

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

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Abstract

The goal of this study is to provide crosslinguistic data on the acquisition of phonetic complexity among children acquiring four different languages: Tunisian Arabic, Tashlhiyt Berber, English, and French. Using an adaptation of Jakielski's (2000) Index of Phonetic Complexity (IPC), we carried out an analysis to assess phonetic complexity of children's early vocabulary in the four languages. Four different samples from each language were analyzed: 50 words selected from an adult dictionary of each language, 50 words from child-directed speech, 50 words targeted by the child, and the child's actual pronunciations of those 50 words. 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. Our findings show that Arabic displays higher degrees of complexity compared to Berber, English and French, and that children acquiring Arabic target and produce more complex words than children learning Berber, English and French.

Keywords: acquisition, crosslinguistic, phonetic complexity, universals, language specificities

Résumé

L'objectif de cette étude est d'analyser, dans une approche translinguistique, l'acquisition de la complexité phonétique dans quatre langues : l'arabe tunisien, le berbère tachelhit, l'anglais, et le français. À partir de l'adaptation de l'Index de Complexité Phonétique (IPC) de Jakielski (2000), nous avons conduit une analyse évaluant la complexité phonétique des premiers mots produits par les enfants de ces quatre langues. Pour chacune des langues, quatre échantillons ont été examinés : 50 mots aléatoirement sélectionnés dans un dictionnaire, 50 mots du langage adressé à l'enfant, 50 mots ciblés par les enfants, et enfin la production effective par les enfants de ces mêmes 50 mots. L'hypothèse générale était que les productions précoces des enfants seraient influencées par des contraintes articulatoires universelles, mais aussi par la complexité phonologique de la langue à laquelle ils sont exposés. Nos résultats montrent que l'arabe est la langue qui manifeste le plus de complexité phonologique comparé au berbère, à l'anglais et au français, et que les enfants en cours d'acquisition de l'arabe ciblent et produisent des mots plus complexes que les enfants acquérant le berbère, l'anglais ou le français.

Mots-clés: acquisition, translinguistique, complexité phonétique, universaux, spécificités langagières

1. INTRODUCTION

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 and McLean-Muse 1986)¹. In English for instance, some phonemes such as /s/ or consonant clusters such as /spl/ are not acquired before 7 and 9 years of age (Smit et al. 1991). This extended period required for the mastery of 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 (Kent and Murray 1982, Green et al. 2002, Stoel-Gammon and Sosa 2007). These anatomical and neurophysiological constraints result in a restriction on children's early phonetic inventories (Nip et al. 2009, Green et al. 2010). Children's phonetic inventory is initially composed of sounds produced primarily by the jaw (MacNeilage et al. 2000), on which they have a better muscle control compared to the motion of lips and tongue movements (Green et al. 2002). As a consequence of these universal biological constraints, children acquiring different languages show a similar restricted inventory of sounds (Locke 1983, 1995). Indeed, babbling and first-word 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 more reduplication than variegation (Vihman et al. 1985, Oller et al. 1994, MacNeilage

¹Abbreviations used : CDS : child-directed speech ; H : hypothesis ; IPC : Index of Phonetic Complexity ; L1 : first language.

et al. 1999). Furthermore, these preferences have been shown to influence the words that children select to produce. Thus, the inventory of children's early vocabulary is not composed of randomly selected words. Rather, it has been suggested that children select words with phonetic characteristics that are already present in their own phonological systems (Ferguson and Farwell 1975, Vihman et al. 1985, Schwartz et al. 1987). Other studies on lexical selectivity have shown that children attempt more complex words targets according to age (Dobrich and Scarborough 1992). An Index of Phonetic Complexity (henceforth IPC), based on the phonetic regularities observed in the babbling and the first-word period, was proposed to assess children's phonetic development (Jakielski 2000, 2002). The IPC has proven to be a valuable tool for different purposes such as assessing phonological skills in toddlers (Morris 2009), comparing speech acquisition in bilingual vs. monolingual children (Gildersleeve-Neumann and Wright 2010), or exploring the relationships between phonetic complexity and stuttering (Howell et al. 2006, Howell and Au-Yeung 2007). The IPC, which considers productions composed of less preferred segments and segment associations as more complex, permits one to measure the development of phonetic complexity in words both targeted and produced by children. In addition, it was shown that IPC scores at 12 months predicted speech and language skills at 18 months (Furey 2003). Biomechanical constraints of the production system (MacNeilage and Davis 1990) and lexical selectivity are both 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. Crosslinguistic analysis of diverse languages enables us to distinguish between potentially universal and language-specific patterns (Stoel-Gammon 2011). In fact, previous analyses have shown that segmental development, namely word shapes and CV co-occurrences, are influenced by input frequency in the ambient language (Saffran et al. 1997), as well as by the functional load of segments in the language, that is, how much use a language makes of its available contrasts (Stokes and Surendran 2005). As languages vary on those parameters, previous findings suggest that some languages may be acquired at a faster rate than others. For instance, So and Dodd (1995) showed that Cantonese children acquire phonology at a faster rate than English-speaking children as they master the contrastive use of tones and vowels by two years and that few phonological errors occur after age four. Similarly, Caselli et al. (1995) observed that Italian children were slower in vocabulary acquisition compared to English-speaking children: Italian children lag behind the English group in total vocabulary size at most ages between 8 and 16 months. Another crosslinguistic study, comparing L1 vocabulary growth at 16–30 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.

However, considering the ambient language, one must 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)². CDS is characterized by simplified syntax, shorter utterances, restricted vocabulary, repetitions, phonetic modifications (Kuhl 2000), increased variations in fundamental frequency and longer pauses (Ferguson 1977, Papoušek et al. 1991, Albin and Echols 1996, Andruski and Kuhl 1996). Moreover, this specific register used by parents to promote infants' language learning has been shown to be almost universal (Ferguson 1964, Kitamura et al. 2001, Kuhl et al. 1997, Monnot 1999, Kitamura et al. 2001).

The current study aims at examining the phonetic complexity of words produced by children acquiring four different languages: Arabic (Tunisian vernacular), Berber (Tashlhiyt variety), English (American) and French (France). These languages show different phonetic and phonological characteristics of interest for early language development, such as word length, word complexity (syllable types, consonant clusters) and phonemic inventory diversity. For example, the Arabic lexicon, which is largely derived from basic consonantal roots, includes many polysyllabic words. In terms of syllable types, French shows a strong preference for open syllables (76%), English exhibits more closed syllables (60%) (Delattre 1965) and Arabic displays 49,92% of closed vs. 50,08% of open syllables (Hamdi et al. 2005). These languages also differ in consonant cluster³ requirements: In Tashlhiyt Berber, clusters are found in any position within the word and in Arabic, they are rarely found in word-initial and 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: Berber and Arabic are highly consonantal languages (Hamdi et al. 2005, Ridouane and Fougeron 2011) whereas vowels are more frequent than consonants in French and, to a lesser extent, English; Berber and Arabic display a significant proportion of fricatives as compared to English and French. Moreover, the phonological inventories of Arabic and Berber put forward a large number of back consonants (i.e., uvulars, pharyngeals and glottals) that are known to be acquired rather late (Omar 2007). In sum, this study aims to provide informative contribution comparing the phonetic development in four languages including Berber and Arabic, languages in which studies of phonetic development are rare.

We elaborated six interrelated hypotheses for our crosslinguistic study:

- 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 the more vocalic English and French.

²However, some studies suggest that CDS is not necessary facilitating as it introduces more variability in input (Sundberg and Lacerda 1999, Dodane and Al-Tamimi 2007, Benders 2013, Dilley et al. 2014)

³In the present study, the term 'cluster' refers to consonant sequences that occur both within and across syllables.

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

1. *Place of articulation*: More complexity expected in Arabic, due to the many back (i.e., dorsal) consonants, and in French, due to the frequent /ʁ/ (Gromer and Weiss 1990).
 2. *Clusters*: More complexity expected in Berber and Arabic, in which clusters are more frequent.
 3. *Complex articulation*⁴ should contribute to complexity in Berber and Arabic.
 4. *Word length*: More complexity on this parameter is expected in Arabic and Berber, which show many polysyllabic words due to the insertion of vocalic patterns and affixes into the root for lexical derivation.
 5. *Final Consonant*: Less complexity is expected in French, due to its preference for open syllables.
 6. *Variagation (Place)*: More variegation is expected in Arabic, due to the non-homorganic consonantal rule, which constrains the root-skeleton.
 7. *Variagation (Manner)*: in Arabic (likewise in all Afro-Asiatic languages) it is well known that the co-occurrence of identical and homorganic consonants in the root sequence is restricted by the Homorganic Cooccurrence Constraint (Greenberg 1950). This restriction leads to expect Arabic will attest more variegation than the other languages under study.
 8. *Rhoticity*⁵ will contribute to complexity in American English only.
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- H2. In each language, we expect the words that mothers use when addressing their children (CDS) to be less complex than the words used in the “adult” language (i.e., represented here through dictionary words).
 - H3. According to the lexical selectivity hypothesis, children should attempt words (targets) that are less complex to produce than many other words in the adult language (Dictionary).
 - 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 Arabic- and Berber-speaking children’s IPC scores to be higher than those observed for English- and French-speaking children.
 - H6. In sum, 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.

Table 1 recapitulates the different hypotheses.

⁴When 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 (Ladefoged and Maddieson 1996, Barkat-Defradas and Embarki 2009).

⁵Rhoticity in English (the pronunciation of the historical rhotic consonant /r/) is one of the most prominent features distinguishing varieties of English. Here we studied the acquisition of American English, which belongs to the rhotic varieties.

H1	Dictionary	Globally, Berber and Arabic should show higher complexity because they are highly consonantal languages <ol style="list-style-type: none"> More complexity in Arabic and French for place of articulation More complexity in Berber and Arabic for clusters More complexity in Berber and Arabic for complex articulations More complexity in Arabic and Berber for word length Less complexity in French for final consonant More complexity in Arabic for variegation (Place) More complexity in Arabic for variegation (Manner) More complexity in English for Rhoticity
H2	CDS	Less complexity in CDS compared to Dictionary
H3	Targets	Less complexity in Targets compared to Dictionary
H4	Actual	Less complexity in Actual compared to Targets
H5	Targets & Actual	Berber and Arabic Targets and Actual more complex than French and English
H6	Targets & Actual	Targets and Actual should reflect the ambient language

Table 1: Predictions for Dictionary, CDS, Target and Actual words in the four different languages

2. METHOD

In this section, we first describe the participants in the study (section 2.1), followed in section 2.2 by the procedures used to gather the data, and then turn to the analysis in section 2.3.

2.1 Participants

Sixteen children from four linguistic communities: Arabic (Tunisian vernacular), Berber (Tashlhiyt variety), American English and French (France) were included in the study (see Table 2). The parents did not report any concerns about the

Language	N	Sex	Age Range (months;days)
Arabic	4	2M/2 F	8;09–24;06
Berber	4	2M/2 F	7;21–18;12
English	4	2M/2 F	11;27–20;05
French	4	3M/1 F	9;09–22;22

Table 2: Participants' demographic information

children's language development, hearing status, or general development. The Arabic and Berber data are part of The PREMs Project⁶ (Principal Investigator: Sophie Kern). The French data are part of the French Kern corpus (Kern et al. 2009), and the English data comes from the Providence Corpus (Demuth et al. 2006).

2.2 Procedures

The children were recorded⁷ in natural settings at home in interaction with their mother. The recording sessions took place twice a month starting slightly before the onset of first word production until a few months after the lexical spurt. As Jakielski (2000) recommends using 50 words to compute the IPC, four lists of 50 words were analyzed for each language: (i) the first 50 words actually produced by each child (hereafter referred to as Actual), (ii) the targets corresponding to these first 50 words, (iii) 50 words randomly extracted from CDS produced by each mother and (iv) 50 words from the adult language randomly selected from dictionaries⁸ (See Appendix 1 to 4 for an illustration). For each list, an adaptation of the Index of Phonetic Complexity (Jakielski, 2000) was computed (see Table 3). The IPC is based on the phonetic regularities observed during the babbling and the first-words periods. Vocal outputs that are composed of the less preferred segments (or segment associations) in early development are rated as more complex in the IPC. This allows measuring the development of phonetic complexity in both word targets and words actually produced by the children. The IPC consists of eight parameters: consonants by place and manner, vowels by class, 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, as this measure was initially designed to capture the phonetic complexity of English, it must be adapted for crosslinguistic comparison in order to account for other determining features of phonetic complexity exhibited in the four languages under examination.

2.3 Data analysis

In order to take into consideration the typological peculiarities of our linguistic sample, we first had to integrate into the original IPC model a new parameter relative to consonantal articulation. We called it *consonant by articulation class* in reference to Jakielski's first two parameters (i.e., Consonant by place and manner class and

⁶<http://www.ddl.ish-lyon.cnrs.fr/projets/prems/index.asp?Langue=ENPage=Presentation>

⁷Audio-video data was obtained using a Sony© HDR CX Camera 740VE. The audio-video recording material was placed so as to capture the profile of the child/mother dyad. In addition to the acoustic signal recorded via the internal microphone of the camera, we used an additional external recording equipment (multidirectional microphone Tascam© DR07 MK2) which was placed in front of the children at about 1 meter.

⁸Dictionaries and databases: for Arabic, we used Cheraifi (2005); for French, Database Corpaix (2000) <http://sites.univ-provence.fr/~veronis/data/freq-oral.txt>; for Berber, El Mountassir (2003) and Chafik (1990/1999); and for English, The Robert and Collins French-English / English-French Dictionary (1993).

Parameter	No points for:	One point each for:	Max. points
1 Consonant by articulation class	simple	complex	1 each
2 Consonant by place class	labials, coronals, glottals	dorsals, pharyngeals	1 each
3 Consonant by manner class	stops, nasals, glides	fricatives, affricates, liquids	1 each
4 Vowel by class	monophthongs, diphthongs	rhotics	1 each
5 Word shape	ending in a vowel	ending in a consonant	1 each
6 Syllable count	monosyllabic and disyllabic	≥ trisyllabic	1 each
7 Consonants by place variegation	reduplicated	variegated	1 each
8 Consonants by manner variegation	reduplicated	variegated	1 each
9 Contiguous consonants	words with no clusters	words with clusters	CC: 1pt. >2C: 2pts.
10 Cluster by type	homorganic	heterorganic	1 each

Table 3: Adapted Index of Phonetic Complexity Scoring Scheme (based on Jakielski, 2000)

Consonant by place class). This new parameter was created in order to discriminate between simple vs. complex articulations (see parameter 1 in Table 3). In Arabic and Berber, two types of secondary (or complex) 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^ɕ, d^ɕ, ð^ɕ]), 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 and Embarki 2009, Lahrouchi and Ridouane 2016), are acquired very late in development (Omar 1973). We therefore 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 of adding lip rounding to the principal articulation. We considered radical consonants (i.e., pharyngeals) as particularly complex in terms of the consonant by place class, 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 and Dyson 1998). Lastly, considering the fact that consonantal clusters are frequent in the Western varieties of colloquial Arabic, under the influence of Berber, and can thus be very long, we decided to add up to 2 points when more than two consonantal

segments are contiguous. Table 3 recapitulates the different parameters included in our IPC adaptation.

Our purpose here is to compare the total phonetic complexity of children's production cross-linguistically, as well as the relative contribution of each of these ten parameters to the overall complexity. 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 4 provides an example of IPC scoring for four dictionary words, one from each language, for the numbered parameters listed in Table 3.

3. RESULTS

The dictionary sample is a window on the expected mean word phonetic complexity of the languages under study. Since we are interested in the differences/similarities between languages or samples rather than in the absolute distribution of the IPC values, we compute the 95% confidence interval error bar (5% type I error, computed through bootstrapping) rather than the standard variation interval, to allow for visual comparison of sample means. As for the actual discussion of results, differences in behavior are supported by a Kruskal-Wallis H-test to test the null hypothesis that the population medians of all of the samples (Dictionary, CDS, Actual and Target) are equal. This test is the non-parametric version of a one-way ANOVA, and is required in our case because data distributions are not normal. This test assumes a chi-square distribution but provides the advantage of allowing both fine grain comparisons between two samples, even samples of different sizes (thus allowing for repeated sampling), and a generalization over more samples.

Figure 1 shows that the four languages have indeed different mean word IPCs, with a decline from Arabic > Berber > English > French. However, confidence intervals are quite large, which was to be expected from the small sample sizes, which casts doubt on the validity of this decreasing pattern. Indeed, inter-language H-test comparisons only support the difference between Arabic and the other languages ($p < 0.05$), but not among Berber, English and French.

This for the overall IPC. However, each of the 10 phonetic parameters used to compute the IPC could contribute differently – depending on the language – while

Parameter:		1	2	3	4	5	6	7	8	9	10	Total IPC
French	fork: [fukʁɛt]	0	1	1	1	0	0	1	1	1	1	7
English	mixture: [mɪkstʃɜː]	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

Table 4: Index of Phonetic Complexity Scoring for one word in each language

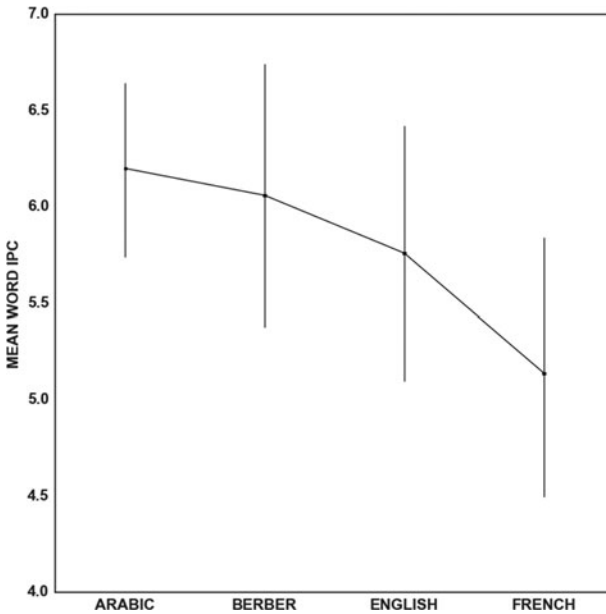


Figure 1: Mean word IPC showing a decreasing decline from Arabic > Berber > English > French. Vertical bars show the 95% confidence interval for the means for the dictionary as a whole.

being leveled out by the others, with the specific expectations formulated under H1. Such individual contributions for the Dictionary sample are displayed in Figure 2 as *specific contributions*, that is, the difference between the proportion of the overall complexity (total 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 to a tenth of the overall complexity (in other words, the baseline corresponds to a 10% contribution of the parameter). Specific parameter contributions should thus vary theoretically between -0.1 and 0.9 .

To explore the sub-hypotheses outlined for H1, we need to proceed parameter by parameter, with specific expectations for each language. To test whether the mean tendency for the language supports our expectations, we proceed to inter-language T-tests to assess whether the mean behaviors of languages taken two-by-two are statistically significantly different.

As expected in H1.a, Arabic and French display significantly greater contributions ($p < 10^{-3}$) of place of articulation (parameter 2: 12–14% contribution to the overall IPC) than Berber and English (6–7%). As for Manner (parameter 3), it accounts for some 20% of the total IPC for all four languages, with no significant inter-language differences. In terms of variegation, Arabic indeed exhibits the highest contributions for both place (parameter 7: 16.2%) and manner (parameter

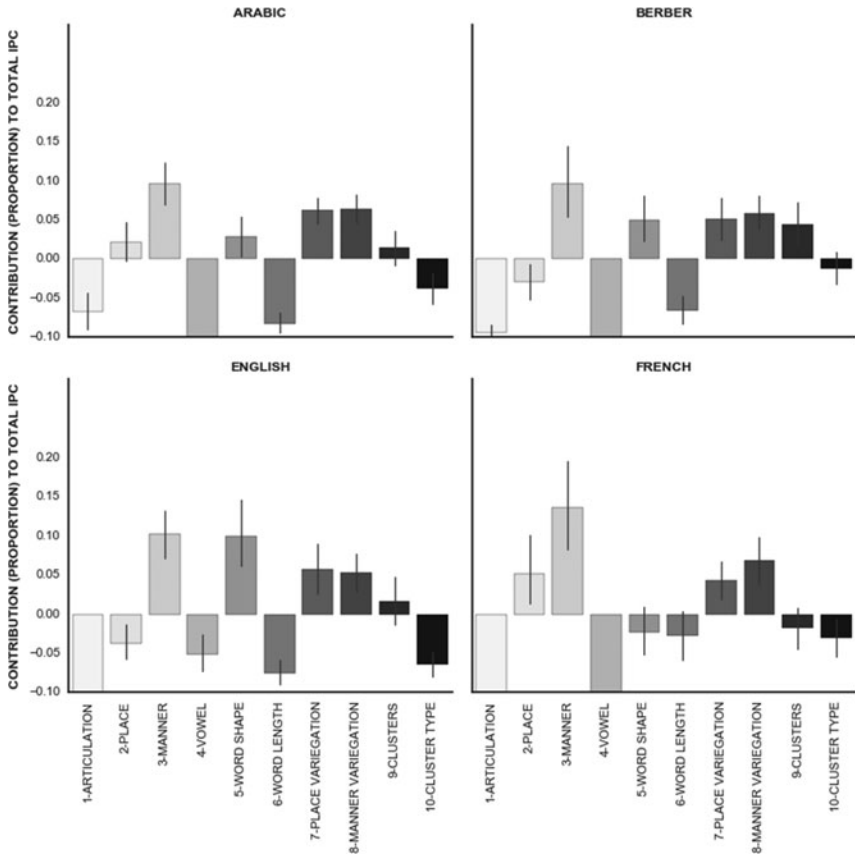


Figure 2: Specific parameter contribution per Language (with respect to the uniform contribution null hypothesis). For each parameter, values could theoretically range between -0.1 and 0.9 .

8: 16.3%), but they are not significantly higher than the contributions of these parameters for the other three languages, where values range from 13.8 to 16.1%, invalidating the expectations of hypotheses H1.f and H1.g. The Rhoticity parameter (parameter 4, H1.h), which is exclusive to English, only accounts in this language for 4.7% of the total IPC, but is still significantly different from zero ($p < 10^{-4}$).

Moving on to complex articulations: contrary to our assumption in H1.b concerning consonantal clusters (parameter 9, Berber and Arabic (14.1% and 11.4% respectively) differ significantly only from French (7.8%, $p \leq 0.05$) but not from English (11.5%), with Arabic and English only slightly above the 10% baseline of a uniform contribution of all parameters to the total IPC. However, Arabic and Berber significantly differ from English in terms of cluster composition (parameter 10: $p \leq 0.05$, 6.1%, 8.6% and 3.5% respectively), but not from French (6.7%), as predicted by H1.c.

To explore the effect of word structure and shape, we first distinguished monophthongs from diphthongs in our data description, then computed word length as the number of vowels, assumed to act as syllabic nuclei (except for Berber, where, null syllabic nuclei were also identified, using Dell and Elmedlaoui's (2002) syllabification algorithm). For this parameter (parameter 6, H1.d), all four languages exhibited less than the 10% contribution anticipated if all parameters had an equal contribution to the overall IPC, with values ranging from 1.7% to 6.9%, and an unexpected low value for Arabic. However, as expected in H1.e, French exhibits significantly less complexity (7.4%, $p < 0.01$) than all three other languages in word shape (parameter 5: 12–20%) due to a preference for open final syllables.

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

Overall, the four samples differ significantly for all four languages ($p < 10^{-6}$), with a general tendency to a decreasing complexity from Dictionary to CDS to Target to Actual child productions. However, major differences exist between languages. Regarding H2, for instance, we find that the lesser complexity expected for CDS compared to the Dictionary sample is supported only for Berber (4.34 vs. 6.06) and French (3.92 vs. 5.14) with $p < 0.01$, but not for Arabic (5.42 vs. 6.2) and English (5.4 vs. 5.76). As for H3, while Arabic, English and French exhibit significant IPC differences between Dictionary or CDS and Target (p at least < 0.02), the Berber data only supports a difference between Dictionary and Target (4.26), but not between CDS and Target, suggesting that adults actually pre-sample their

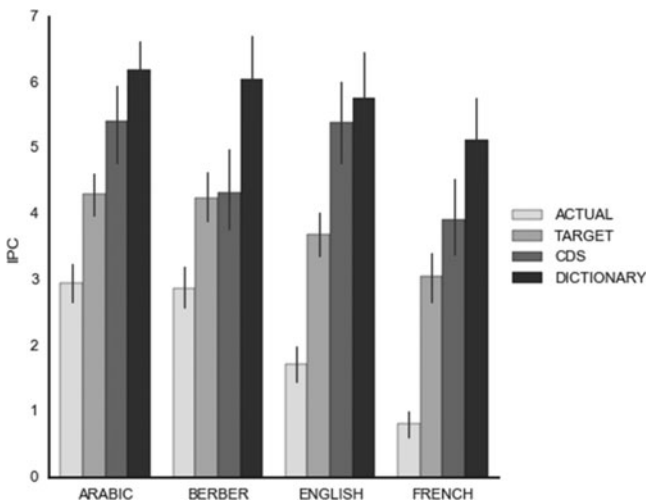


Figure 3: Mean word IPC and 95% confidence intervals for the Dictionary/adult language, CDS, actual child production and target for Arabic, Berber, English and French

language to select for appropriate complexity in the speech they address to the child. Moving on to H4, all languages exhibit significantly lower complexity of the Actual production of the child with respect to the intended Target ($p < 10^{-6}$). Arabic and Berber show similar Target complexity and Actual-to-Target complexity differential (2.96–4.31 and 2.87–4.26 respectively). Nevertheless, while English and French display lower Target complexity (3.7 and 3.06 respectively), and lower Actual complexity as predicted by H5 (1.72 and 0.81 respectively), they also display larger Actual-to-Target complexity differentials especially for French, prompting the question of accuracy.

Given that the individual parameters focus primarily on consonants, we computed the Actual-to-Target accuracy in the realization of consonants for the four languages (see Figure 4) as the proportion/percentage of conformity with target. Despite the larger overall Actual-to-Target complexity differential, French children achieve better accuracy than English children, typically, and fall within the range of accuracy of Berber kids ($p < 0.02$). More importantly though, and despite larger Target complexity, Arabic and Berber children show better accuracy scores (66% and 59% respectively vs. 53% for French and 44% for English). These results show that these Actual-to-Target complexity differentials do not necessary translate into Actual-to-Target accuracy, but more crucially they suggest that the typological characteristics of the language do indeed play a role in the acquisition process, calling for

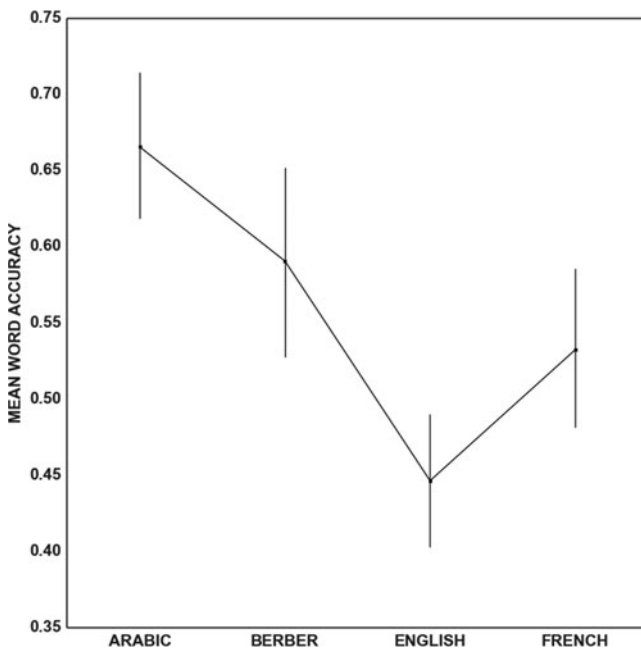


Figure 4: Mean Actual-to-Target accuracy in consonant production for Arabic, Berber, English and French. Vertical bars display the 95% confidence interval

a detailed examination of the individual contribution of each parameter to the overall IPC score of children’s actual production, as compared to the ambient language (dictionary) parameter contribution landscape.

Relevant to H6, Figure 5 shows that not all parameters contribute equally to the mean IPC of the child’s actual production, but also that, depending on the language, they do not depart equally from what is expected from other samples, and especially the dictionary language. For instance, Arabic Actual (16.2%) shows an enhanced tendency for children to produce closed final syllables, irrespective of what is displayed in either the Target (9.1%) or the CDS (9.6%), thus mirroring more of the dictionary tendency (12.9%) than these two latter samples do. On the other hand, clusters, which were shown previously to have a significant contribution to the overall IPC in the dictionary (14.1%), behave differently ($p < 10^{-4}$) in the Targets selected by children (7.7%) and in their Actual productions (6%), while these latter do not depart significantly from the CDS (5%) sample. This suggests that both CDS and Targets selected

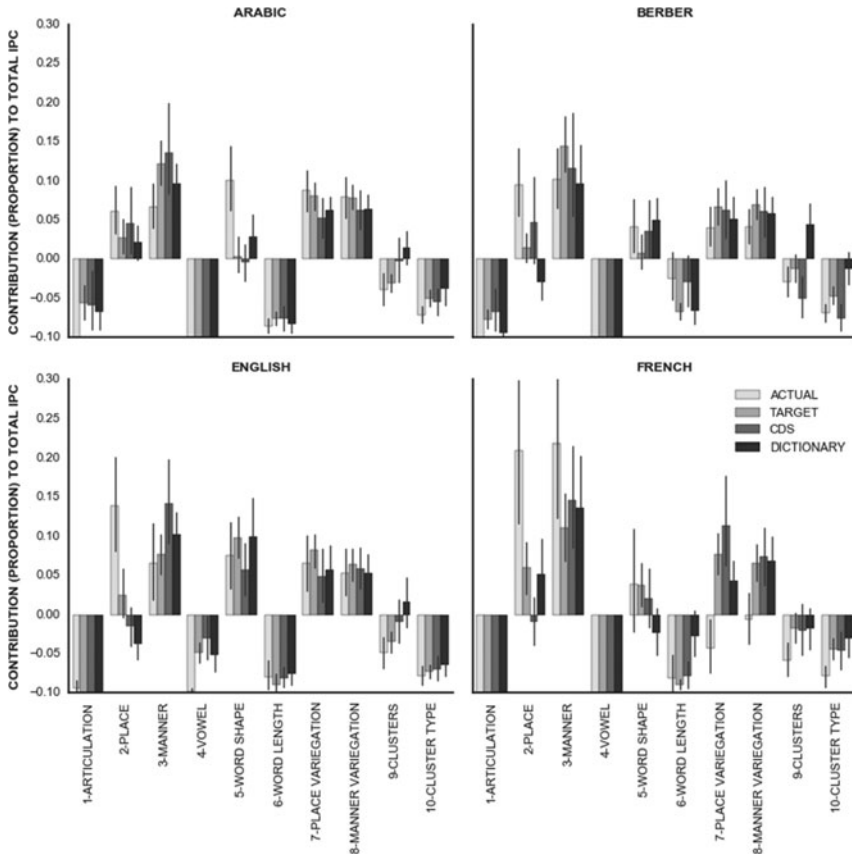


Figure 5: Mean parameter contribution by sample (Dictionary, CDS, Target and Actual) and by language (Arabic, Berber, English, French)

by the children tend to misrepresent clusters during this phase of acquisition, thereby reducing the complexity of their production.

As for manner of articulation (parameter 3), Arabic and Berber tend to have comparable complexity in the Dictionary, CDS and Target samples, but this complexity is not achieved in the Actual children productions ($p < 10^{-3}$). In other words, while the selected targets mirror the complexity of the ambient language for this parameter, children's productions do not. Conversely, in English and French, the CDS does mirror the complexity of the Dictionary for this parameter, but neither the children's Targets nor Actual productions do ($p < 0.01$) as they display similar levels of complexity for this parameter. In terms of place of articulation (parameter 2), Targets and Actual reflect the characteristics of both Dictionary and CDS for Arabic, Berber and English but not for French. In French, Target complexity for this parameter mirrors the CDS, but not the Dictionary, and Actual does not reflect either of the Dictionary, the CDS or the Target. Conversely, place variegation (parameter 7) for this language shows that the Target's complexity mirrors the Dictionary rather than the CDS. In addition, while place and manner contribute the most to Actual productions in this language, their variegation contributes the least, contrary to Arabic, Berber and English.

4. DISCUSSION

Using an adaptation of Jakielski's (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.

Considering language-specific aspects, we observed that as hypothesized, some languages of our samples, namely Arabic and Berber, show higher IPC scores (complexity) than English and especially French (H1). Our results also reveal the different IPC parameters contribute differently to overall phonetic complexity depending on language specificity. Manner and place of articulation contribute significantly to complexity in all four languages, and not only in Arabic and French as predicted by H1.a. In other words, children in these languages do not systematically avoid fricatives or liquids, which are frequent in the ambient language (dos Santos 2007 for French, Nahar et al. 2012 for Arabic), and to which they are consequently frequently exposed to via CDS. 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 these types of sounds are frequently encountered in the ambient language (i.e., typically in Afro-Asiatic languages where they are rather frequent as shown by Basset (1946) and Bonnot (1977)). 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 (H1.b). In Tunisian Arabic, as in all Western

Arabic vernaculars, the prevalence of complex consonantal clusters is mainly due to the loss of unstressed vowels in open syllables under the influence of linguistic substrates (i.e., namely Berber), and this contributes to the increased number of clusters. As for final consonant, French is confirmed to be easier than the other languages, as predicted by H1.e. In contrast, some other parameters that were expected to play a role in complexity scores (H1.c, d, f, g, h), in particular word length and complex articulation (H1.c and d), do not seem to contribute significantly to the global complexity score. Moreover, the expected decreasing complexity: Berber < Arabic < English < French which led us to hypothesize that these differences in phonetic complexity in the adult languages would influence phonetic development in children acquiring these languages. However, our results did not show this expected pattern: only Arabic is significantly more complex than the three other languages. An obvious assumption is that a phonetically complex language such as Arabic would take longer to acquire, and would be more challenging to reach accuracy. Nevertheless, our findings suggest that this is not the case. Although our sample is too small to draw solid conclusions, our data indicate that Arabic infants are not delayed in the timing of first words production, given that first words are produced before the age of twelve months in our sample. Similarly, children acquiring Arabic and Berber show the best accuracy scores compared to the *a priori* articulatory less complex languages, English and French.

Turning to universal aspects of phonetic development (H2, H3 and H4), our findings are in line with previous work underlying the universal tendency for caregivers to modify their speech when addressing children (H2) (Ferguson 1964, 1978; Kuhl et al. 1997; Monnot 1999; Kitamura et al. 2001). Some studies had investigated CDS in Arabic and Berber and cultural differences have been documented in the range of modifications of CDS (Ferguson 1956, Gumperz and Hymes 1964, Bynon 1968, Omar 1973, Haggan 2002, Al-Shatty 2003, Ferguson 2004), and the fact that caregivers use a special register to address young children remains indisputable cross-linguistically. The vast majority of CDS studies are focused on semantic, syntactic or prosodic characteristics. Fewer address the phonetic characteristics of CDS, but Kuhl et al. (1997) for instance showed that mothers in different languages (American English, Russian and Swedish) produce vowels that are acoustically more extreme when addressing their young children, thus providing information about the sound system of the infant's native language in an exaggerated form. CDS 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. This suggests the operation of lexical selectivity in CDS just as lexical selectivity is hypothesized in children's productions. Thus, 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 by H3, children also seem to select the words they produce or attempt to produce depending on their phonetic complexity (Ferguson and Farwell 1975, Vihman et al. 1985, Schwartz et al. 1987). Indeed, in the four languages

under study, we observed that words attempted (Target) or produced (Actual) by children have lower complexity scores than CDS or adult words (H3 and H4). Finally, the fact that in all the four languages, actual productions show reduced complexity compared to attempted words (and obviously to CDS or adult speech) 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 (MacNeilage et al. 2000, Green et al. 2002, Stoel-Gammon and Sosa 2007, Geen et al. 2010). 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 (H5 and H6). The fact that in Arabic, children's use of closed syllables (cf. actual items) mirrors the adult language (dictionary words, but not targets nor CDS) can be explained by the fact that this process of simplification does not affect the word randomly but rather affects morphemes that are added to the root (for example, in the actual item #48 *tatt* it is the morpheme of the third person singular at the imperfective [ji-] prefixed to the verbal root which is dropped. These morphological elisions also explain why children's actual words are not as long as predicted. Another consequence of this phenomenon is illustrated in #39 *?am:i* 'my uncle' which is actualized *?am*: 'uncle' and where the suffixed first person possessive determiner [-i] is dropped, resulting in a CVC sequence. Doing this, the child produces a form that is similar to the one recorded in dictionaries and which corresponds to the radical form of the words. Turning to clusters, which are strong contributors of complexity in Berber (and to a lesser extent in Arabic and English), they seem to be avoided by children acquiring these languages (in Arabic for example, #18 *kaskək* ('your helmet'), #35 *tkasir* ('you break'), #42 *ħizħa* ('lift it' (fem.)) and/or #50 *?istana* ('wait') are actualized under the following simplified forms: *ka*, *kasər*, *tiz:a* and *stan:æ* respectively. 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 et al. 2001). In sum, the different IPC parameters are not equally difficult for children to produce: 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.

	Actual		Target		CDS		Dictionary	
	IPA	IPA	Translation	IPA	Translation	IPA	Translation	
1.	mem:æ	mama	mommy	t ^ʰ ɑ:h	to fall	ʎəfb	medical	
2.	itæj:	t ^ʰ ɑj	peek a boo	ʎi:ʒæ	he comes	huku:m	government	
3.	pæ	papa	daddy	t ^ʰ ɑt ^ʰ ɑ	tata	hi:la	trickery	
4.	dæ	laʔ	no	ʎah:æ:	ouch!	farlɔχla	fieldmouse	
5.	ʎi	ʎej	yes	kiχ:æ	eew!	msisa	bracelet	
6.	tæ:h	t ^ʰ ɑ:h	it fell	qu:l	tell!	həwəl	to try	
7.	bæj	bah	ok	næh:i:	remove	qa:l	he told	
8.	æm	mam:i	mum	ʎahajjæ:	here it is	mrah:əm	marble	
9.	bəh	bah	It disappeared	wi:ni	where is it?	zra:ʎi:	agricultural	
10.	ʎejʒi	ʎiʒa	come here !	fu:	what is it?	md ^ʰ əl	straw	
11.	bəj	baj baj	bye-bye	dad:u:f	walk!	mud ^ʰ if	stewart	
12.	təd:	ʎi:dd	hold !	jez:i	stop!	but ^ʰ ain	ventricle	
13.	ʎæh:	ʎah	ouch !	trəh	show me!	dəhf	baby donkey	
14.	hup	hut ^ʰ	put down !	ba:h	gone (nothing!)	wəsχ	dirty	
15.	ʒaʒæ	ɕʒa:ʒa	chicken	alo	hello	səq:a:t	gourmet	
16.	hibɛf	mænhibɛf	I don't want	ʎaʎmil	do !	kursi	saddle	
17.	ktib	ʎiktibli	write (to me)	hæ:t	put !	ʎrəq	sweat	
18.	ka	kaskak	your helmet	læ:	no	had:	fence	
19.	tæ:ʎi	mtæ:ʎi	mine	ʎej	go !	rij:a:ga	bib	
20.	bebe	bebe	baby	χu:	brother	qəm	estimate	
21.	kak:æ	kaka	poo	kaka	poo	məstəyəl	enjoy	
22.	tat:a	ba t ^ʰ :ɑ	duck	ʎimʎi	he goes/he walks	bəlyɑ	oriental slipper	
23.	tataə	t ^ʰ ɑt ^ʰ ɑ	beat !	s ^ʰ ɑhi:t	thank you	ʎkara	bag	
24.	hutæ:	huta	fish	ʎaqɛf	get up !	bəqra:ʒ	tea pot	
25.	bab	dub	bear	bəʎ	bèè (bleat noise)	hɛ:l	weather	
26.	na:n	hs ^ʰ a:n	horse	ʒi:b	bring	s ^ʰ əf:a	clarify	

27.	næhnæ	lihnæ	here	hæðika	this one	məl:ɛ:h	seller
28.	mæmæ	mæʔ	water	thut ^ʃ	you put	da-ijəb	melting
29.	kæk	qird	monkey	ʔistan:æ	wait !	qəfza	jump
30.	tæ:h	muftæ:h	key	ʔælʃib	play !	da:r	home
31.	tawtaw	taw:a	now	ʃʃær	hair	ma:t	perish
32.	dæb:u:sæ	dab:uzæ	bottle	mtaʃ	his	rʒaʃ	take back
33.	ʃbi:k	ʃbi:k	what happens to you?	s ^ʃ afiq	applaud !	t ^ʃ bi:b	doctor
34.	ʔuxdæn	ʔuxzur	watch !	ʃnuwæ	what is it ?	fah:əm	explain
35.	kas:ər	tkas:ir	you broke	bismilah	bless you	hdər	argue
36.	bæz	xubz	bread	ʃaqu:la	nice	sqət ^ʃ	fall
37.	fasu:	ʃas ^ʃ fu:ra	bird	ʔaʃt ^ʃ i	give	γri:b	unheard-of
38.	tax:a	kix:a	eew !	matmis:if	don't touch (to her)	bət ^ʃ t ^ʃ əl	idle
39.	ʃam:	ʃam:i	my uncle	ʔuqʃud	sit down !	mʃal:əm	expert
40.	ku:ra	ku:ra	ball	γa:di	there	səndu:q	coffin
41.	di	haði	this one	ʃbi:k	what happens ?	hənd	magnet
42.	tizza	hihza	lift it up (fem.)	nraqablik	I'll put it together for you	qəmr	moon
43.	lahda	lahð ^ʃ a	one minute please	tkal:im	talk !	qəsmə	part
44.	kuja	xuja	my brother	nɣab:i:h	I hide it	stəɣbər	be informed
45.	ku:	qu:m	get up !	hš ^ʃ ɑ:n	horse	zəʃ:ada	spatula
46.	nan:i	nan:i	sleep !	ʃas ^ʃ fu:ra	bird	aθat	furniture
47.	ʔahu	ʔahuwa	here it is !	matibki:ʃ	don't cry	mədwəd	nursery
48.	tatt	jitattti	(he) beats	kifæ:ʃ	how ?	rqi:q	thin
49.	ræjæ	mræjæ	mirror	nhizz	bring	dərbuka	drum
50.	stan:æ	ʔistana	wait !	su:q	market	ʃilaqa	coat rack

Appendix 1: Examples of Arabic data

	Actual	Target	Translation	CDS		Dictionary	
	IPA	IPA		IPA	Translation	IPA	Translation
1.	b:ab:a	bajbaj	goodbye	d:ah	hit (have a pain)	ara	give
2.	baba:	baba	dad	ʔaw	noise	aman	water
3.	am:a:	mama	mom	aratid	give it to me	afus	hand
4.	hb:a	s: ^h b:at ^h	shoes	xix:i	poo	ilm	skin
5.	ajal:a	lal:a	auntie	tit:i	sit down	krf	tie
6.	ha:h	hak	take	x:if	it is bad (thing)	adr	press
7.	man:ama	lmunika	toy	ʃaf:a	a donkey	rgl	close
8.	q:aq:a	ʔika	like this	ʃif:i	eat	ifta	he went
9.	t:a	xt:a	this one (fem.)	baʃ:a	sheep	usin	they took
10.	b:ah	b:ah	disappeared	b:ah	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	ufiy	I found
13.	aj:a:	taj:a:	another one (fem.)	baʃ:atin	sheep	lkmy	I arrived
14.	ʃeʃ	ʃaf:a	horse (baby talk)	ʃt:i	grandfather	tam:nt	honey
15.	b:əhb:a	aħb:ud ^h	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	buʃ:u	monster	tafruxt	girl
18.	qaq:a	kukuʃ:u	cock (baby talk)	tinxarin	nose	afrux	boy
19.	alaqa	alq:af	sheep	tabat: ^h aħt	foot	imi	mouth
20.	a:la:	ara	give me	tafust	hand	argaz	man
21.	baʃp:εʃ	lbanan	banana	tamz: ^h uxt	ear	tamyart	woman
22.	t:εtεt:ε	ʔid	here	tagaj:ut	head	amadl	hill
23.	tʃtʃk	juʃkad	he came	timim:it	small mouth	amdlu	cloud
24.	a:pb:	ib:i	it is ripped	tiwal:in	eyes	skr	do
25.	aca:ca	agaj:u	head	mimif	mouth	fl	let
26.	mem:e	ʃmti	my aunt	tabit:u	eyes	ls	wear

27.	handb:a	and:u	we are going	tid ^h ud ^h in	fingers	gn	sleep
28.	fu	fuf	look	ʃk:ata	eat (it)	iz ^h uran	veins
29.	ne:n:e	nin:i	sleep (baby talk)	tas:awalt	trousers	az ^h alim	onion
30.	af:e	adf:Ɂ	I will eat	banana	banana	tiwit	you took away
31.	aj:i	haj:i	here I am	biʒ:u	baby	tabrat	letter
32.	haftʃk:a	ifq:a	it is tough	t ^h rft	break	smun	pick up
33.	fual	fuw:r	slow down	ʃan:	car	knu	lean
34.	anana	wijn:a	mom's one	babat	shoes	kru	rent
35.	ʃafa:	mat ^h eʃa	tomatoes	fuf:u	fire/ hot	igawr	he sit down
36.	bak:aʔ	baraka	that's enough	ak:ik	give / Show	tkʃmt	you entered
37.	Ɂ:a	Ɂw:a	this one	baja	biscuits	ssnkr	wake
38.	alti	xalti	my aunt	st:ii	grandfather	udm	face
39.	mamiand:u	manisrand:u	where	hmal	donkey	idam:n	blood
40.	d	ad ^h ad ^h	finger	ʃ:u	fermented milk	ayrum	bread
41.	mim:i	amuf:	cat	daʃ	also	juda	it's enough
42.	bwa	iswa	he drank	x:ix:if	dirty	izra	he saw
43.	j:ah	jah	yes	kukuʃ:u	cok	alim	straw
44.	u:f:uʔ	sf:uɁt	get him out	hah:a	boho / cut	afunas	bull
45.	f:uf:u	if:uɁ	he went out	d:ah:ati	hit (me)	ajdi	dog
46.	m:am	im:im	it's tasty	b: ^h at ^h	shoes	ngr	between
47.	px:u	bux:uf	here's the insect	hawa	cow	tirmt	food
48.	f:aʔ	f:	eat	hawhaw	dog	azur	terrace
49.	s:as:a	ʃhs:a	be quite	t ^h anun	yogourt	izgr	he crossed
50.	ad:a	td: ^h r ^h	she fell down	tiziz:it	meat	xdmn	they worked

Appendix 2: Examples of Berber data

	Actual	Target	CDS		Dictionary		
	IPA	IPA	Translation	IPA	Translation	IPA	Translation
1.	dʌbe	bʌmbəlbi:	bumblebee	ækɹəˌbæt	acrobat	əsi:təs	acetous
2.	dædeɪ	dædi:	daddy	ədɔ:r	adore	ɑ:ɹfɹdju:k	archduke
3.	æzi	dʌɹti:	dirty	ænt	ant	bækəs	bacchus
4.	dʌwɪ	dəgi:	doggie	əsli:p	asleep	bæstfən	bastion
5.	dʌdi	dʌki:	duckie	bɛbɪsɪɹdər	babysitter	'bætəl	battle
6.	abwi:	bɛɪbi:	baby	bædəl	battle	Klæ:f	clash
7.	hʌ	kaʊ	cow	bɪskət	biscuit	kɔɪn	coin
8.	dʌ	dət	dot	kɛərfəl	careful	kʌm	come
9.	hʌbu	lɒbstər	lobster	tʃɔ:k	chalk	saiikliŋ	cyclin
10.	ʌmɛ	mami:	mommy	dɑ:rlɪŋ	darling	dælmeɪfən	dalmatian
11.	mʌm	mu:n	moon	dɪfərənt	different	ded	dead
12.	bəbe	pʌpi:	puppy	i:zi	easy	dɪsgɹʌntəld	disgruntled
13.	ʊ'wʌ	bəl	ball	ɛnɹʤɔɪ	enjoy	ɛstʃuəri	estuary
14.	ɛ	aɪ	eye	fɑ:ɹm	farm	fri:ziŋ	freezing
15.	ɑtʃɪ	anti:	auntie	filθi	filthy	fju:z	fuse
16.	kɪzi	kɪdi:	kitty	ʤɛrɑ:f	giraffe	heɪz	haze
17.	æ:	rɔr	roar	gɜ:rl	girl	hevi	heavy
18.	diθɦɪ	ti:ʃər	teacher	gɹɛɹt	great	ɦaɪbɔrneɹt	hibernate
19.	dʌʔdæ	bækpæk	backpack	gɪtɑ:r	guitar	ɪnseɹt	incest
20.	bʌ	bɛr	bear	hevi	heavy	ɪntu:n	intone
21.	peɪ	bai	bye	ɦɔ:rs	horse	lægər	lager
22.	dʌk ^h	stʌk	stuck	ɪnsekt	insect	lɪv	live
23.	bʌ	blu:	blue	ɹtʃɪ	itchy	mætʃ	match
24.	bʌk	bɔʊt	boat	ʤækət	jacket	mɛntəl	mental
25.	bʌk	bʊk	book	ʤʌgəlɪŋ	juggling	mɪksʃər	mixture

26.	bo	baʊ	bow	kæŋɡəru:	kangaroo	peɪpəl	papal
27.	bu	bru:m	broom	kɑ:t	kite	roʊmən	roman
28.	ɡʊkeɪ	kʊki:	cookie	leɪtər	later	ru:l	rule
29.	du:f	ʃu:z	shoes	li:v	leave	skɛərsli	scarcely
30.	bu	bɜ:rd	bird	lɪkɪŋ	licking	tæb	tab
31.	bæk	blæk	black	lʌv	love	tækəl	tackle
32.	pɪteɪ	pɪɡlət	piglet	mæɡnət	magnet	viəməns	vehemence
33.	bu	bu:ts	boots	mi:n	mean	vɜ:rdʒənəl	virginal
34.	bʌbɑʊwɪs	bʌbəlz	bubbles	mʌŋki	monkey	vəsɪfərəsli	vociferously
35.	bɔ:	bʌɡ	bug	neɪm	name	wi:kli	weekly
36.	keɪk	keɪk	cake	nekləs	necklace	wɑɪld	wild
37.	kɑ:	kɑ:r	car	nɑ:s	nice	kæərɪdʒ	carriage
38.	kʌk	klɒk	clock	ɔ:rændʒ	orange	tekst	text
39.	flɛlə	floʊwər	flower	peɪntɪŋ	painting	bɒks	box
40.	fu:	fu:d	food	pɪktʃər	picture	aʊtlɑ:n	outline
41.	kɪk	kɪk	kick	'reɪni	rainy	pækt	pact
42.	mu	mu:s	moose	rɔ:r	roar	pʊt	put
43.	pɪk	pɪŋk	pink	sændi	sandy	riˈpʌblɪk	republic
44.	dɒf	stɑ:z	stars	skrʌbɪŋ	scrubbing	raɪt	right
45.	sɛ:	sʌn	sun	si:t	seat	sædnəs	sadness
46.	fwi	θri:	three	spəɡɛdi	spaghetti	snæp	snap
47.	tɒs	təʊz	toes	tɪkət	ticket	skwi:z	squeeze
48.	wet	wet	wet	'ju nɪkɔ:rn	unicorn	tam	thyme
49.	pʌpɔ	pɜ:rpəl	purple	wæks	wax	traɪəl	trial
50.	dʒi:	tri:	tree	jeləʊ	yellow	voʊɡ	vogue

Appendix 3: Examples of English data

	Actual IPA	Target IPA	Translation	CDS IPA	Translation	Dictionary IPA	Translation
1.	ma:ma	mamā	mummy	ɤgagɔd	look	ātɔks	sprain
2.	pa:	papa	daddy	komāse	start	bɔutij	trinket
3.	toχto tɔe:	dodo	sleep	pās	think	ātuzjasme	enthusiasm
4.	pa:	pē	bread	vjē	come	ekezi	heresy
5.	tɔede:	tete	suck	tɛlmā	so much	ɤɔtɤe	withdrawal
6.	ta:te	taɔtin	sandwich	ivɛk	winter	tɔuve	find
7.	da:da:	gato	cake	dusmā	slowly	kɤɔvɛzɔ	flat tire
8.	ɔbi:	abej	bee	pø	can	kanɔk	duck
9.	bɛbe:	bebe	baby	dɔdā	inside	dulukø	painful
10.	te:te	tete	head	gɤā	big	libɛɔalism	liberalism
11.	tata:	tata	auntie	fɛ	do	pɤɔvizjɔ	supply
12.	bibi:	bebe	baby	vvala	here	zødi	Thursday
13.	ɔp	ɔp	hop	kɔm	like	kɔist	Christ
14.	awo:a aalo	alo	hello	atā	wait	avavɔ	damage
15.	kuku:	kuku	hello	lezɔk	lizard	āgɔk	shed
16.	apo:	pɔpje	fireman	dakɔk	okay	ɤɔzɔvɔk	razor
17.	po:	po	pot	ale	go	tā	time
18.	kokɔe	tɔtɔ	uncle	aviv	arrive	atakde	linger
19.	ape:	papje	paper	avūtaɔ	advantage	kuje	lying
20.	ɔma:ɤɔe:	kameɤa	camera	mɔwē	less	maɤfū	seller
21.	tete:	tete	sucking	dā	in	sɔkwe	shake
22.	kokɔe:	elikɔptɤk	helicopter	pɔɔtik	crossbar	tɔiko	knitting
23.	ɔva:	ɔɔvɔvɔk	bye bye	pusē	chick	vā	wind
24.	tatɔ:	klakson	horn	amne	brought	deɤegle	upset
25.	ba:	bal	ball	ɤapel	remember	deɤm	dermis
26.	ba:	bē	bath	zø	games	ɔtɔmatik	automatic
27.	apa:	lapē	rabbit	butɔ	button	āgɔse	constrained
28.	bi:bo:	bibɔ	bottle	tele	TV	ɔkiv	offer

29.	gu:	lego	lego	komā	how	vəly	hairy
30.	mɔ:	mɔʁ	bite	les	let	velē	vellum paper
31.	ma:	mal	hurt	lynet	glasses	εʁb	grass
32.	ne:ne	mimi	cute	aple	called	defile	parade
33.	apo:	fapo	hat	pwasɔ̃	fish	kale	wedge
34.	ame:	fεʁme	closed	penibl	tiresome	kɔ̃tεʁpεtʁi	spoonerism
35.	bε	tɔ̃b	fall	vaf	cow	εpanwiʁ	blooming
36.	pu:	pul	hen	ēteʁdi	forbidden	dɔsil	docile
37.	fwa	fɪʁwa	cold	fɔset	socks	fās	chance
38.	vy:	pyl	jumper	gaksɔ̃	boy	apsā	absent
39.	ka:	kask	helmet	pətit	small	aspik	aspic
40.	py:	py	stink	kat	four	fam	woman
41.	afa:	paʁfε̃	perfume	pʁε	ready	manifestasjɔ̃	demonstration
42.	no:ne	koksineʎ	ladybird	tabl	table	peje	payed
43.	ane:	fεʁme	close	aspɪʁatεʁ	vacuum cleaner	sē	saint
44.	bu:	bul	ball	mɔʁ	show	tɪʁɑjɔ̃	infantryman
45.	af	ʒɪʁaf	giraffe	telekomād	remote control	ynite	unity
46.	ɔu:	fɔsyʁ	shoe	dəbu	stand	ɔnɔʁε	honored
47.	bube:	pubel	trash	nuʁityʁ	food	etē	off
48.	dada:	salad	salad	kanaj	raffish	kā	camp
49.	ʁo:gwε	dekrɔʁʁe	pick up	pubel	trash	seʁɔm	serum
50.	api:	apɪ	press	māʒe	eat	kātɔnad	To no one in particular

Appendix 4: Examples of French data

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