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Development of phonetic complexity in 4 languages: Berber, English, French and Tunisian-Arabic
(children's productions, targets, and 50 randomly selected words in the adult language)

Frédérique Gayraud, Melissa Barkat-Defradas, Mohamed Lahrouchi, Mahé Ben Hamed

Children typically produce their first words around 12 months of age. However, the full mastery of an adult-like sound system is not achieved before 8 (Sander, 1972) or even 10-12 years of age (Smith & McLean-Muse, 1986). This extended period required to master the speech sound system of the adult language is due to the fact that young children are neither endowed initially with an adult-like vocal tract configuration nor with the neuromuscular control for producing the range of sounds of their ambient language (Green, Moore, & Reilly, 2002; Stoel-Gammon & Sosa, 2007). These anatomical and neurophysiological constraints result in a restriction of children's early phonetic inventories (Green, Nip, Maassen, & Van Lieshout, 2010; Nip, Green, & Marx, 2009). Initially, children's phonetic inventory is composed of sounds produced primarily by the jaw (MacNeilage, Davis, Kinney, & Matyear, 2000), on which they have a better control compared to lips and tongue movements (Green et al., 2002). As a consequence of these biological universal constraints, children acquiring different languages show a similar restricted inventory of sounds (Locke, 1983, 1995). Indeed, babbling and first words productions demonstrate universal patterns: children show a preference for labials and coronals, stops, nasals and glides, open syllables, short utterances, few consonant clusters (and if any, they tend to be homorganic), and they use more reduplication than variegation (MacNeilage, Davis, Kinney, & Matyear, 1999; Oller, Eilers, Steffens, Lynch, & Urbano, 1994; Vihman, Macken, Miller, Simmons, & Miller, 1985). Furthermore, these preferences have been shown to influence the words that children select to produce. Indeed, the inventory of children's early vocabulary is not composed of randomly selected words. It has been suggested that children select words with phonetic characteristics that are already present in their own phonological systems (Ferguson & Farwell, 1975; Schwartz, Leonard, Loeb, & Swanson, 1987; Vihman et al., 1985). Other 'lexical selectivity' studies showed that children attempt more complex words targets according to

age (Dobrich & Scarborough, 1992). An Index of Phonetic Complexity (henceforth IPC), which is based on the phonetic regularities observed in the babbling and the first words period was proposed to assess children's phonetic development (Jakielski, 2002; Jakielski, 2000; Jakielski, Maytasse, & Doyle, 2006). This measure, which considers as more complex the productions composed of the less preferred segments and segments associations, permits to measure the development of phonetic complexity in both targeted and produced words by children. By measuring the phonetic complexity of targeted words, (Ward, 2001) documented a lexical selectivity bias in children aged 16 to 24 months. In addition, it was shown that IPC scores at age 12 months predicted speech and language skills at 18 months (Furey, 2003). Both biomechanical constraints of the production system (MacNeilage & Davis, 1990) and lexical selectivity are universal tendencies.

Crosslinguistic studies hence provide support for a strong determination of early phonetic inventories by biological constraints. However, they do not rule out an influence of the ambient language. Languages differ to a large extent in terms of their phonological inventories and phonotactics, making the input more or less difficult to acquire for children. Cross linguistic analysis of diverse languages permits the distinction of potentially universal patterns from language and/or language specific patterns (Stoel Gammon, 2012). Indeed, previous analysis have shown that segmental development, namely word shapes and CV co-occurrences, are influenced by input frequency in the ambient language (Saffran, Newport, Aslin, Tunick, & Barrueco, 1997) as well as by the functional load of segment in the language (i.e. how much use a language makes of its available contrasts) (Stokes & Surendran, 2005). As languages vary on those parameters, previous findings suggest that some languages may be acquired earlier than others. For instance, (So & Dodd, 1995) showed that Cantonese children acquire phonology at a faster rate than English-speaking children. Similarly, (Loatman, 2001) showed that the Spanish words produced by Spanish children are more complex than those found for Cantonese. (Caselli et al., 1995) also observed that Italian children were slower in vocabulary acquisition compared to English-speaking children between 8 and 16 months of age. Another cross linguistic study comparing vocabulary growth between 16 and 30

months of age found that Galician children produce fewer words than Basque, French and Mexican-Spanish-learning children (Pérez-Pereira et al., 2007). In brief, phonetic development seems to be strongly influenced by universal biological constraints but also by the characteristics of the ambient language.

When considering the ambient language however, one has to keep in mind that the type of language to which children are exposed (referred to as Child Directed Speech, henceforth CDS) differs in several important ways from the adult language. When addressing children, caregivers adjust their language by simplifying and clarifying the linguistic material (Ferguson, 1964) in order to engage children's attention and facilitate language acquisition (Snow, 1977; Werker et al., 2007). CDS is characterized by simplified syntax, shorter utterances, restricted vocabulary, repetitions, phonetic modifications (Kuhl, 2000) increased variations in fundamental frequency and longer pauses (Albin & Echols, 1996; Andruski & Kuhl, 1996) (Ferguson, 1977; Papoušek, Papoušek, & Symmes, 1991). Moreover, this specific register used by parents to promote infants' language learning has been shown to be almost universal (Ferguson, 1964; Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin, 2001; Kuhl et al., 1997; Monnot, 1999).

The current study aims at examining the phonetic complexity of words produced by children acquiring different languages: Arabic (Tunisian vernacular), Berber (Tashlhiyt variety), English (American) and French. These languages show different phonetic and phonological characteristics of interest for early language development, such as word length, word complexity (syllable types, consonant clusters) as well as phonemic inventory diversity. For example, Arabic lexicon, which is largely derived from basic consonantal roots, displays a lot of polysyllabic words. Concerning syllable types, French shows a strong preference for open syllables (76%); English exhibits largely closed syllables (60%) (Delattre, 1965) and Tunisian displays 23% of closed vs. 33% of open syllables (Hamdi, Ghazali & Barkat-Defradas, 2005). These languages also differ in consonant cluster requirements: in Tashlhiyt, consonant clusters are very common and not restricted to word-initial position. They occur in any position within the word or the syllable while in Tunisian Arabic, they are hardly found in word

final position. In French both positions are permitted but a bias towards word initial position is attested. Phonemic inventories are also quite diverse. Indeed, when computing the consonant/vowel ratio, two groups emerge: Tashlhiyt and Tunisian Arabic are highly consonantal languages (Ridouane & Fougeron, 2011; Hamdi, Ghazali & Barkat-Defradas, 2002) whereas in French and, to a lesser extent English, vowels are more represented. Tashlhiyt and Tunisian display an important proportion of fricatives as compared to the two other languages. Moreover Tunisian and Tashlhiyt phonological inventories put forward a large number of back consonants (i.e. uvulars, pharyngeals and glottals) that are known to be acquired rather late (Omar & Nydell, 2007).

Given these phonetic and phonological characteristics, the following hypotheses deserve to be tested:

H1. The different languages should display different degrees of complexity. The dictionary words in Berber and Arabic, which are highly consonantal languages, should have higher complexity scores compared to English and to French, which are more vocalic.

The following IPC parameters are of special interest for our cross linguistic analysis:

- *Place of articulation*: Arabic, which contains many back (i.e. dorsal) consonants and French in which /ʁ/ is rather frequent (Gromer & Weiss, 1990) should display more complexity on this parameter.
- *Clusters*: Berber and Arabic in which clusters are more frequent should be more complex on that parameter.
- *Complex articulation*¹ should contribute as a factor of complexity in Berber and Arabic.
- *Word length*: Arabic, which shows many polysyllabic words because of vocalic patterns and affixes that are interweaved to the root for lexical derivation, should display more complexity on this parameter specifically.

¹ When a consonant articulation occurs at the same time as another articulation is being made at a different place in the vocal tract, the consonant is said to form a complex articulation.

- *Final Consonant*: French, which shows a preference for open syllables should be less complex compared to the other languages.
- *Variegation*: in Arabic the non-homorganic consonantal rule which constraints the root-skeleton leads to expect this language will attest more variegation than the others.
- *Rhoticity*² will contribute to complexity in American English only.

H2. In each language, we expect the words that mothers use when addressing their children (child directed speech) to be less complex than the words from the “adult” language (i.e. represented here through different dictionary words).

H3. According to the lexical selectivity hypothesis, children should attempt words that are less complex to produce than the adult language’s words.

H4. Given the biomechanical constraint hypothesis, we expect children’s actual productions to be less complex than the targets they attempt.

H5. However, we expect an effect of the ambient language: children acquiring a phonologically more complex language should target and produce more complex forms. Hence, we expect Tunisian and Berber children’s IPC scores to be higher than those observed for English and French.

H6. More generally, if a complex parameter is frequent in the ambient language, children should use it or attempt it more often than if it is not present in the ambient language.

Method

Participants

Sixteen children from four linguistic communities: Arabic (Tunisian vernacular), Berber (Tashlhiyt variety), American English and French were included in the study. The Arabic and Berber data are

² Rhoticity in English refers to the situations in which English speakers pronounce the historical rhotic consonant /r/, and is one of the most prominent distinctions by which English varieties can be classified. Here we studied the acquisition of American English, which belongs to the rhotic varieties.

part of The PREMs Project³ (Principal Investigator: Sophie Kern). The French data are part of the French Kern corpus (Kern, Davis, & Zink, 2009), and the English data comes from the Providence Corpus (Demuth, Culbertson, & Alter, 2006).

Table 1. Participants' demographic information

Language	n	Sex	Age range
Arabic	4	2M-2F	8;09 – 24;06
Berber	4	2M-2F	7;21 – 18;12
English	4	2M-2F	11;27 – 20;05
French	4	3M-1F	9;09 – 22;22

The children were recorded in natural settings at home in interaction with their mother. The recording sessions took place twice a month from the onset of first word production until a few months after lexical spurt. Four lists of words were analyzed for each language: (i) the words actually produced by children (hereafter referred to as Actual), (ii) the targets corresponding to these words, (iii) 50 words extracted from CDS and (iv) 50 words from the adult language randomly selected from dictionaries (See APPENDIX 1 to 4 for an illustration). For each list, an adaptation of the Index of Phonetic Complexity (Jakielski, 2000) was computed. IPC is based on the phonetic regularities observed during the babbling and the first- words periods. The IPC rates as more complex those vocal outputs that are composed of the less preferred segments (or segments associations) in early development. It allows measuring the development of phonetic complexity in both word targets and words actually produced by children. The IPC consists of eight parameters: consonants and vowels by place and manner classes, word shape and word length (in syllable type and number), singleton consonants by place variegation, contiguous consonants and cluster by type (i.e. homo vs. hetero organic). However, this measure was initially designed to capture the phonetic complexity of English and therefore, needed to be adapted for cross-linguistic comparison in order to account for other determining features of phonetic complexity exhibited in the 4 languages under examination.

³ <http://www.ddl.ish-lyon.cnrs.fr/projets/prems/index.asp?Langue=EN&Page=Presentation>

Adaptation

In order to take into consideration the typological peculiarities of our linguistic sample, we first had to integrate to the original IPC model a new parameter relative to consonantal articulation, which we labeled Consonant by articulation class in reference to Jakielski's first two parameters (i.e. Consonant by articulation class and Consonant by place class). This new parameter has been added in order to discriminate between simple vs. complex articulations. Indeed, when a consonant articulation occurs at the same time as another articulation is being made at a different place in the vocal tract, the consonant is said to form a secondary (or complex) articulation. In Arabic and Berber two types of secondary articulation are phonemically attested: pharyngealization (both in Arabic and Berber) and labialization (in Berber only). Basically, during the realization of a pharyngealized consonant (for example [t^ħ, d^ħ, ð^ħ]), the pharynx is constricted and the root of the tongue is retracted. Such consonants, which require a skillful control of the back of the vocal tract (Barkat-Defradas & Embarki, 2009), are acquired very tardily (Omar, 1973); that is why we added 1 point for such complex segments that are typical of Afro-asiatic languages (Hetzron, 1997). The same rationale was applied for labialization, which consists in adding lip rounding to the principal articulation. As for consonant by place class, we considered radical consonants (i.e. pharyngeals) as particularly complex since they are, on the one hand, even more posterior than dorsals – that are themselves considered as complex in the original IPC model – and, on the other hand, since the mastery of production for these consonants is reported to occur rather late (Amrayeh, 1994; Amrayeh & Dyson, 1998). Lastly, considering the fact that under the influence of Berber, consonantal clusters are frequent in the Western varieties of colloquial Arabic and can be very long, we decided to add up to 2 points when two or more consonantal segments are contiguous. Table 2 recapitulates the different parameters included in our IPC adaptation.

Table 2. Adapted Index of Phonetic Complexity Scoring Scheme (based on Jakielski, 2000).

Parameter		No points for:	One point each for:	Maximum possible points:
1	Consonant by articulation class	Simple	Complex	1 point each
2	Consonant by place class	Labials, Coronals, Glottals	Dorsals Pharyngeals	1 point each
3	Consonant by manner class	Stops, Nasals, Glides	Fricatives, Affricates, Liquids	1 point each
4	Vowel by class	Monophthongs Diphthongs	Rhotics	1 point each
5	Word shape	Word ending in a vowel	Word ending in a consonant	1 point each
6	Word length in syllables	Monosyllabic and dissyllabic words	Tri+ syllabic words	1 point each
7	Consonants by place variegation	Reduplicated	Variegated	1 point each
8	Consonants by manner variegation	Reduplicated	Variegated	
9	Contiguous consonants	Words without a cluster	Words with consonant clusters	CC = 1 point > 2C = 2 points
10	Cluster by type	Homorganic clusters	Heterorganic clusters	1 point each

Our purpose is to compare cross-linguistically the total phonetic complexity of children's production, but also the contribution of each of the parameters accounting for it. Translating each word into a phonetic sequence in which each element is described as a vowel, a consonant, or a secondary articulation, with consonants being identified in terms of place and mode of articulation, we can identify and compute each parameter, and the IPC as their total sum. Table 3 provides an example of ICP scoring for four dictionary words in each language.

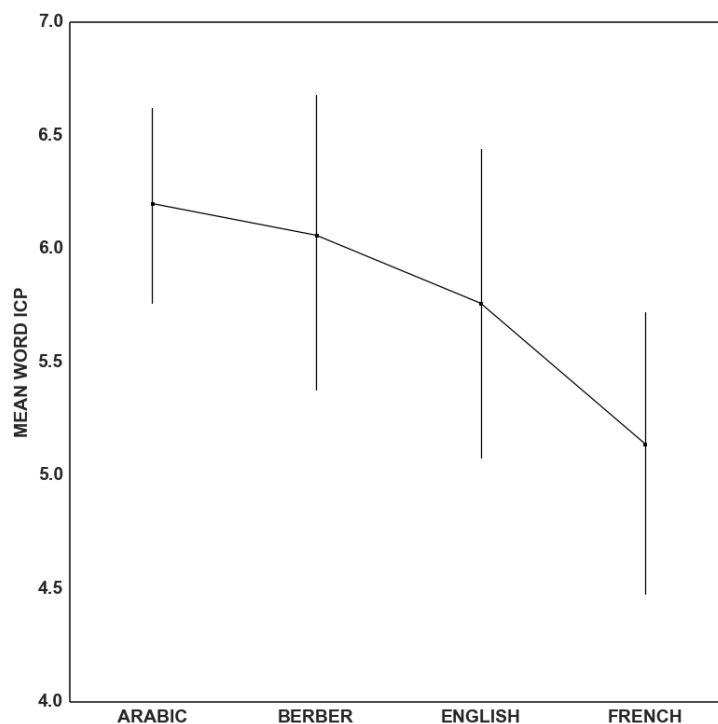
Table 3. Index of Phonetic Complexity Scoring for 4 words in each language

Language	Item	IPA Transcription	Consonant by articulation class	Consonant by place class	Consonant by manner class	Vowel by class	Word shape class	Word length in syllables	Consonants by place	Consonants by manner	Contiguous consonants	Cluster by type	Total IPC
French	fork	furʒet	0	1	1	1	0	0	1	1	1	1	7
English	mixture	mɪkstʃər	0	1	3	1	1	0	1	1	2	1	11
Berber	girl	tafruxt	0	1	2	0	1	1	1	1	2	2	11
Arabic	he fell	sqəṭ ^c	1	1	1	0	1	0	1	1	1	1	8

Results

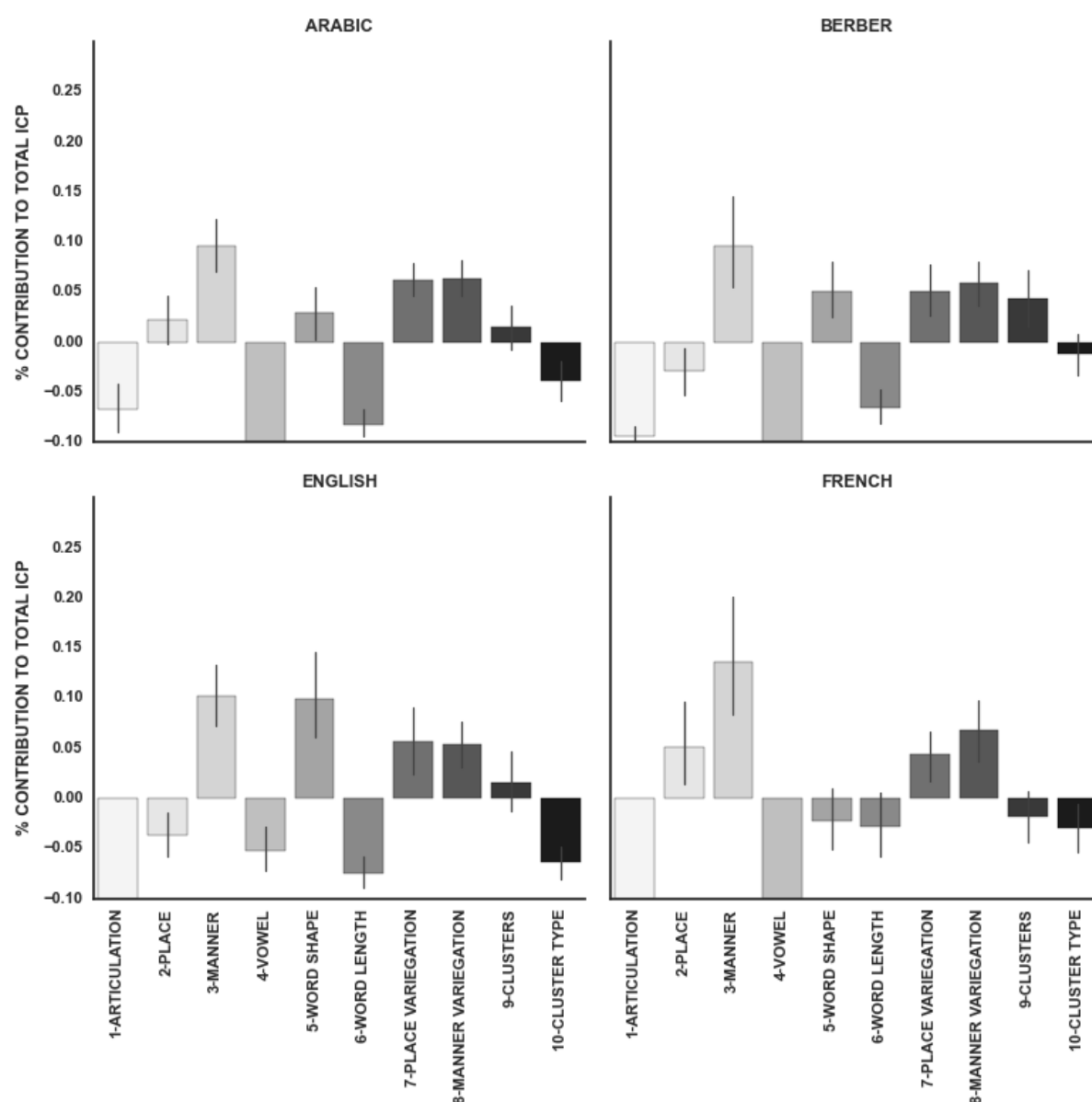
The dictionary sample is a window on the expected mean word phonetic complexity of the languages under study. The sample being rather small, we also computed the confidence interval of the mean with a 5% type I error by bootstrapping the sample to estimate the interval of values for the mean phonetic complexity for the dictionary as a whole. Figure 1 shows that the 4 languages have indeed different mean word IPCs, with a decreasing cline from Arabic > Berber > English > French. As expected given the sample size, the 95% confidence intervals are large, but they still support this complexity cline.

Figure 1. Mean word IPC showing a decreasing cline from Arabic > Berber > English > French. Vertical bars show the 95% confidence interval for the means for the dictionary as a whole.



The IPC being computed as the sum of 10 phonetic parameters, depending on the language, this overall complexity can be attributed to different parameters. Figure 2 shows the individual contribution of each parameter to the overall IPC for the dictionary sample. Contributions are computed as the difference between the proportions of the overall complexity (that is the IPC), the parameter actually accounts for, and what would be expected from a uniform contribution of all parameters. Since there are ten of those, the uniform contribution null hypothesis would set each parameter's contribution at 10 %. Specific parameter contributions will thus vary between -0,1 and 0,9.

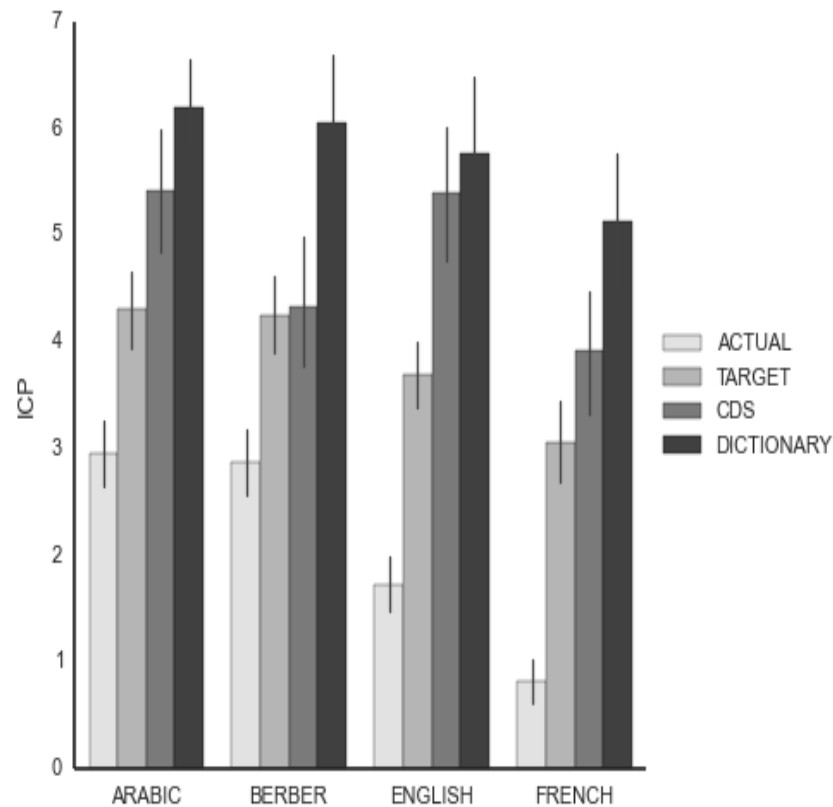
Figure 2: Specific parameter contribution with respect to the uniform contribution null hypothesis. Values range from -0,1 to 0,9 for each of the 10 parameters composing the IPC.



As expected, Arabic and French display a greater contribution of place of articulation, and French exhibits less complexity than all three other languages as to word shape due to preferential open final syllables. However, contrary to our assumptions about consonantal clusters, only Berber displays them as significant contributors to the overall phonetic complexity, whereas Arabic and English scale the same, in only slight excess of the 10 % contribution baseline, while French is slightly in deficit for this specific complexity component. The number of syllables does not behave according to our expectations either. Having distinguished monophthongs and diphthongs in our data description, word length is computed as the number of vowels – assumed to act as syllabic nuclei (except for Berber, where, additionally, syllabic consonants were identified using (Dell & Elmedlaoui, 2002)'s syllabification algorithm.

Complexity measures on the dictionary samples provide the baseline against which children's production and lexical selectivity, but also Child Directed Speech (CDS) can be analyzed. Figure 3 shows the mean IPC values for the different lists in the different languages.

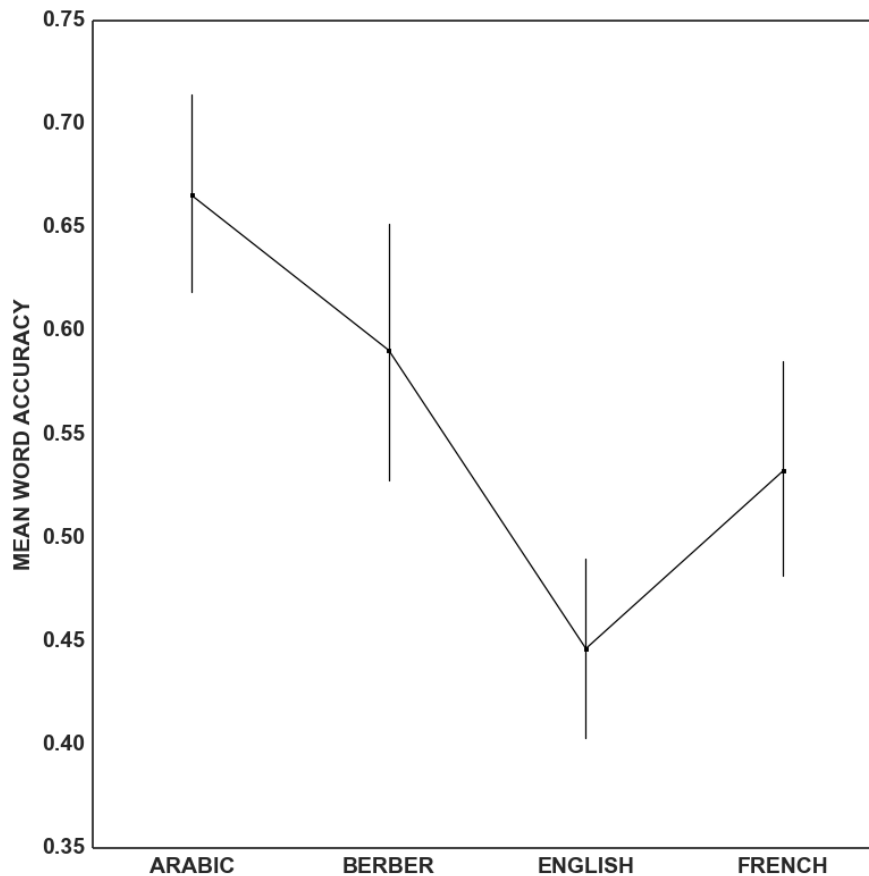
Figure 3. Mean word IPC and 95M confidence intervals for the Dictionary/adult language, CDS, actual child production and target for Arabic, Berber, English and French



Although the general tendency is that of a decreasing complexity cline from Dictionary/adult language to CDS to Target to Actual child productions, major differences exist between languages. For instance, Arabic and English Child Directed Speech show the highest complexity compared to the dictionary sample, but Berber, while showing a lower mean IPC for CDS, also exhibits comparable levels of phonetic complexity between the CDS and the targets selected by children for production. Moreover, Arabic and Berber show similar Target complexity and Actual-to-Target complexity differential. But while English and French display lower Target complexity, they also display larger Actual-to-Target complexity differentials, with lower achieved complexity in children's actual production, especially for French.

However, these Actual-to-Target complexity differentials do not necessary translate into Actual-to-Target accuracy. Given that the individual parameters focus primarily on consonants, we computed the Actual-to-Target accuracy in the realization of consonants for the 4 languages (Figure 4).

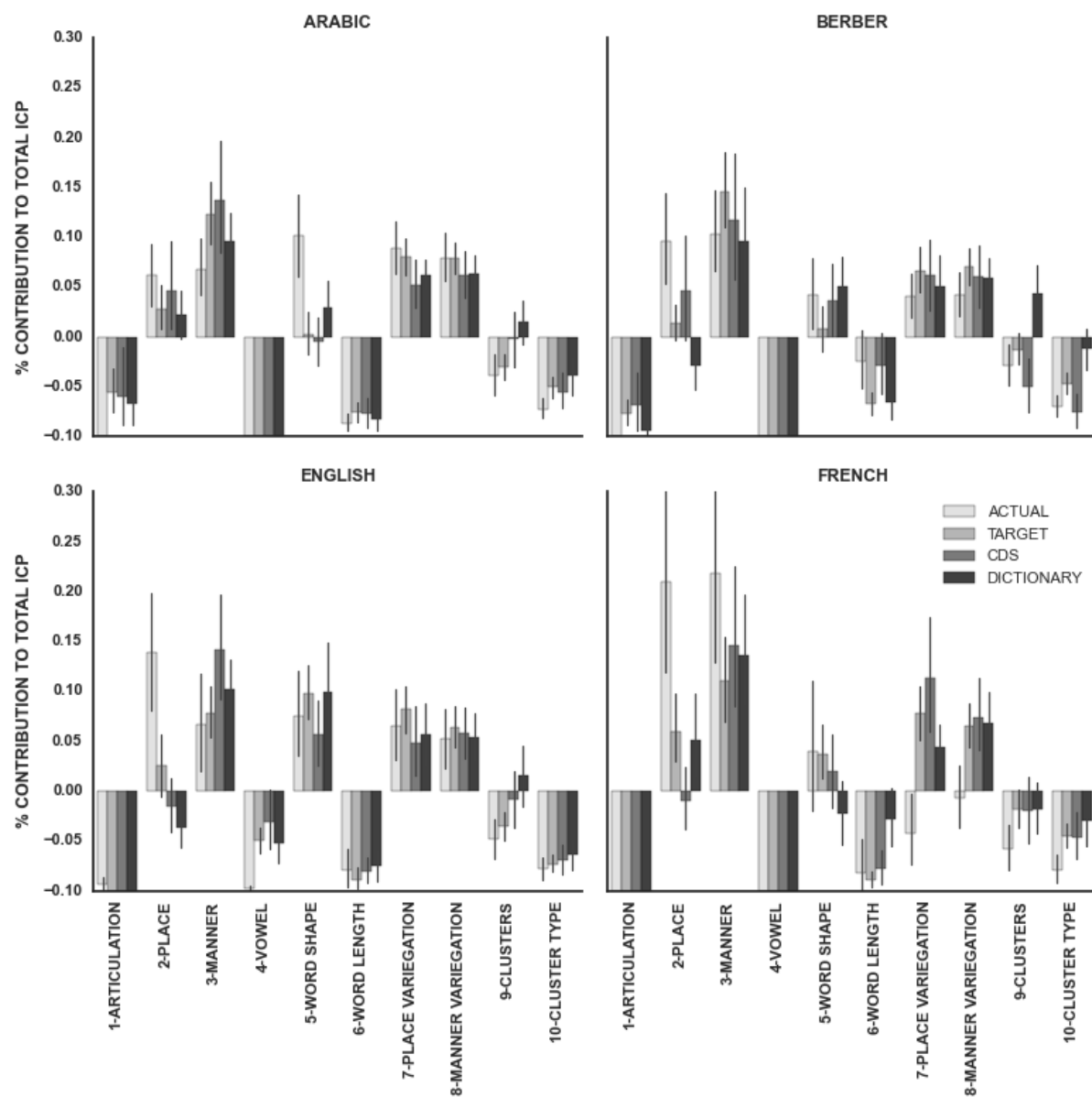
Figure 4. Mean Actual-to-Target accuracy in consonant production for Arabic, Berber, English and French. Vertical bars display the 95% confidence interval



Despite the larger overall Actual-to-Target complexity differential, French children achieve better accuracy, while English children achieve the worst accuracy scores. More importantly though, and despite larger Target complexity, Arabic and Berber children achieve the highest accuracy scores. These results suggest that typological characteristics of the language play indeed a role in the acquisition process and call for a detailed examination of the individual contribution of each parameter to the overall IPC score of children's actual production, as compared to the language (dictionary) parameter contribution landscape.

Figure 5 shows that not all parameters contribute in the same way to the mean IPC of the actual production of the child, depending on the language, with respect to how they contribute in the other samples, and especially, the Dictionary.

Figure 5. Mean parameter contribution by sample (Dictionary, CDS, Target and Actual) and by language (Arabic, Berber, English, French)



For instance, Arabic Actual shows an enhanced tendency for children to produce closed final syllables, irrespective of what is displayed in either the Target or the CDS, thus mirroring more of the dictionary tendency than these two latter samples do. On the other hand, clusters, which contribute to different extents to the IPC of Berber, Arabic and English (dictionary), do not in either of the other samples, suggesting that both CDS and Targets selected by the children tend to misrepresent clusters during this phase of acquisition, thereby reducing the complexity of their production.

A tendency that appears common to all languages, however, is the enhanced contribution of manner of articulation in CDS with respect to Dictionary, that translates for Arabic and Berber in the Target

selected by children for production, while French, where this is not the case, displays an enhanced contribution of manner in the Actual production of the children. Place of articulation also displays a trend common to all languages, with enhanced contributions in Actual production, irrespective of their contribution in the other samples. However, whereas place and manner contribute the most in French, their variegation contributes the least, contrary to all three other languages.

Discussion

Using an adaptation of Jakielski, (2000) Index of Phonetic Complexity (IPC), we carried out an analysis to assess phonetic complexity of children's early vocabulary in four languages: Arabic, Berber, English and French. Globally, we hypothesized that children's early productions would be shaped by universal articulatory constraints, but also by the language they are exposed to, depending on its phonological complexity.

A first subset of our hypotheses (H2, H3 & H4) relates to universal aspects of phonetic development. First, our findings are in line with previous work underlying the universal tendency for caregivers to modify their speech when addressing children (Ferguson, 1964, 1978; Kitamura et al., 2001; Kuhl et al., 1997; Monnot, 1999). Some studies had investigated motherese in Arabic and Berber and cultural differences have been documented in the range of modifications of CDS (Ferguson, 1956, Gumperz & Hymes, 1964, Bynon, 1968, Omar, 1973, Haggan, 2002, Al-Shatty, 2003 and Ferguson, 2004) and the fact that caregivers use a special register to address young children remains undisputable cross-linguistically. The vast majority of CDS studies are focused on semantic, syntactic or prosodic characteristics. Fewer address the issue of CDS phonetic characteristics, but Kuhl et al. (1997) for instance showed that in different languages (American English, Russian and Swedish), mothers addressing their young children produce vowels that are acoustically more extreme, thus providing information about the sound system of the infant's native language in an exaggerated form. It thus promotes language learning by separating sounds into contrasting categories. The present study did not focus on potential modifications of segments in CDS but our findings show that caregivers use words that are less complex than in the adult language. It suggests that there is a lexical selectivity in

CDS just like a lexical selectivity is hypothesized in children's productions. By doing so, one can assume that caregivers reduce the gap between children's restricted articulatory capacities and the necessary capacities to produce phonetically complex words of the adult language.

As predicted, children also seem to select the words they produce or attempt to produce depending on their phonetic complexity (Ferguson & Farwell, 1975; Schwartz et al., 1987; Vihman et al., 1985). Indeed, in the four languages under study, we observed that words attempted or produced by children have lower complexity scores than CDS or adult words. Finally, the fact that in all the four languages actual productions show reduced complexity compared to attempted (and obviously CDS or adult) words illustrates the fact that during this early period of first word productions, children's early phonetic inventories are strongly limited by anatomical and neurophysiological constraints (Green et al., 2010, 2010; MacNeilage et al., 2000; Stoel-Gammon & Sosa, 2007).

Turning to language specific aspects, we observed that as hypothesized, some languages of our samples, namely Arabic and Berber show higher IPC scores than English and especially French. The different IPC parameters contribute differently to complexity. Manner and place of articulation contribute significantly to complexity in the four languages. In other words, children in these languages do not systematically avoid fricatives or liquids, which are frequent in the ambient language. Similarly for Place of articulation, although children prefer labials and coronals to dorsals in the early period of production, they are able to produce posterior consonants (like dorsals and/or pharyngeals) when required by the ambient language (i.e. typically in Arabic and Berber where they are rather frequent). However, some parameters clearly differ across languages. Clusters are significant contributors to phonetic complexity in Berber, and, to a lesser extent, in Arabic and English. As for final consonant, French differs from other languages as being easier, as expected. By contrast some other parameters expected to play a role in the global complexity scores, in particular word length and complex articulation, do not seem to contribute significantly to the global complexity score. In sum, we found a decreasing complexity from Berber to Arabic to English and French. We hypothesized that these differences in phonetic complexity in the adult languages would

influence phonetic development in children acquiring these languages. An obvious assumption is that a phonetically complex language such as Berber would take longer to acquire, and would be more challenging to reach accuracy. Nevertheless, our findings suggest that it is not the case. Although our sample is too small to draw solid conclusions, Berber infants are not delayed in the timing of first words production, as first words are produced as early as 7 months of age in one of our subjects. Similarly, children acquiring Arabic and Berber show the best accuracy scores compared to the *a priori* easier languages, English and French. Looking at the detailed parameters that children either produce or avoid depending on the language, our findings show a mixed influence of language specificity and neurophysiological constraints. Globally children's actual productions tend to reflect the tendencies displayed in adult productions for place and manner of articulation. The fact that Arabic children's use of closed syllables mirrors the adult language (dictionary words) but not targets nor CDS remains to be explained. However clusters, which are strong contributors of complexity in Berber (and to a lesser extent in Arabic and English), seem to be avoided by children acquiring these languages. This finding is not surprising, as consonant clusters appear to be especially challenging for children. Indeed, they are not produced before age 2 and their acquisition is one of the longest-lasting aspects of speech acquisition in normally developing children (McLeod, Van Doorn, & Reed, 2001). In sum, the different IPC parameters are not equally complex to produce by children: while some such as producing fricatives or dorsals can be overcome by children even at a very early age in spite of biological constraints, others such as consonant clusters need more time to master.

APPENDIX 1. Examples of ARABIC data

	Actual IPA	Target IPA	Translation	CDS IPA	Translation	Dictionary IPA	Translation
1	mɛm:æ	mama	mommy	tʰɑ:h	To fall	ʕəʃb	<i>medical</i>
2	itæjj	tʰɑj	Peek a boo	ʔi:zæ	He comes	ħuku:m	<i>monopole</i>
3	pæ	papa	daddy	tʰɑtʰɑ	tata	ħi:la	<i>ruse</i>
4	dæ	la:	no	ʔaħħæ:	Ouch !	farlæχla	<i>fieldmouse</i>
5	ʔi	ʔej	yes	kixχæ	Beurk !	msisa	<i>bracelet</i>
6	tæ:h	tʰɑ:h	It fell	qu:l	tell	ħəwəl	<i>to try</i>
7	bæj	bah	ok	næħħi:	remove	qa:l	<i>tell</i>
8	æm	mam:i	Mum	ʔahajjæ:	here it is	mraħħəm	<i>marble</i>
9	bæħ	baħ	It disappeared	wi:ni	Where is it ?	zra:ʕi:	<i>agricultural</i>
10	ʔejzi	ʔiza	Come here !	ʃu:	What is it ?	mdʰəl	<i>straw</i>
11	běj	baj baj	Bye-bye	daddu:ʃ	walk	mudʰif	<i>stewart</i>
12	təd:	ʃi:d:	Hold !	jɛzzi	Stop !	butʰa-in	<i>ventricle</i>
13	ʔæħ:	ʔaħ:	Ouch !	træh	Show me !	dəħʃ	<i>baby donkey</i>
14	hup	ħutʰ:	Put down !	ba:h	Gone (nothing !)	wəsx	<i>fouling</i>
15	zazæ	dʒa:za	chicken	alo	hello	səqqa:t	<i>gourmet</i>
16	ħibɛʃ	mænħibɛʃ	I don't want	ʔaʕmil	do	kursi	<i>saddle</i>
17	ktib	ʔiktibli	Write (to me)	hæ:t	put	ʕrəq	<i>sweat</i>
18	ka	kask	Your helmet	læ:	no	ħadd	<i>fence</i>
19	tæ:ʕi	mtæ:ʕi	mine	ʔej	go !	rija:ga	<i>bib</i>
20	bebe	bebe	baby	χu:	brother	qəm	<i>estimate</i>
21	kak:æ	kaka	poo	kaka	poo	məstəyəl	<i>profiteer</i>
22	tat:a	batʰ:ɑ	canard	jimʃi	He goes	bəlyɑ	<i>oriental slipper</i>
23	tatæ	tʰɑtʰɑ	Beat !	sʰɑhi:t	Thank you	ʃkara	<i>bag</i>
24	ħutæ:	ħuta:	fish	ʔaqɛf	Up !	bəqra:z	<i>tea pot</i>
25	bab	dub	ours	bæʕ	Bèè (bleat noise)	ħɛ:l	<i>weather</i>
26	na:n	ħsʰa:n	Horse	zi:b	Bring	sʰəffa	<i>clarify</i>
27	næhnæ	lihnæ	here	hæðika	This one	məlle:ħ	<i>seller</i>
28	mæ mæ	mæ:	water	tħutʰ	place	da-ijəb	<i>melting</i>
29	kæk	qird	monkey	ʔistannæ	wait	qəʔza	<i>jump</i>
30	tæ:h	muftæ:h	key	ʔælʕib	play	da:r	<i>home</i>
31	taw taw	taw:a	now	ʃʕær	hair	ma:t	<i>perish</i>
32	dæb:u:sæ	dab:uzæ	bottle	mtaʕ	his	rzaʕ	<i>take back</i>
33	ʃbi:k	ʃbi:k	What happens to you ?	sʰɑfiq	Applaud !	tʰbi:b	<i>doctor</i>
34	ʔuxdæn	ʔuxzur	Watch !	ʃnuwæ	what	faħħəm	<i>explain</i>
35	kas:ar	tkas:ir	You broke	bismilah	Bless you	ħdər	<i>argue</i>
36	bæz	xubz	bread	ʕaqu:la	nice	sqəʔʰ	<i>fall</i>
37	fasu:	ʕasʰfu:ra	bird	ʔaʕtʰi	give	ʔri:b	<i>unheard-of</i>
38	tax:a	kix:a	Eew !	matmissif	Don't touch	bəʔtʰəl	<i>idle</i>
39	ʕam	ʕam:i	My uncle	ʔuqʕud	Sit down !	mʕalləm	<i>expert</i>
40	ku:ra	ku:ra	ball	ʔa:di	there	səndu:q	<i>coffin</i>
41	di	haði	This one	ʃbi:k	What happens	hənd	<i>magnet</i>
42	tiz:a	hizha	Lift it up	nraɤablik	I'll put it together	qəmr	<i>moon</i>
43	laħda	laħðʰa	One minute please	tkallim	talk	qəsmɑ	<i>part</i>

44	kuja	xuja	My brother	nxabbi:h	I hide	stəxbar	<i>be informed</i>
45	ku:	qu:m	Get up !	hs'a:n	horse	ʒəʃʒada	<i>spatula</i>
46	nan:i	nan:i	Sleep !	ʃas'fu:ra	bird	aθat	<i>furniture</i>
47	ʔahu	ʔahuwa	Here it is !	matibki:ʃ	Hurry up (don't cry)	mədwəd	<i>nursery</i>
48	tat:	jtat:ti	(he) beats	kifæ:ʃ	how ?	rqi:q	<i>menu</i>
49	ræjæ	mræjæ	mirror	nhizz	mirror or bring	dərbuka	<i>drum</i>
50	stan:æ	ʔistana	Wait !	su:q	Market+	ʃilaqa	<i>Coat rack</i>

APPENDIX 2. Examples of BERBER data

	Actual IPA	Target IPA	Translation	CDS IPA	Translation	Dictionary IPA	Translation
1	b:ab:a	bajbaj	<i>good bye</i>	d:aʰ	<i>Hit (have a pain)</i>	ara	<i>give</i>
2	baba:	baba	<i>dad</i>	ʃaw	<i>noise</i>	aman	<i>water</i>
3	am:a:	mama	<i>mom</i>	aratid	<i>Give it to me</i>	afus	<i>hand</i>
4	hb:a	s:ʃb:atʃ	<i>shoes</i>	ixʃ	<i>It is bad (thing)</i>	ilm	<i>skin</i>
5	ajal:a	lal:a	<i>auntie</i>	tit:i	<i>sit down</i>	krf	<i>tie</i>
6	ha:h	hak	<i>take</i>	x:iʃ	<i>It is bad (thing)</i>	adr	<i>press</i>
7	man:ama	lmunika	<i>toy</i>	ʃa:ʃa	<i>a donkey</i>	rgl	<i>close</i>
8	q:aq:a	ʁika	<i>like this</i>	fuf:u	<i>hot/fire</i>	ifta	<i>he went</i>
9	t:a	xt:a	<i>this one (fem.)</i>	baʃ:a	<i>sheep</i>	usin	<i>they took</i>
10	b:aʰ	b:aʰ	<i>disappeared</i>	b:aʰ	<i>It's over</i>	awid	<i>bring!</i>
11	məməm	mum:u	<i>toy (generic)</i>	d:aw	<i>Walk / go</i>	inijas	<i>tell him</i>
12	hat:i	hat:i	<i>here it is (fem.)</i>	dajd:a	<i>Fall down</i>	ufiʃ	<i>i found</i>
13	aj:a:	taj:a:	<i>another one (fem.)</i>	baʃ:atin	<i>Sheeps</i>	lkmy	<i>i arrived</i>
14	ʃeʃ	ʃa:ʃa	<i>horse (baby talk)</i>	ft:i	<i>Grandfather</i>	tam:nt	<i>honey</i>
15	b:ɛʰb:a	aʰb:udʃ	<i>tummy</i>	kak:a	<i>Chocolate</i>	takurt:	<i>ball</i>
16	bula	bula	<i>this is a light bulb</i>	et:ej	<i>Move !</i>	agrzam	<i>lion</i>
17	mna	magana	<i>this is a watch</i>	buʃ:u	<i>Monster</i>	tafruxt	<i>girl</i>
18	qaq:a	kukuʃ:u	<i>cock (baby talk)</i>	tinxarin	<i>Nose</i>	afrux	<i>boy</i>
19	alaqa	alq:aʃ	<i>sheep</i>	tabat:ʃaʰt	<i>Foot</i>	imi	<i>mouth</i>
20	a:la:	ara	<i>give me</i>	tafust	<i>hand</i>	argaz	<i>man</i>
21	baʃp:ɛʃ	lbanan	<i>banana</i>	tamz:ʃuxt	<i>Ear</i>	tamyart	<i>woman</i>
22	t:ɛtet:e	ʁid	<i>here</i>	tagaj:ut	<i>Head</i>	amadl	<i>hill</i>
23	tʃtʃk	juʃkad	<i>he came</i>	timimit	<i>Mouth</i>	amdlu	<i>cloud</i>
24	a:pb:	ib:i	<i>it is ripped</i>	tiwalin	<i>Eyes</i>	skr	<i>do</i>
25	aca:ca	agaj:u	<i>head</i>	mimiʃ	<i>Mouth</i>	fl	<i>let</i>
26	mem:e	ʃmti	<i>my aunt</i>	tabit:u	<i>Eyes</i>	ls	<i>wear</i>
27	handb:a	and:u	<i>we are going</i>	tidʃudʃin	<i>Fingers</i>	gn	<i>sleep</i>
28	ʃu	ʃuf	<i>look</i>	ʃk:ata	<i>Eat (it)</i>	izʃuran	<i>veins</i>
29	ne:n:e	nin:i	<i>sleep (baby talk)</i>	tas:awalt	<i>Trousers</i>	azʃalim	<i>onion</i>
30	a:ʃe	adʃ:ʁ	<i>I will eat</i>	banana	<i>banana</i>	tiwit	<i>you took away</i>
31	aj:i:	haj:i	<i>here I am</i>	biz:u	<i>baby</i>	tabrat	<i>letter</i>
32	haʃtʃk:a	ifq:a	<i>it is tough</i>	tʃrʃt	<i>Break</i>	smun	<i>pick up</i>
33	ʃual	ʃuw:r	<i>slow down</i>	ʃan:	<i>Car</i>	knu	<i>lean</i>
34	anana	wijn:a	<i>mom's one</i>	babat	<i>Shoes</i>	kru	<i>rent</i>
35	ʃaʃa:	matʃeʃa	<i>tomatoes</i>	fuf:u	<i>Fire/ hot</i>	igawr	<i>he sit down</i>
36	bak:aʔ	baraka	<i>that's enough</i>	ak:ik	<i>Give / Show</i>	tkʃmt	<i>you entered</i>
37	ʁ:a	ʁw:a	<i>this one</i>	baja	<i>Biscuits</i>	ssnkr	<i>wake</i>
38	alti	xalti	<i>my aunt</i>	st:ii	<i>Grandfather</i>	udm	<i>face</i>
39	mamiand:u	manisrand:u	<i>where</i>	ʃmal	<i>Donkey</i>	idam:n	<i>blood</i>
40	d	adʃadʃ	<i>finger</i>	ʃ:u	<i>Fermented milk</i>	ayrum	<i>bread</i>
41	mim:i	amuf:ʃ	<i>cat</i>	daʃ	<i>Also</i>	juda	<i>it's enough</i>
42	bwa	iswa	<i>he drank</i>	x:ix:if	<i>Dirty</i>	izra	<i>he saw</i>
43	j:ah	jah	<i>yes</i>	kukuʃ:u	<i>Cok</i>	alim	<i>straw</i>

44	:uf:u?	sf:uət	get him out	həh:a	Boho / cut	afunas	bull
45	f:uf:u	if:uə	he went out	d:ah:ati	Hit (me)	ajdi	dog
46	m:am	im:im	it's tasty	b:ˈatˈ	Shoes	ngr	between
47	px:u	bux:uf	here's the insect	hawa	Cow	tirmt	food
48	f:a?	f:	eat	hawhaw	Dog	azur	terrace
49	s:as:a	shs:a	be quite	tˈanun	Yogourt	izgr	he crossed
50	ad:a	td:ˈrˈ	she felt down	tiziz:it	Meat	xdmn	they worked

APPENDIX 3. Examples of ENGLISH data

	Actual IPA	Target IPA	Translation	CDS IPA	Translation	Dictionary IPA	Translation
1	dʌˈbe	bʌmbəl ˈbi:	bumble-bee	ˈækrəˌbæt	acrobat	əˈsi:təs	acetous
2	dæˈde-ɪ	dædi:	daddy	əˈdɔr	adore	ˈɑrtʃˌduk	archduke
3	əˈzi	dɜrti:	dirty	ænt	ant	ˈbæktɪs	Bacchus
4	dʌwɪ	dəgi:	doggie	əˈslip	asleep	ˈbəstʃən	bastion
5	dʌdi	dʌki:	duckie	ˈbe-ɪbiˌsɪtər	babysitter	ˈbætəl	Battle
6	əbwɪ:	be-ɪbi:	baby	ˈbætəl	battle	klæʃ	clash
7	hʌ	ka-ʊ	cow	ˈbɪskət	biscuit	kɔɪn	coin
8	dʌ	dət	dot	ˈkeɪfəl	careful	kʌm	come
9	hʌbu	lɒbstər	lobster	tʃak	chalk	sɪkɪn	cyclin
10	ʌme	mami:	mommy	ˈdɑrlɪŋ	darling	dælˈmeɪʃən	Dalmatian
11	mʌm	mu:n	moon	ˈdɪfərənt	different	dɛd	dead
12	bəˈbe	pʌpi:	puppy	ˈizi	easy	dɪsˈgrʌntəld	disgruntled
13	ʊˈwʌ	bəl	ball	enˈdʒɔ-ɪ	enjoy	ˈestʃuˌeri	estuary
14	ɛ	a-ɪ	eye	fɑrm	farm	ˈfrɪzɪŋ	freezing
15	ɑtʃɪ	anti:	auntie	ˈfɪlθi	filthy	fjuːz	fuse
16	kɪzɪ	kɪti:	kitty	dʒəˈræf	giraffe	he-ɪz	haze
17	æ:	rɔr	roar	ɡɜrl	girl	ˈhevi	heavy
18	dɪθɦɪ	ti:tʃər	teacher	ɡre-ɪt	great	ˈha-ɪbərˌne-ɪt	hibernate
19	dʌʔdæ	bækpæk	backpack	ɡɪˈtɑr	guitar	ˈɪnˌsest	incest
20	bə	bɛr	bear	ˈhevi	heavy	ɪnˈto-ʊn	intone
21	pe-ɪ	bə-i	bye	hɔrs	horse	ˈlɑɡər	lager
22	dʌkʰ	stʌk	stuck	ˈɪnˌsekt	insect	lɪv	live
23	bu	blu:	blue	ɪtʃɪ	itchy	mætʃ	match
24	bak	bə-ʊt	boat	dʒækət	jacket	ˈmentəl	mental
25	bʊk	bʊk	book	dʒʌɡəlɪŋ	juggling	ˈmɪkstʃər	mixture
26	bə	bə-ʊ	bow	kæŋɡəˈru	kangaroo	ˈpe-ɪpəl	papal
27	bʊ	bru:m	broom	ka-ɪt	kite	ˈro-ʊmən	Roman
28	ɡʊˈke-ɪ	kʊki:	cookie	ˈle-ɪtər	later	rul	rule
29	duʃ	ʃu:z	shoes	lɪv	leave	ˈskɜrsli	scarcely
30	bʊ	bɜrd	bird	ˈlɪkɪŋ	licking	tæb	tab
31	bak	blæk	black	lʌv	love	ˈtækəl	tackle
32	pɪˈte-ɪ	pɪɡlət	piglet	ˈmæɡnət	magnet	ˈviəməns	vehemence
33	bʊ	bʊ:ts	boots	mɪn	mean	ˈvɜrdʒənəl	virginal
34	bʌˈbə-ʊwɪs	bʌbəlz	bubbles	ˈmʌŋki	monkey	vəˈsɪfərəsli	vociferously
35	bə:	bʌɡ	bug	ne-ɪm	name	ˈwikli	weekly
36	ke-ɪk	ke-ɪk	cake	ˈnekləs	necklace	wɑ-ɪld	wild
37	kɑ:	kɑr	car	nə-ɪs	nice	kæɪɪdʒ	carriage
38	kak	klak	clock	ˈɔrændʒ	orange	tekst	text
39	flɛla	flawər	flower	ˈpe-ɪntɪŋ	painting	baks	box
40	fu:	fu:d	food	ˈpɪktʃər	picture	ˈa-ʊtˌla-ɪn	outline
41	kik	kɪk	kick	ˈre-ɪni	rainy	pækt	pact
42	mu	mu:s	moose	rɔr	roar	pʊt	put
43	pik	pɪŋk	pink	ˈsændi	sandy	riˈpʌblək	republic
44	dɔʃ	stɑrʒ	stars	ˈskrʌbɪŋ	scrubbing	rɑ-ɪt	right

45	sɛ:	sʌn	sun	sɪt	seat	'sædnəs	sadness
46	fwi	θri:	three	spə'geti	spaghetti	snæp	snap
47	tɒs	tɒ-ʊz	toes	'tɪkət	ticket	skwɪz	squeeze
48	wet	wet	wet	'junɪ,kɔrn	unicorn	θa-ɪm	thyme
49	pʌpə	pʌrpəl	purple	wæks	wax	'tra-ɪəl	trial
50	dʒi:	tri:	tree	'jelə-ʊ	yellow	vo-ʊg	vogue

APPENDIX 4. Examples of FRENCH data

	Actual IPA	Target IPA	Translation	CDS IPA	Translation	Dictionary IPA	Translation
1	ma:ma	mamã	mummy	ʌgəʌd	look	ãtɔʌs	sprain
2	pa:	papa	daddy	komãse	start	bɔʌtij	trinket
3	toɪto tœ:	dodo	sleep	pas	think	ãtuzjasme	get enthusiastic
4	pa:	pẽ	bread	vjẽ	come	eʌezi	heresy
5	tœde:	tete	suck	tɛlmã	So much	ʌtɔʌ	withdrawal
6	ta:te	taɪtin	sandwich	ivɛʌ	winter	tɛʌve	find
7	da:da:	gato	cake	dusmã	slowly	kʌʌvɛzɔ	flat
8	æbi:	abɛj	bee	pø	can	kanaʌ	duck
9	bebe:	bebe	baby	dədã	inside	duluʌø	painful
10	te:te	tete	head	gʌã	big	libɛʌalism	liberalism
11	tata:	tata	auntie	fɛ	do	pɔʌvizjɔ	supply
12	bebe:	bebe	baby	vʌwala	here	ʒødi	thursday
13	ɔp	ɔp	hop	kɔm	like	kʌɪst	criste
14	awo:	Alo	hello	atã	wait	avaʌi	dammage
15	kuku:	kuku	hello	lezʌʌ	lizard	ãgaʌ	shed
16	apo:	pɔɪpje	fireman	dakʌʌ	okay	ʌazʌʌʌ	rasor
17	po:	Po	pot	ale	go	tã	time
18	kokœ	tɔɪtɔ	uncle	aviv	arrive	ataʌde	linger
19	ape:	papje	paper	avãtaʒ	advantage	kuʌje	lying
20	œma:ʌœ:	kameʌa	camera	mʌwẽ	less	maʌʌã	seller
21	tete:	tete	sucking	dã	in	sakwe	shake
22	kokœ:	elikɔptɛʌ	helicopter	pɔʌtik	crossbar	tʌiko	knitting
23	ɔʌa:	ɔʌʌʌʌʌ	Bye bye	pʌsẽ	chick	vã	wind
24	tatɔ:	klakson	horn	amne	brought	dɛʌegle	upset
25	ba:	bal	ball	ʌpɛl	remember	dɛʌm	derm
26	ba:	bẽ	bath	ʒø	games	ɔtɔmatik	automatic
27	apa:	lapẽ	rabbit	butɔ	button	ãgɔse	constrain
28	bi:bo:	bibʌɔ	bottle	tele	TV	ɔfɛʌʌ	offer
29	gu:	lego	lego	komã	how	vəly	hairy
30	mɔ:	mʌʌ	bite	lɛs	let	vele	vellum paper
31	ma:	mal	hurt	lynɛt	glasses	ɛʌb	grass
32	ne:ne	mimi	cute	aple	called	defile	parade
33	apo:	ʌapo	hat	pʌʌsɔ	fish	kale	wedge
34	ame:	fɛʌme	closed	pɛnɪbl	tiresome	kɔɪtʌpɛtɛʌi	spoonerism
35	bɛ	tɔɪb	fall	vaf	cow	ɛpanwɪʌ	blooming
36	pu:	pul	hen	ẽtɛʌdi	forbidden	dɔsil	docile
37	fwa	fɛʌwa	cold	ʒosɛt	socks	ʌs	chance
38	vy:	pyl	jumper	gaʌsɔ	boy	apsã	absent
39	ka:	kask	helmet	pɛtit	small	aspik	aspic
40	py:	py	stink	kat	four	fam	woman
41	afa:	pʌʌfœ	perfume	pʌɛ	ready	manɪfɛstasjɔ	demonstration

42	nɔːne	kɒksɪnəl	<i>ladybird</i>	tabl	<i>table.</i>	peje	<i>pay</i>
43	aneː	fɛɣme	<i>close</i>	aspɪvatoɐ̯	<i>Vacuum cleaner</i>	sɛ̃	<i>saint</i>
44	buː	bul	<i>ball</i>	mɔ̃tɐ	<i>show</i>	tɪvɑjɔɐ̯	<i>skirmisher</i>
45	af	ʒɪvaf	<i>giraffe</i>	telekomād	<i>Remote control</i>	ynite	<i>unit</i>
46	ɔuː	ʃosyɐ	<i>shoe</i>	dəbu	<i>stand</i>	ɔnɔɐ̯	<i>honor</i>
47	bubeː	pubəl	<i>trash</i>	nɒvɪtɪɐ̯	<i>food</i>	etɛ̃	<i>off</i>
48	dadaː	salad	<i>salad</i>	kanaj	<i>raffish</i>	kā	<i>camp</i>
49	ɐoːgwɛ	dekɒfoje	<i>Pick up</i>	pubəl	<i>trash</i>	sɛɐ̯ɔm	<i>serum</i>
50	apiː	apɪ	<i>press</i>	māʒe	<i>eat</i>	kātɔnad	<i>No one in particular</i>

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