليسة أطفال	
nom de la baby-sitter	اسم جليسة الأطفال	
garçon	ولد	
frère	أخ	
enfant	طفل	
papa	أبي	
docteur	طبيب	
ami	صديق	
fille	بنت	
grand-mère	جده	
grand-père	جد	
dame	سيدة	
homme	رجل	
maman	أمي	
gens	ناس	
personne	شخص	
policier	شرطي	
soeur	أخت	
professeur	مدرس	
oncle	خال/عم	

12. Jeux et routines

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
petit-déjeuner	افطار	
au revoir	مع السلامة	
coup de fil	مكالمة فى التليفون	
tape dans les mains	تصفيق	
dîner	عشاء	
ne fais pas	لا تفعل	
bonjour	مرحبا	
déjeuner/dîner	غذاء	
musique	موسيقى	
sieste	قيلولة	
bonne nuit	ليلة سعيدة	

non	لا	
oups	عفوا	
s'il te plait	من فضلك	
chut	هش	
pardon	معذرة	
merci	شكرا	
attends	انتظر	
je veux	يريد	
oui	نعم	

13. Mots d'action

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
mordre	يعض	
souffler	تهب	
casser	يكسر	
apporter	يحضر	
cogner	يضخ	
appeler	ينادي	
porter	يحمل	
attraper	يمسك	
chasser/poursuivre	يطارد	
nettoyer	ينظف	
fermer	يغلق	
venir/arriver	يأتي	
pleurer	يبكي	
câliner	يعانق	
couper	يقطع	
danser	يرقص	
dessiner	يرسم	
boire	يشرب	
conduire	يقود	
faire tomber	يسقط	
manger	يأكل	
nourrir	يغذي	
trouver	يجد	
finir	ينهي	
recevoir/obetnir	يحصل على	
donner	يعطي	

aller	يذهب		
avoir	يملك		
entendre	يسمع		
aider	يساعد		
frapper	يضرب		
dépêcher	يسرع		
sauter	يقفز		
embrasser	يقبل		
savoir	يعرف		
regarder	ينظر		
aimer	يحب		
faire	يعمل		
ouvrir	يفتح		
jouer	يلعب		
tirer	يسحب		
pousser	يدفع		
mettre	يضع		
lire	يقرأ		
monter	يركب		
courir	يجرى		
dire	يقول		
gratter	يخدش		
voir	يرى		
montrer	يظهر		
chanter	يغنى		
dormir	ينام		
sentir	يشم		
sourire	يبتسم		
éclabousser	يرش		
arrêter	يقف		
nager	يسبح		
balancer	يتمرجح		
prendre	يأخذ		
dire/raconter	يخبر		
jeter	يرمى		
chatouiller	يدغدغ		
toucher	يلمس		
laver	يغسل		
regarder	يشاهد		

écrire	يكتب	

14. Mots sur le temps

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
jour	نهار	
plus tard	فيما بعد	
matin	صباح	
nuit	مساء	
maintenant	الآن	
aujourd'hui	اليوم	
demain	غدا	
ce soir	الليلة	

15. Mots descriptifs (adjectifs)

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
mauvais	سيئ	
grand	كبير	
bleu	أزرق	
cassé	مكسور	
soigneux	حذر	
propre	نظيف	
froid	بارد	
mignon	جذاب	
sombre	مظلم	
sale	قذر	
sec	جاف	
vide	فارغ	
rapide	سريع	
fin/beau	جيد	
vert	أخضر	
content	سعيد	
dur	شاق /صعب	
chaud	ساخن	
faim	جائع	

blessé	مجروح			
petit	قليل			
vilain/méchant	شقي			
vieux	كبير السن			
beau/joli	جميل			
rouge	أحمر			
triste	حزين			
effrayé	خائف			
malade	مريض			
endormi	نائم			
doux	ناعم			
soif	عطشان			
fatigué	متعب			
mouillé	مبلل			
jaune	أصفر			
dégoutant	مقذذ			

16. Pronoms

Français	Arabe classique/standard		Cocher si l'enfant dit le mot
il	هو		
sa/à elle	لها		
son/à lui	له		
je	أنا		
mon	لي		
elle	هي		
cela, ça, ce-là	هذ (للبعيد)		
ceci, ce, ce-ci	هذا (للقريب)		
tu	أنت		
ton/ta/tes	لك		

17. Interrogatifs

Français	Arabe classique/standard		Cocher si l'enfant dit le mot
comment	كيف		
quel	ماذا		
quand	متى		
où	أين		

qui	من	
pourquoi	لماذا	

18. Prépositions et localisations

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
loin	في الخارج	
de derrière	خلف	
en bas	أسفل	
dans	في	
sur	على	
là	هناك	
à/pour	الى	
en haut	فوق	

19. Quantificateurs

Français	Arabe classique/standard	Cocher si l'enfant dit le mot
encore	مرة اخرى	
tout	كل	
un autre	اخر	
plus	أكثر	
aucun	لا يوجد	
pas	ليس	
même	نفس	
quelques/un peu	بعض	

Appendix 7

List of all the items of the naming task with the item's age of acquisition and the source of the picture (where AoA stands for age of acquisition, DB stands for lexical database and CDI for parental report).

Items	AoA (in months)	Source of the picture
Lit	32,5 (DB)	Moreno-Martinez & Montoro, 2012
Bébé	30,6 (DB)	Google
Bateau	23,4 (DB)	Moreno-Martinez & Montoro, 2012
Maya	/	*Google*
Oui-Oui	/	*Google*
Feuille	38,5 (DB)	Brodeur et *al*., 2012
Pomme	32,5 (DB)	Moreno-Martinez & Montoro, 2012
Robe	36,5 (DB)	Google
Chaise	32,5 (DB)	Moreno-Martinez & Montoro, 2012
Peigne	56,5 (DB)	Brodeur et *al*., 2012
Vache	50,5 (DB)	Brodeur et *al*., 2012
Langue	8-16 (CDI)	Google
Doigt	38,5 (DB)	Google
Chien	32,5 (DB)	Brodeur et *al*., 2012
Bras	62,5 (DB)	Brodeur et *al*., 2012
Train	50,5 (DB)	Google
Fleur	32,5 (DB)	Brodeur et *al*., 2012
Cloche	44,5 (DB)	Google
Glace	16-30 (CDI)	Google
Porte	32,5 (DB)	Google
Parc	59,16 (DB)	Google
Livre	32,5 (DB)	Google
Zèbre	50,5 (DB)	Brodeur et *al*., 2012
Arbre	38,5 (DB)	Brodeur et *al*., 2012
Coucou	8-16 (CDI)	Google
Cadeau	36 (DB)	Brodeur et *al*., 2012
Souris	32,5 (DB)	Google
Cheveux	8-16 (CDI)	Google
Poisson	32,5 (DB)	Google
Panier	38,5 (DB)	Brodeur et *al*., 2012
Pingouin	68,5 (DB)	Google

Items	AoA (in months)	Source of the picture
Oiseau	32,5 (DB)	Moreno-Martinez & Montoro, 2012
Crayon	32,5 (DB)	Brodeur et *al*., 2012
Grenouille	38,5 (DB)	Google
Tortue	32,5 (DB)	Brodeur et *al*., 2012
Fourmi	68,5 (DB)	Brodeur et *al*., 2012
Banane	38,5 (DB)	Brodeur et *al*., 2012
Carotte	38,5 (DB)	Brodeur et *al*., 2012
Chaussure	32,5 (DB)	Google
Girafe	32,5 (DB)	Brodeur et *al*., 2012
Cuillère	32,5 (DB)	Brodeur et *al*., 2012
Fromage	55,2 (DB)	Google
Étoile	32,5 (DB)	Google
Nombril	8-16 (CDI)	Google
Yaourt	16-30 (CDI)	Google
Echarpe	8-16 (CDI)	Google
Pantalon	32,5 (DB)	Moreno-Martinez & Montoro, 2012
Pyjama	8-16 (CDI)	Google
Champignon	38,5 (DB)	Google
Éléphant	32,5 (DB)	Brodeur et *al*., 2012
Parapluie	32,5 (DB)	Google
Escalier	37,8 (DB)	Google
Téléphone	32,5 (DB)	Google

Appendix 8

List of all the items of the naming task with the items' phonological complexity and lexical frequency.

Items	Complexity index value	Complexity category	Lexical frequency	Frequency category
bébé	0.00	1	65.79	2
lit	0.00	1	69.32	2
bateau	0.17	1	62.8	2
coucou	0.00	1	53.49	1
langue	0.06	1	60.56	1
cheveux	0.28	2	65.03	2
nombril	0.33	2	35.77	1
pyjama	0.44	2	58.64	1
écharpe	0.61	3	55.5	1
pomme	0.00	1	66.68	2
robe	0.00	1	64.1	2
glace	0.11	1	65.22	2
souris	0.17	1	67.11	2
livre	0.22	1	67.85	2
yaourt	0.39	2	57.36	1
fleur	0.11	1	63.12	2
cadeau	0.17	1	62.78	2
porte	0.22	1	67.36	2
tortue	0.28	2	67.12	2
poisson	0.33	2	68.65	2
étoile	0.39	2	62.37	2
oiseau	0.28	2	66.5	2
chaussures	0.28	2	53.88	1
chaise	0.33	2	61.54	2
crayon	0.33	2	60.36	1
pantalon	0.44	2	61.12	1
éléphant	0.50	2	64.2	2
chien	0.28	2	68.95	2
cuillère	0.28	2	56.41	1
girafe	0.28	2	59.93	1
téléphone	0.33	2	63.31	2
parapluie	0.56	3	60.36	1
escalier	0.67	3	59.75	1
feuille	0.00	1	63.91	2
doigt	0.11	1	58.57	1

Items	Complexity index value	Complexity category	Lexical frequency	Frequency category
banane	0.17	1	59.86	1
panier	0.28	2	62.92	2
grenouille	0.28	2	61.11	1
arbre	0.44	2	66	2
train	0.17	1	65.52	2
vache	0.22	1	62.46	2
carotte	0.28	2	45.71	1
zèbre	0.33	2	60.8	1
cloche	0.50	2	57.7	1
champignon	0.56	3	60.46	1
peigne	0.00	1	58.88	1
bras	0.11	1	63.85	2
parc	0.22	1	59.14	1
fourmi	0.28	2	58.1	1
pingouin	0.39	2	54	1
fromage	0.56	3	64.66	2

Appendix 9

Adapted decomposition into distinctive features and cost matrix for PDAP-IS.

DÉCOMPOSITION EN TRAITS

	p	t	k	b	d	g	f	s	t͡s	ʃ	t͡ʃ	ç	x	h	v	z	d͡z	ʒ	d͡ʒ	m	n	ñ/ɲ	l	ʁ	j	w	ɥ
vocalique	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
continu	0	0	0	0	0	0	1	1	0	1	0	1	1	1	1	1	0	1	0	0	0	0	0	1	1	1	1
nasal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0
voisé	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
compact	0	0	1	0	0	1	0	0	0	1	1	1	1	1	0	0	0	1	1	0	0	1	0	1	1	0	0
aigu	0	1	1	0	1	1	0	1	1	1	1	1	0	0	0	1	1	1	1	0	1	1	1	0	1	0	0
affriqué	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
sibilant							0	1	1	1	1	0	0	0	0	1	1	1	1					0			
glotte ouv.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

MATRICE

	p	t	k	b	d	g	f	s	t͡s	ʃ	t͡ʃ	ç	x	h	v	z	d͡z	ʒ	d͡ʒ	m	n	ñ/ɲ	l	ʁ
p	0	1	2	1	2	3	1	2	2	3	3	3	2	3	2	3	3	4	4	3	4	5	3	4
t	1	0	1	2	1	2	2	1	1	2	2	2	3	4	3	2	2	3	3	4	3	4	2	5
k	2	1	0	3	2	1	3	2	2	1	1	1	2	3	4	3	3	2	2	5	4	3	3	4
b	1	2	3	0	1	2	2	3	3	4	4	4	3	4	1	2	2	3	3	2	3	4	2	3
d	2	1	2	1	0	1	3	2	2	3	3	3	4	5	2	1	1	2	2	3	2	3	1	4
g	3	2	1	2	1	0	4	3	3	2	2	2	3	4	3	2	2	1	1	4	3	2	2	3
f	1	2	3	2	3	4	0	2	4	3	5	2	1	2	1	3	5	4	6	4	5	6	4	3
s	2	1	2	3	2	3	2	0	2	1	3	2	3	4	3	1	3	2	4	5	4	5	3	5
t͡s	2	1	2	3	2	3	4	2	0	3	1	4	5	6	5	3	1	4	2	5	4	5	3	7
ʃ	3	2	1	4	3	2	3	1	3	0	2	1	2	3	4	2	4	1	3	6	5	4	4	4
t͡ʃ	3	2	1	4	3	2	5	3	1	2	0	3	4	5	6	3	2	3	1	6	5	4	4	6
ç	3	2	1	4	3	2	2	2	4	1	3	0	1	2	3	4	5	2	4	6	5	4	4	3
x	2	3	2	3	4	3	1	3	5	2	4	1	0	1	2	4	6	3	5	5	6	5	5	2
h	3	4	3	4	5	4	2	4	6	3	5	2	1	0	3	5	7	4	6	6	7	6	6	3
v	2	3	4	1	2	3	1	3	5	4	6	3	2	3	0	2	4	3	5	3	4	5	3	2
z	3	2	3	2	1	2	3	1	3	2	3	4	4	5	2	0	2	1	3	4	3	4	2	4
d͡z	3	2	3	2	1	2	5	3	1	4	2	5	6	7	4	2	0	3	1	4	3	4	2	6
ʒ	4	3	2	3	2	1	4	2	4	1	3	2	3	4	3	1	3	0	2	5	4	3	3	3
d͡ʒ	4	3	2	3	2	1	6	4	2	3	1	4	5	6	5	3	1	2	0	5	4	3	3	5
m	3	4	5	2	3	4	4	5	5	6	6	6	5	6	3	4	4	5	5	0	1	2	2	3
n	4	3	4	3	2	3	5	4	4	5	5	5	6	7	4	3	3	4	4	1	0	1	1	4
ñ/ɲ	5	4	3	4	3	2	6	5	5	4	4	4	5	6	5	4	4	3	3	2	1	0	2	3
l	3	2	3	2	1	2	4	3	3	4	4	4	5	6	3	2	2	3	3	2	1	2	0	3
ʁ	4	5	4	3	4	3	3	5	7	4	6	3	2	3	2	4	6	3	5	3	4	3	3	0