Development of phonetic complexity in Arabic, Berber, English and French

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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)

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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.

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[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

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[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 Project[3] (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 [$t^ʕ$, $d^ʕ$, $ð^ʕ$]), 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	Monophtongs Diphtongs	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 dissylabic 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.

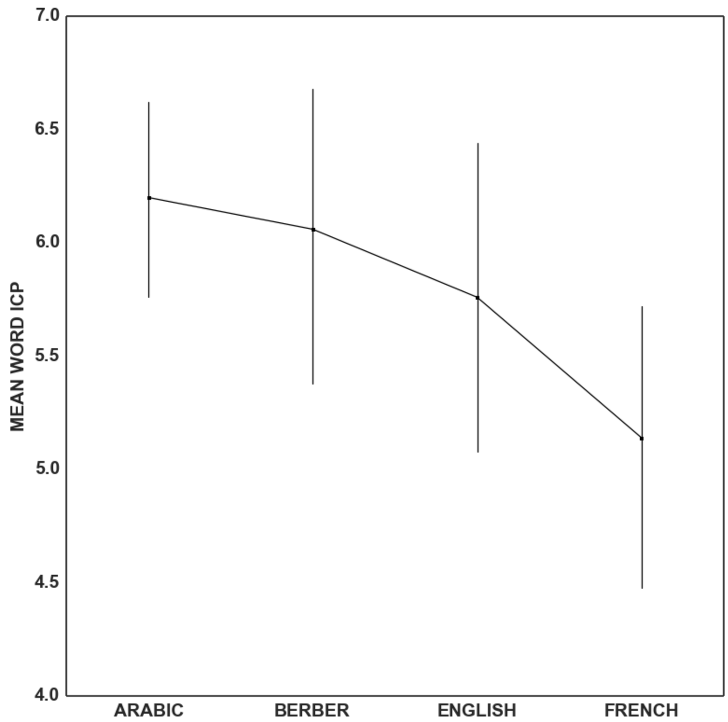
Table 3. Index of Phonetic Complexity Scoring for 4 words in each language

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	fuʁʃɛt	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	sqətˤ	1	1	1	0	1	0	1	1	1	1	8

Results

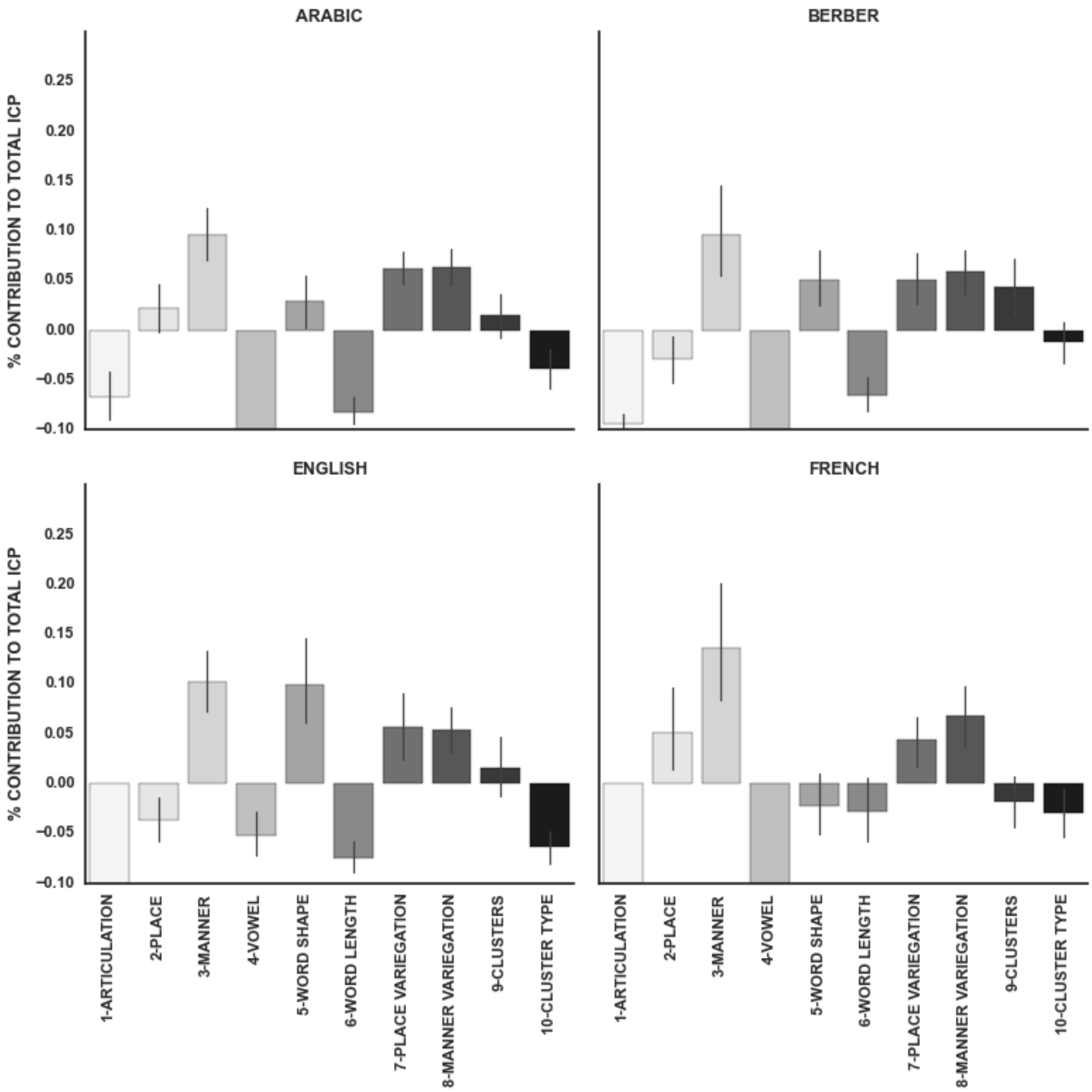
The dictionary sample is a window on the expected mean word phonetic complexity of the languages under study. The sample being rather small, we also computed the confidence interval of the mean with a 5% type I error by bootstrapping the sample to estimate the interval of values for the mean phonetic 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 >
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.

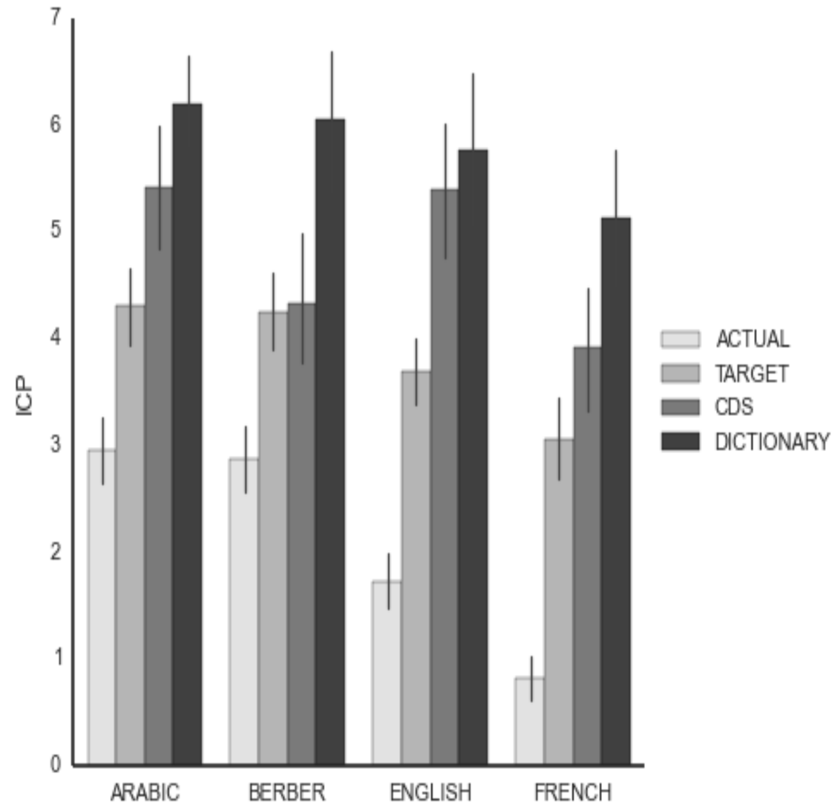
Figure 2: Specific parameter contribution with respect to the uniform contribution null hypothesis. Values range from -0,1 to 0,9 for each of the 10 parameters composing the IPC.



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 monophtongs and diphtongs 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.

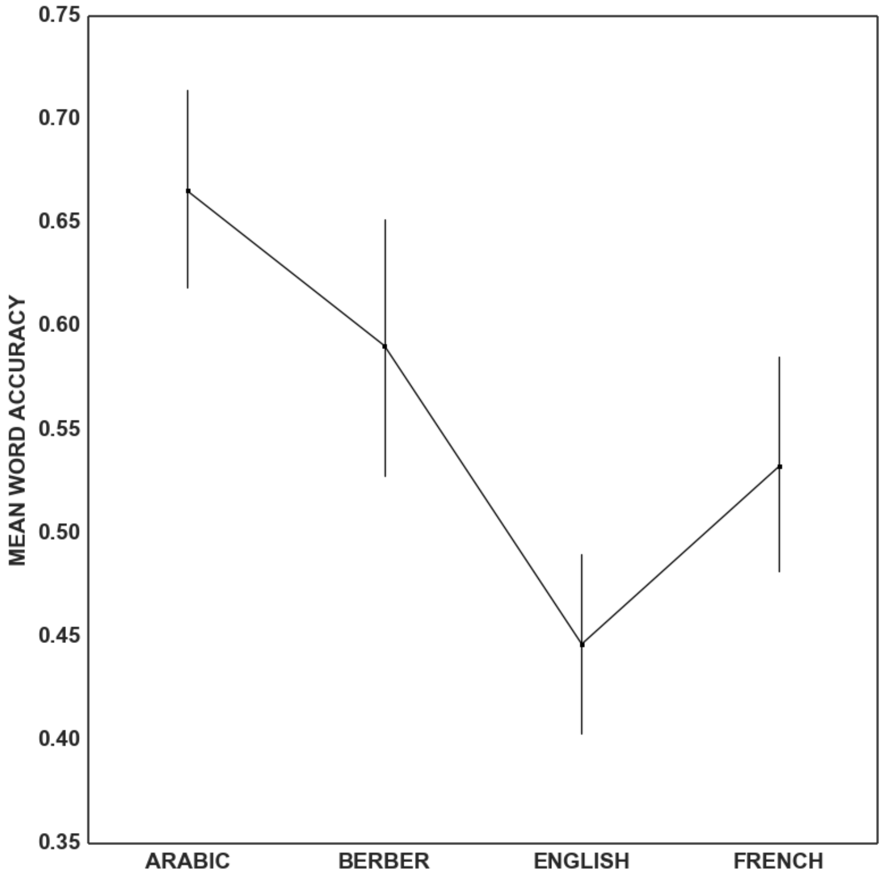
Figure 3. Mean word IPC and 95M confidence intervals for the Dictionary/adult language, CDS, actual child production and target for Arabic, Berber, English and French



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).

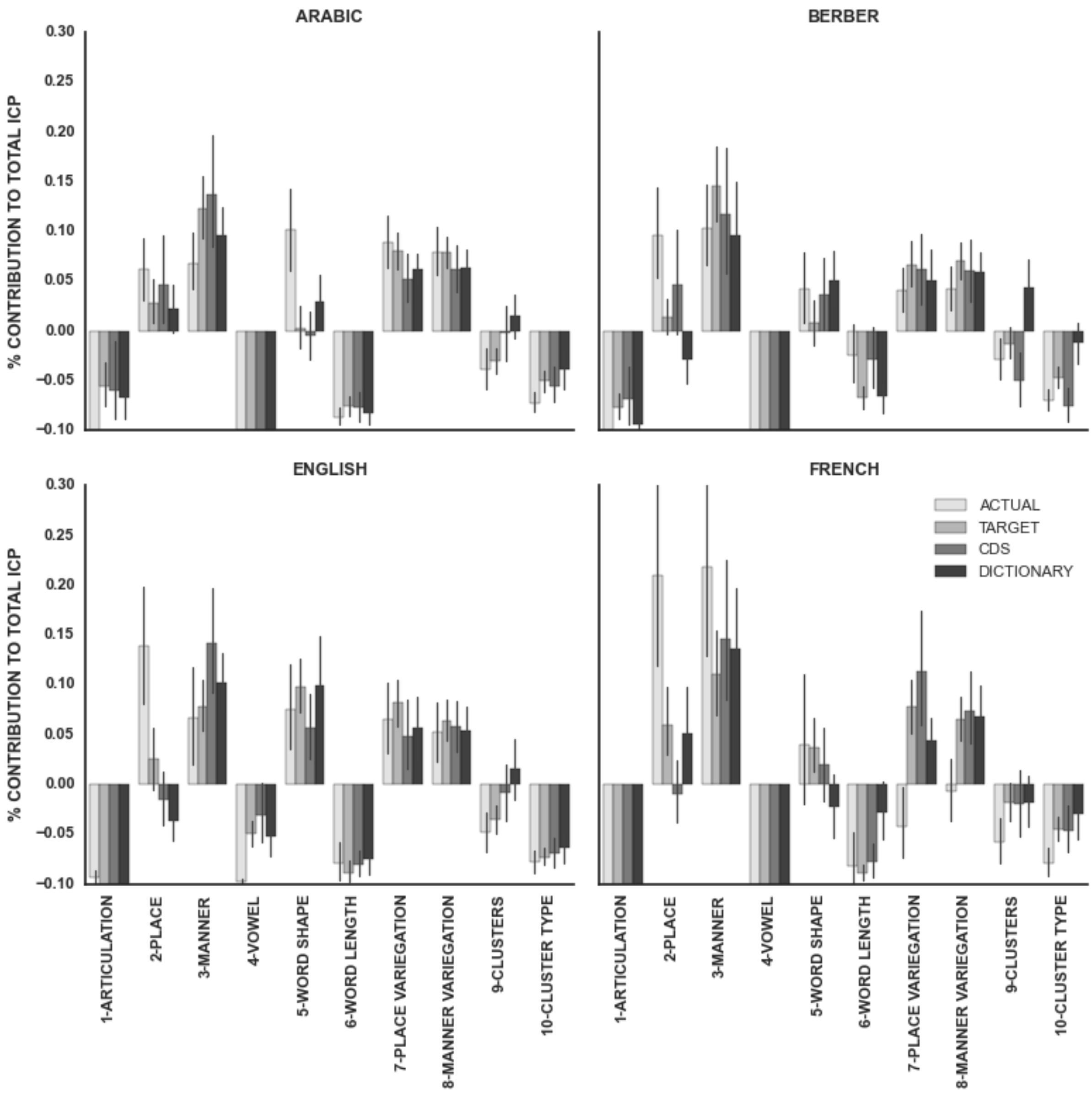
Figure 4. Mean Actual-to-Target accuracy in consonant production for Arabic, Berber, English and French. Vertical bars display the 95% confidence interval



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 to 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	tˤɑ:ħ	To fall	ʕəʃb	*medical*
2	itæjj	tˤɑj	Peek a boo	ʔi:ʒæ	He comes	ħuku:m	*monopole*
3	pæ	papa	daddy	tˤɑtˤɑ	tata	ħi:la	*ruse*
4	dæ	la:	no	ʔaħħæ:	Ouch !	farləχla	*fieldmouse*
5	ʔi	ʔɛj	yes	kiχχæ	Beurk !	msisa	*bracelet*
6	tæ:ħ	tˤɑ:ħ	It fell	qu:l	tell	ħəwəl	*to try*
7	bæj	bah	ok	næħħi:	remove	qa:l	*tell*
8	æm	mam:i	Mum	ʔahajjæ:	here it is	mraħħəm	*marble*
9	bæħ	baħ	It disapeared	wi:ni	Where is it ?	zra:ʕi:	*agricultural*
10	ʔɛjʒi	ʔiʒa	Come here !	ʃu:	What is it ?	mdˤəl	*straw*
11	bɛj	baj baj	Bye-bye	daddu:ʃ	walk	mudˤif	*stewart*
12	tɛd:	ʃi:d:	Hold !	jɛzzi	Stop !	butˤa-in	*ventricule*
13	ʔæħ:	ʔaħ:	Ouch !	træh	Show me !	dəħʃ	*baby donkey*
14	hup	ħutˤ:	Put down !	ba:ħ	Gone (nothing !)	wəsχ	*fouling*
15	ʒaʒæ	ʤa:ʒa	chicken	alo	hello	səqqa:t	*gourmet*
16	ħibɛʃ	mænħibɛʃ	I don’t want	ʔaʕmil	do	kursi	*saddle*
17	ktib	ʔiktibli	Write (to me)	hæ:t	put	ʕrəq	*sweat*
18	ka	kask	Your helmet	læ:	no	ħadd	*fence*
19	tæ:ʕi	mtæ:ʕi	mine	ʔɛj	go !	rijja:ga	*bib*
20	bebe	bebe	baby	χu:	brother	qəm	*estimate*
21	kak:æ	kaka	poo	kaka	poo	məstəɣəl	*profiteer*
22	tat:a	batˤ:ɑ	canard	jimʃi	He goes	bəlɣa	*oriental slipper*
23	tatæ	tˤɑtˤɑ	Beat !	sˤɑħi:t	Thank you	ʃkara	*bag*
24	ħutæ:	ħuta:	fish	ʔaqɛf	Up !	bəqra:ʒ	*tea pot*
25	bab	dub	ours	bæʕ	Bèè (bleat noise)	hɛ:l	*weather*
26	na:n	ħsˤa:n	Horse	ʒi:b	Bring	sˤəffa	*clarify*
27	næhnæ	lihnæ	here	hæðɪka	This one	məllɛ:ħ	*seller*
28	mæ mæ	mæ:	water	tħutˤ	place	da-ijəb	*melting*
29	kæk	qird	monkey	ʔistannæ	wait	qəfza	*jump*
30	tæ:ħ	muftæ:ħ	key	ʔælʕib	play	da:r	*home*
31	taw taw	taw:a	now	ʃʕær	hair	ma:t	*perish*
32	dæb:u:sæ	dab:uzæ	bottle	mtaʕ	his	rʒaʕ	*take back*
33	ʃbi:k	ʃbi:k	What happens to you ?	sˤɑfiq	Applaud !	tˤbi:b	*doctor*
34	ʔuxdæn	ʔuxzur	Watch !	ʃnuwæ	what	faħħəm	*explain*
35	kas:ar	tkas:ir	You broke	bismilah	Bless you	hdər	*argue*
36	bæz	xubz	bread	ʕaqu:la	nice	sqətˤ	*fall*
37	fasu:	ʕasˤfu:ra	bird	ʔaʕtˤi	give	ɣri:b	*unheard-of*
38	tax:a	kix:a	Eew !	matmissiʃ	Don’t touch	bətˤtˤəl	*idle*
39	ʕam	ʕam:i	My uncle	ʔuqʕud	Sit down !	mʕalləm	*expert*
40	ku:ra	ku:ra	ball	ɣa:di	there	səndu:q	*coffin*
41	di	haði	This one	ʃbi:k	What happens	hənd	*magnet*
42	tiz:a	hizha	Lift it up	nrakablik	I’ll put it together	qəmr	*moon*
43	laħda	laħðˤa	One minute please	tkallim	talk	qəsma	*part*

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

APPENDIX 2. Examples of BERBER data

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

44	ːufːuʔ	sfːuʁt	*get him out*	ħaħːa	*Boho / cut*	afunas	*bull*
45	fːufːu	ifːuʁ	*he went out*	dːaħːati	*Hit (me)*	ajdi	*dog*
46	mːam	imːim	*it's tasty*	bːˤatˤ	*Shoes*	ngr	*between*
47	pxːu	buxːuʃ	*here's the insect*	ħawa	*Cow*	tirmt	*food*
48	ʃːaʔ	ʃː	*eat*	hawhaw	*Dog*	azur	*terrace*
49	sːasːa	sħsːa	*be quite*	tˤanun	*Yogourt*	izgr	*he crossed*
50	adːa	tdːˤrˤ	*she felt down*	tiʒiʒːit	*Meat*	xdmn	*they worked*

APPENDIX 3. Examples of ENGLISH data

	Actual IPA	Target IPA	*Translation*	CDS IPA	*Translation*	Dictionary IPA	*Translation*
1	dʌˈbɛ	bʌmbəl ˈbiː	*bumble-bee*	ˈækrəˌbæt	*acrobat*	əˈsiːtəs	*acetous*
2	dæˈde-ɪ	dædiː	*daddy*	əˈdɔr	*adore*	ˈarʧˌduk	*archduke*
3	əˈzi	dʌrtiː	*dirty*	ænt	*ant*	ˈbækɪs	*Bacchus*
4	dʌwɪ	dɑgiː	*doggie*	əˈslip	*asleep*	ˈbæsʧən	*bastion*
5	dʌdi	dʌkiː	*duckie*	ˈbe-ɪbiˌsɪtər	*babysitter*	ˈbætəl	*Battle*
6	ɑbwiː	be-ɪbiː	*baby*	ˈbætəl	*battle*	klæʃ	*clash*
7	hʌ	ka-ʊ	*cow*	ˈbɪskət	*biscuit*	kɔɪn	*coin*
8	dʌ	dɑt	*dot*	ˈkɛrfəl	*careful*	kʌm	*come*
9	hʌbu	lɑbstər	*lobster*	ʧɑk	*chalk*	cyclin	*cyclin*
10	ʌmɛ	mɑmiː	*mommy*	ˈdarlɪŋ	*darling*	dælˈmeɪʃən	*Dalmatian*
11	mʌm	muːn	*moon*	ˈdɪfərənt	*different*	dɛd	*dead*
12	bəˈbɛ	pʌpiː	*puppy*	ˈizi	*easy*	dɪsˈgrʌntəld	*disgruntled*
13	ʊˈwʌ	bɑl	*ball*	ɛnˈʤɔ-ɪ	*enjoy*	ˈɛsʧuˌeri	*estuary*
14	ɛ	a-ɪ	*eye*	fɑrm	*farm*	ˈfrizɪŋ	*freezing*
15	ɑʧi	ɑntiː	*auntie*	ˈfɪlθi	*filthy*	fjuz	*fuse*
16	kizɪ	kɪtiː	*kitty*	ʤəˈræf	*giraffe*	he-ɪz	*haze*
17	æː	rɔr	*roar*	gɜrl	*girl*	ˈhɛvi	*heavy*
18	diθhɪ	tiːʧər	*teacher*	gre-ɪt	*great*	ˈha-ɪbərˌne-ɪt	*hibernate*
19	dʌʔdæ	bækpæk	*backpack*	gɪˈtɑr	*guitar*	ˈɪnˌsɛst	*incest*
20	bɑ	bɛr	*bear*	ˈhɛvi	*heavy*	ɪnˈto-ʊn	*intone*
21	pe-ɪ	ba-i	*bye*	hɔrs	*horse*	ˈlɑgər	*lager*
22	dʌkʰ	stʌk	*stuck*	ˈɪnˌsɛkt	*insect*	lɪv	*live*
23	bu	bluː	*blue*	ˈɪʧi	*itchy*	mæʧ	*match*
24	bɑk	bo-ʊt	*boat*	ˈʤækət	*jacket*	ˈmɛntəl	*mental*
25	bʊk	bʊk	*book*	ˈʤʌgəlɪŋ	*juggling*	ˈmɪksʧər	*mixture*
26	bo	ba-ʊ	*bow*	ˌkæŋgəˈru	*kangaroo*	ˈpe-ɪpəl	*papal*
27	bu	bruːm	*broom*	ka-ɪt	*kite*	ˈro-ʊmən	*Roman*
28	gʊˈke-ɪ	kʊkiː	*cookie*	ˈle-ɪtər	*later*	rul	*rule*
29	duʃ	ʃuːz	*shoes*	liv	*leave*	ˈskɛrsli	*scarcely*
30	bu	bʌrd	*bird*	ˈlɪkɪŋ	*licking*	tæb	*tab*
31	bɑk	blæk	*black*	lʌv	*love*	ˈtækəl	*tackle*
32	pɪˈte-ɪ	pɪglət	*piglet*	ˈmægnət	*magnet*	ˈviəməns	*vehemence*
33	bu	buːts	*boots*	min	*mean*	ˈvɜrʤənəl	*virginal*
34	bʌˈba-ʊwɪs	bʌbəlz	*bubbles*	ˈmʌŋki	*monkey*	vəˈsɪfərəsli	*vociferously*
35	boː	bʌg	*bug*	ne-ɪm	*name*	ˈwikli	*weekly*
36	ke-ɪk	ke-ɪk	*cake*	ˈnɛkləs	*necklace*	wa-ɪld	*wild*
37	kɑː	kɑr	*car*	na-ɪs	*nice*	kærɪʒ	*carriage*
38	kɑk	klɑk	*clok*	ˈɔrənʤ	*orange*	tɛkst	*text*
39	flɛlɑ	flawər	*flower*	ˈpe-ɪntɪŋ	*painting*	bɑks	*box*
40	fuː	fuːd	*food*	ˈpɪkʧər	*picture*	ˈa-ʊtˌla-ɪn	*outline*
41	kik	kɪk	*kick*	ˈre-ɪni	*rainy*	pækt	*pact*
42	mu	muːs	*moose*	rɔr	*roar*	pʊt	*put*
43	pik	pɪŋk	*pink*	ˈsændi	*sandy*	riˈpʌblək	*republic*
44	doʃ	stɑrz	*stars*	ˈskrʌbɪŋ	*scrubbing*	ra-ɪt	*right*

45	sɛː	sʌn	*sun*	sit	*seat*	ˈsædnəs	*sadness*
46	fwi	θriː	*three*	spəˈgɛti	*spaghetti*	snæp	*snap*
47	tos	to-ʊz	*toes*	ˈtɪkət	*ticket*	skwiz	*squeeze*
48	wɛt	wɛt	*wet*	ˈjunɪˌkɔrn	*unicorn*	θa-ɪm	*thyme*
49	pʌpo	pʌrpəl	*purple*	wæks	*wax*	ˈtra-ɪəl	*trial*
50	dʒiː	triː	*tree*	ˈjɛlo-ʊ	*yellow*	vo-ʊg	*vogue*

APPENDIX 4. Examples of FRENCH data

	Actual IPA	Target IPA	*Translation*	CDS IPA	*Translation*	Dictionary IPA	*Translation*
1	maːma	mamɑ̃	*mummy*	ʁəgaʁd	*look*	ɑ̃tɔʁs	*sprain*
2	paː	papa	*daddy*	komɑ̃se	*start*	bʁutij	*trinket*
3	toχto tœː	dodo	*sleep*	pas	*think*	ɑ̃tuzjasme	*get enthusiastic*
4	paː	pɛ̃	*bread*	vjɛ̃	*come*	eʁezi	*heresy*
5	tœdeː	tete	*suck*	tɛlmɑ̃	*So much*	ʁətʁɛ	*withdrawal*
6	taːte	taʁtin	*sandwich*	ivɛʁ	*winter*	tʁuve	*find*
7	daːdaː	gato	*cake*	dusmɑ̃	*slowly*	kʁəvɛzɔ̃	*flat*
8	œbiː	abɛj	*bee*	pø	*can*	kanaʁ	*duck*
9	bɛbeː	bebe	*baby*	dədɑ̃	*inside*	duluʁø	*painful*
10	teːte	tɛte	head	gʁɑ̃	big	libeʁalism	liberalism
11	tataː	tata	auntie	fɛ	do	pʁɔvizjɔ̃	supply
12	bebɛː	bebe	baby	vwala	here	ʒødi	thursday
13	ɔp	ɔp	hop	kɔm	like	kʁist	criste
14	awoː	Alo	hello	atɑ̃	wait	avaʁi	dammage
15	kukuː	kuku	hello	lezaʁ	lizard	ɑ̃gaʁ	shed
16	apoː	pɔ̃pje	fireman	dakɔʁ	okay	ʁazwaʁ	rasor
17	poː	Po	pot	ale	go	tɑ̃	time
18	kokœ	tɔ̃tɔ̃	uncle	aʁiv	arrive	ataʁde	linger
19	apeː	papje	paper	avɑ̃taʒ	advantage	kuʃe	lying
20	œmaːʁœː	kameʁa	camera	mwɛ̃	less	maʁʃɑ̃	seller
21	teteː	tete	sucking	dɑ̃	in	səkwe	shake
22	kokɛː	elikɔptɛʁ	helicopter	pɔʁtik	crossbar	tʁiko	knitting
23	ɔvaː	oʁəvwaʁ	Bye bye	pusɛ̃	chick	vɑ̃	wind
24	tatɔː	klakson	horn	amne	brought	deʁegle	upset
25	baː	bal	ball	ʁapɛl	remember	dɛʁm	derm
26	baː	bɛ̃	bath	ʒø	games	ɔtɔmatik	automatic
27	apaː	lapɛ̃	rabbit	butɔ̃	button	ɑ̃gɔ̃se	constrain
28	biːboː	bibʁɔ̃	bottle	tele	TV	ɔfʁiʁ	offer
29	guː	lego	lego	komɑ̃	how	vəly	hairy
30	mɔː	mɔʁ	bite	lɛs	let	velɛ	vellum paper
31	maː	mal	*hurt*	lynɛt	*glasses*	ɛʁb	*grass*
32	neːne	mimi	*cute*	aplɛ	*called*	defile	*parade*
33	apoː	ʃapo	*hat*	pwasɔ̃	*fish*	kale	*wedge*
34	ameː	fɛʁme	*closed*	penibl	*tiresome*	kɔ̃tʁəpɛtʁi	*spoonerism*
35	bɛ	tɔ̃b	*fall*	vaʃ	*cow*	epanwiʁ	*blooming*
36	puː	pul	*hen*	ɛ̃tɛʁdi	*forbidden*	dɔsil	*docile*
37	fwɑ	fʁwa	*cold*	ʃosɛt	*socks*	ʃɑ̃s	*chance*
38	vyː	pyl	*jumper*	gaʁsɔ̃	*boy*	apsɑ̃	*absent*
39	kaː	kask	*helmet*	pətit	*small*	aspik	*aspic*
40	pyː	py	*stink*	kat	*four*	fam	*woman*
41	afaː	paʁfœ̃	*perfume*	pʁɛ	*ready*	manifɛstasjɔ̃	*demonstration*

42	nɔ:ne	koksinɛl	*ladybird*	tabl	*table.*	peje	*pay*
43	ane:	fɛʁme	*close*	aspiʁatœʁ	*Vacuum cleaner*	sɛ̃	*saint*
44	bu:	bul	*ball*	mɔ̃tʁ	*show*	tiʁajœʁ	*skirmisher*
45	af	ʒiʁaf	*giraffe*	telekomɑ̃d	*Remote control*	ynite	*unit*
46	ɔu:	ʃosyʁ	*shoe*	dəbu	*stand*	ɔnɔʁe	*honor*
47	bube:	pubɛl	*trash*	nuʁityʁ	*food*	etɛ̃	*off*
48	dada:	salad	*salad*	kanaj	*raffish*	kɑ̃	*camp*
49	ʁo:gwɛ	dekʁoʃe	*Pick up*	pubɛl	*trash*	seʁɔm	*serum*
50	api:	apɥi	*press*	mɑ̃ʒe	*eat*	kɑ̃tɔnad	*No one in particular*

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