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Early development of syllable structure in French

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Early development of syllable structure in French

Cross-linguistic studies describing the syllabic structures of babbling productions agree on the high prevalence of the CV structure, but few have addressed the other types of syllables emerging during this pre-linguistic stage. However, studying the evolution of the distribution of syllabic structures during babbling would make it possible to test both the influence of motor constraints and the influence of the perceptually based patterns from the infant's language environmental input on the production of early syllables. A monthly follow-up of 22 French infants from 8 to 14 months showed that the distribution CV>V>CCV>CVC>VC was shared by the majority of infants in the sample and remained the same throughout the observation period. The comparison of the frequencies of the structures observed with those attested in adult-French (Adda-Decker et al., 2005) and in 4 other languages (Dutch, Korean, Moroccan Arabic and Tunisian Arabic) revealed significant differences between all adult samples and infant productions. The results have implications for understanding the nature of factors impacting syllable production at the babbling stage. We discuss the possibility that the target language does not affect the production of babbled syllables.

Keywords: babbling; syllable structure; complexity; ambient-language effect; motor constraint

Introduction

The babbling period is an important stage in infants' vocal development recognizable by the emergence of speech-like syllables in their oral productions. In studies about babbling, particular attention is usually paid to the adult-like Consonant-Vowel (CV) syllable shape. Interest is given in either the age when CV syllables appear or in the ratio of these structures to all vocalizations (Cychosz, 2021). Even if this syllable type is predominant, other types are also produced during this stage.

Moreover, during the babbling period which extends over several months (from 6 months to more than 12 months), modifications in infant vocal behaviors occur as a result of the interaction between biological changes (Kent 2021, 2022), the increase in motor control (Green et al., 2000; Nip et al., 2011) and the influence of auditory exposure to ambient

language (Vihman et al., 2009). Although the impact of auditory experience on babbling output is shown on consonant sounds (Majorano & D'Odorico, 2011) or on the acoustic characteristics of vowels (Boysson-Bardies et al., 1989), it is rarely assessed on the syllable structures which can also be language-specific.

This study firstly aimed at studying the distribution of adult-like syllabic structures and its evolution in 22 French infants followed between the ages of 8 and 14 months, and secondly, at comparing the results obtained with those observed in adult French and in other languages.

Babbling: universal articulatory constraints...

Babbling is a well-identified language development milestone characterized by the production of rhythmic speech-like syllables (Oller et al., 1980, 1999) that show many similarities between children from different language environments (Cychosz et al., 2021; Davis & MacNeilage, 1995; Kern & Davis, 2009; MacNeilage et al., 2000; Morgan & Wren, 2018; Rvachew & Alhaidary, 2018). One of the main similarities is the predominance of open syllables (see Lahrouchi & Kern p.498 for review) and more specifically of the consonant-vowel (CV) syllable structure. Its very high prevalence is widely attested in infants learning languages such as English (Davis & MacNeilage, 1994; Fagan, 2009; Kent & Bauer, 1985), Spanish (Oller & Eilers, 1982), Russian (Weir, 1966), Tashlhiyt (Lahrouchi & Kern, 2018), Malayalam (Roy & Sreedevi, 2013), Kannada (Anjana & Sreedevi, 2008), French, Swedish and Yoruba (Boysson-Bardies et al., 1993), Swahili, Quechua, Estonian, Hebrew, Japanese, German, Maori (MacNeilage et al., 2000), or Tunisian, Flemish and Romanian (Kern & Davis, 2009).

The emergence of the CV structure and its predominance in the syllabic repertoire at babbling stage can be explained by biological factors and by a limited oro-motor control evidenced by several theoretical models. The 'Frame-Content' theory proposed by

MacNeilage and Davis (1990 a and b) supports that the jaw is the primary active articulator at babbling stage (MacNeilage, 1998; Green et al., 2000), and that its rhythmic movements of raising and lowering, available from birth in infant sucking patterns, combined with phonation provide the syllable structure's frame. The alternative model of articulatory phonology (Browman & Goldstein, 1988; Goldstein et al., 2009) denies the wholistic jaw-based frame and supports the temporal coordination of individual consonantal and vocalic gestures to explain the strong occurrence of the CV structure compared to others. In a syllable [bæ] for example, lip gesture for consonant closure and tongue body gesture of the vowel are initiated simultaneously in adults (in-phase coupling). By contrast, in a syllable [æb], the lip closure occurs after the lingual gesture (anti-phase coupling). So, the CV structure is easier to produce and acquired earlier than VC, because the time required to plan synchronous consonant and vowel constriction gestures is shorter than when these gestures are coupled in anti-phase (Mooshammer et al., 2012; Nam et al., 2009).

Beyond the primacy of CV structure, other recognizable syllables are also produced (Davis & MacNeilage, 1994; Lahrouchi & Kern, 2018). Speech development relies on continuous anatomical and motor changes (Kent 2021, 2022) and it is generally accepted that articulatory control improves during babbling (Canault et al., 2020; Green & Wilson, 2006; Nip & Green, 2013). The articulatory possibilities can therefore widen between the beginning and the end of the babbling period and syllables diversify and become more complex with time (Gerhold et al., 2020; Morris, 2010; Nathani et al., 2006).

... under the influence of the language environmental input

If babble output is in part driven by biological factors and by limited oro-motor skills, it is also well accepted that the auditory exposure to adult speech has an impact on early productions (Vihman et al., 2009). There is a frequency effect of the perceptually based patterns from the language environmental input on the infant's learning path, and babbling is

considered to already share some of the features of the target language (Morgan & Wren, 2018 for reviews; Rvachew & Alhaidary, 2018). Cross-linguistic differences are found **in vowels** (Boysson Bardies et al., 1989; Kern & Davis, 2009 ; Rvachew et al., 2008), in consonant manner and place (Boysson-Bardies & Vihman, 1991; Chen & Kent, 2005; Lee et al., 2010), in consonant voicing (Whalen et al., 2007), in prosody (Hallé et al.,1991; Levitt & Wang, 1991), as well as in intersyllabic (Geambasu et al., 2016 ; Kern & Davis, 2009) and intra-syllabic associations (Chen & Kent, 2005; Lee et al., 2008; Lee & Davis, 2010; Majorano & D'Odorico, 2011).

As the distribution and the variety of syllable structures differ from one language to another (Blevins, 1995; Maddieson, 2013), the structure of the infant's syllables should also shift in the direction of the ambient language. But as far as we know, studies conducted in different languages showing an effect of the language environment on the production of syllabic structures have mostly focused on the word stage (a.o. Demuth & Kehoe, 2006; Fikkert, 2007; Jarosz, 2010; Jarosz et al., 2017; Keffala et al., 2018; Kirk & Demuth, 2005; Levelt & Van de Vijver, 2004; Levelt et al., 2000; Lleó & Prinz, 1996; Mashaqba et al., 2019; McLeod et al., 2001; Wauquier & Yamaguchi, 2011), but less frequently on the babbling stage. When such studies exist, the examination of syllabic structure distribution does not constitute the main objective of the research or the sample is very small. For example, Boysson-Bardies and colleagues (1993) compared the productions of 5 French, English, Swedish and Yoruba infants aged 10-12 months. Part of the analyses was devoted to the utterance shape and showed that the CVCV pattern was more frequent than the VCV pattern in the French, English and Swedish groups, but not in the Yoruba group. The effect of language on syllabic structures can be inferred, but the scope of this interpretation remains limited since very few different structures were considered. Levitt and Utman (1992) showed that from 11 months onwards, the English child they studied, unlike the French one, began to

increase his production of closed syllables. The authors interpreted this result with regard to the characteristics of the respective languages, since English contains more closed syllables and French more open ones (Delattre & Olsen, 1969; Goldman et al., 1996). However, even if the results were supported by a longitudinal follow-up at 5 months, 8 months, 11 months and 14 months, the comparison included only two infants (one French and one English).

Syllabic structure distribution in spoken French

Several studies have identified the frequency of occurrence of syllabic structures in spoken French (Table 1). For example, Wioland (1985) analysed 20 television broadcasts between March and July 1973. Half of them were taken from programs in which people conversed on various subjects and the other half were taken from stage plays. The total sample consisted of 86934 syllables. More recently, Adda-Decker and colleagues (2005) worked on a sample of 30 1-hour French radio interviews composed of 245000 word occurrences containing over 350000 syllables. In their study, they used two types of syllabic segmentation: a "canonical" segmentation resulting from the transcripts of the orthographic code into the oral code and an "aligned" segmentation in which each pronunciation variant was selected in accordance to the actual acoustics. In this later segmentation, a word like "retrouver" ("to find again") could be transcribed, depending on the context, [ʁətʁuve], [ʁtʁuve] or even [tʁuve] (with the deletion of the first syllable). The two types of segmentation followed the rules of spoken French syllabification established by Wioland (1985), at the word domain for the canonical segmentation, and across word boundaries for the aligned segmentation.

The cited sources in Table 1 agree that CV, V, CCV and CVC are the 4 most frequent types of syllables with CV occupying the first rank, and that open syllables are predominant in the French language. However, it should be noted that by comparing the two types of segmentation Adda-Decker and colleagues (2005) also showed that the number of closed

syllables increased substantially in the aligned segmentation (16%) as compared to the canonical syllable segmentation (9.7%), with a more pronounced increase in CVC syllables.

(Insert table 1 about here)

When analyzing the influence of **language environmental input** on infant productions, a corpus based on spoken language is more pertinent. The study by Adda-Decker and colleagues (2005) and that of Wioland (1985) therefore seem more appropriate in the context of this study. It should be pointed out, however, that the results of Adda-Decker and colleagues (2005) are based on a sample size that is four times larger. Moreover, the variety of French considered is more contemporary than that of Wioland (1985). We therefore used these data as a reference and comparison point for our analysis.

The question whether the choice to use data from an Adult Directed Speech (ADS) vs. a Child Directed Speech (CDS) corpus arises naturally in the context of a study on speech development. However, CDS does not constitute the only language environmental input of the infant. More than half of the speech that s/he hears is adult-directed while only 15% is addressed to him/her (van de Weijer, 2002) and speech directed to others may also play a role in language development (see Soderstrom, 2017 for a review). Moreover, even if the differences between the two registers have been explored on a variety of dimensions (e.g. F0, rate, phonetic features) (Cristia, 2013), results are not always consensual. In addition, the comparisons between CDS and ADS involving the analysis of syllable structures are rare and come to the conclusion of very little or no differences. Van de Weijer's data (1999) for instance show that frequency orderings of syllable structures in child-directed and adult-directed speech are mostly the same (Levelt et al., 2000). Finally, the studies supporting the advantage of CDS over ADS for the learnability of linguistic phenomena are often based on data collected in laboratory while the benefits of CDS are smaller in ecological/naturalistic

speech context (Cristia et al., 2019). For all these reasons, we have singled out a corpus of naturalistic adult speech.

Current study

To the best of our knowledge, no longitudinal study on the production of syllabic structures at the babbling stage has been carried out on a large number of French-speaking infants. Moreover, no study compares the distribution of infant syllabic structures with that observed in adult spoken French and in other adult languages. Studying the evolution of the syllable structures during babbling with regard to adult speech samples would thus make it possible to better understand the weight of the influence of motor constraints and that of the perceptually based patterns from the infant's language environmental input on the production of early syllables.

At the beginning of babbling, syllabic structure is strongly constrained (Canault et al., 2020; Green & Wilson, 2006; Nip & Green, 2013). As the result of a motor behavior which restricts the complexity of syllabic structure, the simple CV structure is expected to be over-represented in babbling productions. Nevertheless, during the babbling stage, oro-motor skills progress and other structures may also appear in the syllabic repertoire of the infant. What are the syllable structures found in French babbling and what is their distribution? Does the distribution of syllabic structures change with age and do syllables become more complex during this period as the result of the improvement of articulatory abilities? If so, does this progression integrate the characteristics of the target language?

Parallel to the motor constraints that may homogenize the patterns of the output at the babbling stage, infants' output could also be influenced by the linguistic environment characteristics (a.o. Rvachew et al., 2008; Lee et al., 2010). The distribution of syllable structures varies across languages and the influence of ambient language on the acquisition of syllable structures has been shown at the word stage (Fikkert, 2007). If the syllable patterns in

babbling reflect as well the distribution of syllables of the ambient language, then those structures should be closer to adult French than to other adult languages with different syllable structure distributions. Otherwise, it would show that the syllable, unlike other linguistic units, cannot integrate at this stage the characteristics of the perceptual environment. If in addition its complexity does not increase, this would illustrate that the production of the syllable would be essentially driven by the articulatory system at the babbling stage.

Method

The study is based on the oral productions of 22 French infants recorded monthly from 8 to 14 months drawn from Canault et al.'s (2020) and on Adda-Decker and colleagues' data (2005).

Participants

Twenty-two normally developing infants (12 girls and 10 boys) from a French-speaking monolingual environment participated in the study. Typical development was assessed via the French version of the MacArthur-Bates Communicative Development Inventory, IFDC (Kern & Gayraud, 2010).

Exclusion criteria were preterm birth, previous or current ENT pathologies, neurological disability, sensory dysorality syndrome, a known mental disorder and twinning.

Data collection

All infants were audio-recorded during a 1-hour session at the nursery or at the parents' home, in a room that was sufficiently quiet or isolated to avoid interference from unwanted noise, in interaction with a parent, an investigator or a caregiver. The session was audio-recorded using a portable device equipped with a microphone (Zoom® Handy Recorder H1) placed near the infant. The recordings took place monthly from the age of 8 months to 14 months, with a total of 7 sessions per infant. A mean of 102 syllables were produced in each session, with an

important variability (SD=86.17). Over the 152 sessions, 135 reached a minimum of 40 produced syllables.

One participant (M03) did not produce any syllables at 8 months and at 10 months, thus we excluded these two sessions.

Data segmentation and transcription

All babbling productions from infants were selected, defined as “speech-like” (Oller et al. 1976) excluding cries, whimpers, coughs, grunts, laughs, breathing artifacts, swallows, squeals and trills. Using the version 6.0.29 of the Praat® software which is a free software for analyzing, synthesizing and manipulating the speech signal (Boersma & Weenink, 2017), each babbling production was segmented into syllables following the syllabification of Wioland (1985) and annotated. Post-graduate students or researchers in speech pathology or speech sciences, who were experts or trained in phonetic transcription (including the authors of the present article) manually performed the speech segmentation and annotation on complementary parts of the data. Each syllable was segmented using acoustic cues on the waveform and the spectrogram, such as the presence of periodic cycles, the amplitude envelope, and intensity peaks.

The annotators transcribed phonetically each syllable. The phonetic transcription was based on the annotators’ auditory perception and observation of acoustic cues in Praat, such as the presence of a voice bar, friction noise, formant transitions, burst duration, etc.

From this phonetic transcription, each syllable was automatically described as a syllable pattern using C (for consonant) and V (vowel), by means of an algorithm adapted from Yamaguchi and colleagues (2015).

Adult data

Infant data were compared to adult data from French but also from other languages: Dutch (Schiller et al., 1996), Korean (Yun et al., 2015), Moroccan Arabic and Tunisian Arabic (Hamdi et al., 2005). All samples were adult spoken speech. Following Levelt et al. (2000), syllables with long vowels or diphthongs (VV) were merged into the corresponding structure with short vowels (V). In order to perform statistical tests, percentages of syllable frequencies in adult speech were converted to raw numbers, using the total numbers provided in the sources. The syllable structures in languages other than French are displayed in Table 2.

(Insert table 2 about here)

Data analyses

Syllables shorter than 100 ms and longer than 1000 ms were excluded as well as that with overlapping noise or speech. In total, 15165 syllables were annotated for the present study.

Following the criteria of Vihman & McCune (1994), potential words were identified in all sessions. Only seven children out of 22 produced identifiable words, from the age of 11 months. 85 utterances were identified as words, that being 167 syllables, which corresponds to 1.1% of our final sample. Word identification cannot be fully assured using only audio recordings. This is why, in accordance with Gerhold et al. (2020), no distinction was made between recognizable words and babble in analyses.

Reliability

The first 10 syllables of each infant at each age were segmented and transcribed by a second expert, a graduate student in phonetics, totalling 1540 double-transcribed syllables (12% of the sample set).

Agreement on syllable structures was reached on 89.4% of the sample, and Cohen's Kappa was 0.769, which suggests a strong agreement between the second and all the first annotators.

Statistical analysis

All statistical analyses were performed using R software. Comparisons of distributions were analyzed with Pearson's Chi² tests and multinomial logistic regressions. When needed, the data were analyzed with linear mixed-effects models, using the *lme4* library (Bates et al., 2015), with infants considered as a random effect. The significance of the predictor effects was estimated with ANOVA based on Fisher tests. When relevant, post-hoc pairwise comparisons of means (Tukey contrasts) were performed. The dependent measure was the number of syllables produced by infants and fixed effects were the type of syllable structure and age.

Results

We first present the distribution of syllable structures in the whole corpus and by age. We then compare our data to adult speech samples from different languages such as Dutch, Korean, Moroccan and Tunisian.

Distribution of syllable structures

The number of syllables produced by infants and by syllable types is shown in Appendix 1. Figure 1 shows the overall distribution of syllable structures in the whole sample.

(Insert Fig.1 about here)

The number of syllables produced depended on the type of syllable structure ($F=125.53, p<.001$). Post-hoc tests with a Holm correction showed that CV syllables were the most prevalent category among the 6 types of structures ($p<.001$ with all five structures). They also reveal that V syllables were more frequent than CCV syllables ($p=.019$), CVC syllables ($p=.004$), VC syllables ($p=.019$) and Others ($p=.034$).

CV, V, CCV, CVC and VC structures occurred in every infant and represented 99.61% of the whole sample. The most frequent was the CV structure, which represented 74.9% of all syllables in the sample, and was the most frequently produced syllable type in all

infants (from 55.9% to 83.7%). The second most common structure was the V structure (15.7%), which occupied the second rank in 21 infants out of 22 (from 8.03% to 28.32%). Globally, CCV was the third most frequent structure (4.86%) and occupied the third place in 17 infants out of 22 (from 2.16% to 12.03%), while this position was occupied by CVC for two infants, VC for two infants and V for one infant. CVC was the fourth most frequent structure in the whole sample (2.58%) and occupied the fourth rank in 15 infants out of 22 (from 1.36% to 6.21%) while this position was occupied by CCV in four infants, and VC in three infants. The fifth structure was VC (1.57%) in the whole sample and in 17 infants, CVC being the fifth in five infants. Finally, the CCVC, CCVCC, CVCC and VCC structures, that we name “Others”, were not observed in every infant’s inventory and represented only 0.39% of the whole sample.

In total, 14 infants out of 22 presented the distribution CV>V>CCV>CVC>VC, three infants presented the distribution CV>V>CCV>VC>CVC, two infants presented CV>V>CVC>CCV>VC, two infants presented CV>V>VC>CCV>CVC and one infant presented the distribution CV>CCV>V>CVC>VC.

Distribution of syllable structures across age

Figure 2 shows the distribution of syllable structures by age in the whole sample.

(Insert Fig.2 about here)

Likelihood ratio tests indicated no statistically significant Age × Syllable Structure interaction ($F = .41, p = .999$) showing that the proportion of each syllable structure does not change with age. At each age, the order of frequency for syllable structures was CV>V>CCV>CVC>VC, when collapsing all infants together.

Comparison with adult data

Figure 3 shows the distribution of syllable structures in infants, in French adult aligned segmentation, in French adult canonical segmentation and in other adult languages (Dutch, Korean, Moroccan, Tunisian).

(Insert Fig.3 about here)

The results from multinomial logistic regression models, which examined the relationship between the languages and type of syllable structures, are presented as odds ratios in Table 3. The reference level for Syllable Structure was CV, and the reference level for Speech Type was the infant data (Freq.child).

(Insert Table.3 about here)

Analyses showed that the distribution of syllable structures in infants is significantly different from that in all adult languages, except for the V structure in French aligned speech and the VC structure in Moroccan. It has to be noted that the distribution of V structure in infant data was closer to the Korean sample (OR= 1.12) than to the French canonical sample (OR=0.84). For the CCV structure, both Dutch (OR=2.02) and Tunisian (OR=2.24) are closer to the infant data than the two French adult corpora (Aligned=2.34; Canonical=2.4). For the CVC structure, the French canonical speech is significantly different from infant data but has the smaller effect (OR=3.28). For the Others structures the French aligned speech is significantly different from infant data but has the smaller effect (OR=10.1). Overall, the distribution of syllable structures in infant data was not systematically closer to the two French adult data.

Because the high prevalence of CV structures may mask similarities within other structures, statistical comparisons with adult French data were done without CV syllables. Even without CV syllables, Pearson's Chi² test showed a significant difference between the distribution of all other syllable structures in our sample and in canonical spoken French ($\chi^2 =$

1750.4, $p < .001$) and in aligned spoken French ($\chi^2 = 1751.7$, $p < .001$). The inspection of the contribution of each category to the χ^2 statistics showed that infants displayed more V syllables and less CVC and Others.

Comparisons between French adult syllable distributions and infant syllable distributions were performed at each age. Pearson's χ^2 tests showed significant differences between adult aligned segmentation, adult canonical segmentation and infant productions at all ages (see Appendix 2 for statistical results). The examination of the contributions of each category to the χ^2 statistics indicated that at all ages, the syllable structures CCV, CVC and Others were underrepresented in infants compared to canonical and aligned adult speech. The CV structure was more frequent in infants than in both adult corpora at all ages. The V structure was produced more by infants than in both adult speeches at the ages of 9, 10, 11 months and more than adult canonical speech at the ages of 12 and 14 months. Finally, the VC structure was overrepresented in infant speech compared to adult canonical speech at the ages of 11 and 12 months.

The comparison of individual data with the two types of French adult segmentations showed differences (see Appendix 3 for statistical results). Fifteen infants produced a greater proportion of CV syllables when compared with adult aligned speech, and only eight infants in comparison to adult canonical speech. While 22 infants demonstrated a smaller proportion of CVC compared with adult aligned speech, 18 infants showed the same tendency compared with adult canonical speech. As for other complex syllables, they represented a smaller proportion in 17 infants compared to aligned speech and in 20 infants compared to canonical speech. About the same number of infants produced different proportions of V, VC, and CCV syllables in comparison with both adult speech samples.

Discussion

The order of frequency of syllabic structures observed in French babbling was CV>V>CCV>CVC>VC. The whole distribution was found in 63.6% of the infants and 77.3% shared the order of the first 3 structures. These results are in line with the work carried out in different languages showing the dominance of the CV structure and more broadly of open syllables in babbling productions (a.o. Lahrouchi & Kern, 2018; Levitt & Utman, 1992; Roy & Sreedevi, 2013). Although it is generally accepted that articulatory control improves during babbling (Green & Wilson, 2006; Canault et al., 2020), this progression does not seem to have an impact on the complexity of syllabic structures since their distribution remained the same between 8 and 14 months of age. CV and V represented respectively 74.9% and 15.7% of the structures produced at 8 months and 75.6% and 15.2% at 14 months. Our results diverge from those of Gerhold et al. (2020) who showed that the level of complexity of structures increased between 7 and 18 months in English infants. However, the infants included in Gerhold and colleagues' study were followed at 7, 11 and 18 months, which corresponds to a later follow-up window than that covered by our study, and the observed evolution was significantly more marked between 11 and 18 months when the lexical development is strong (as a reminder, only 1.1% of the syllables in our sample are included in words). Levitt and Utman (1992) also found a change between the syllabic structures of a French infant and those of an English infant from 11 months of age, with an increase in the production of closed syllables for the English infant indicating that the target language has an influence on early productions, since there are more closed syllables in English than in French (Delattre & Olsen, 1969; Goldman et al. 1996).

The syllables with the highest prevalence in infant's data are also those with the highest frequency in spoken French (Adda-Decker et al., 2005; Wioland, 1985). CV and V syllables are the most numerous syllables in adult spoken French (72.9%) as well as in the

babbling of the 22 French infants included (90.6%). This could be interpreted as the sign of an effect of the ambient language on the infant's syllable production. But two other results weaken this interpretation. First our results showed that infant distributions differ significantly from French adult ones, even when the predominant CV structure is not included in the analysis. We also showed that the syllable rankings were not completely similar especially when adult aligned segmentation was taken into account. Second, the comparison of infant syllables with that of other adult languages than French showed that the distribution of V, CCV and VC structures in infant data were closer to the ones of other languages than to at least one of the French adult samples. This result cannot be explained by the influence of language environmental input, since the infants in our study were only exposed to French. Even if there is evidence, in the literature, that infants in the first year learn about their ambient language by listening to it (Goldstein et al., 2003; Goldstein & Schwade, 2008), Engstrand et al. (2003) and more recently Lee et al. (2017) respectively showed, in Swedish and American 12- and 18-month-olds and in English and Chinese 8, 10, and 12-month-olds, that ambient-language effects are not discernible in babbling. Other studies show that the frequency of input does not completely explain the production patterns observed during development, even in older children, suggesting that the effect of the language environmental input is also modulated by the degree of articulatory difficulty of the phonetic targets (Jarosz et al., 2017). This could explain the over-representation of the simplest CV structure which was by far the most frequent syllabic type (74.93%) in all infants. Our results provide additional evidence for the dominance of this syllabic structure at the early stage supported by articulatory models such as the “Frame-Content” Theory (MacNeilage & Davis, 1990 a & b; MacNeilage, 1998) or the “Articulatory Phonology” framework (Nam et al., 2009), and more recently by new neurological (Brown et al., 2021) and biological (Kent, 2021, 2022) arguments. This structure seems to be the least complex to produce and would be an

articulatory unit resulting either from a single jaw oscillatory cycle coupled with voicing or from the synergy of tongue movements for the consonant and vowel gestures.

The frequency of other types of structures is lower. After CV, the open syllables V and then CCV are the most preferred ones. In 21 infants, V was the second most frequently occurring syllable structure (15.71%) and CCV the third most often produced syllable in 17 of them (4.86%). The closed syllables CVC and VC ranked respectively fourth (15 infants) and fifth (16 infants) in the infant's syllabic repertoire with low average occurrence rates of 2.58% and 1.57%. In 18 infants out of 22, the three types of open syllables were more frequent than the two types of closed syllables. The predominance of open syllables (95.5%) could be explained by the fact that this type of syllable can be produced on a mandibular oscillatory cycle that provides a temporal frame for the gestures of the other oral articulators that are used for the realization of segmental content. The number of consonants could result from the number of constriction points occurring during the raising phase of the jaw (0 constriction point implies a V structure, 1 constriction point a CV structure and 2 a CCV structure). If this is the case, the motor synchronization of gestures within this frame may promote the emergence of open syllables as opposed to closed syllables, which involve desynchronization of articulatory gestures in the coda with respect to the rest of the syllable (Nam et al., 2009).

In conclusion, our results show significant differences in the distribution of syllable structures found in the babbling of French infants between the ages of 8 and 14 months and the ones in adult speech. The lack of changes in the distribution of structures over time, the dominance of the CV structure attested so far in languages other than French and to a greater extent the dominance of the structures simpler to produce seems in line with the hypothesis that syllable production would be essentially driven by the articulatory system at the babbling stage (Cychosz et al., 2020). The influence of the target language on the production of syllable

structure would be revealed later: crosslinguistic differences in the order of development of syllabic structures in older children are documented in the literature (Demuth & Kehoe, 2006; Fikkert, 2007; Levelt et al., 2000; Lleó & Prinz, 1996). Even if recent crosslinguistic studies focusing on the babbling stage (Cychosz et al., 2020; Geambasu et al., 2016; Kern & Davis, 2009; Lee et al., 2017; Lou, 2020) are now available, most of them are not directly interested in the syllabic structure and when it is the case, the number of languages compared is limited and these are languages often well described (e.g. English and Mandarin in Lou, 2020). Further crosslinguistic investigations focusing on syllable shapes in infants and including languages with simple, moderate and complex syllabic structures should be conducted to better understand the interaction of linguistic and articulatory factors on the development of syllable complexity at the babbling stage.

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Word count: 7643

Table 1. Distribution (in %) of syllabic structures in French

Table 2. Distribution of syllable structures in other adult languages

Table 3. Odds ratios (and 95% CI) from multinomial logistic regression analyses investigating language differences between the distribution of syllable structures. The reference level for Syllable Structure was CV, and the reference level for Speech Type was the infant data (Freq.child).

Fig. 1. Distribution (in %) of syllable structures in the infant corpus.

Fig. 2. Distribution of syllable structure by age for the whole corpus.

Fig. 3. Distribution of syllable structure in our infant corpus (Freq.child), French adult aligned syllabification (Alig.Syll), French adult canonical syllabification (Cano.Syll) both from Adda-Decker et al. (2005), in Dutch (Schiller et al., 1996), Korean (Yun et al., 2015) and Moroccan and Tunisian both from Hamdi et al. (2005).