Perception of accent in bilingual French/American-English children by native adult speakers

Ranka Bijeljac-Babic, Chloé Lehoucq, Thierry Nazzi, Lionel Granjon

Perception of accent in bilingual French/American-English children by native adult speakers

Ranka Bijeljac-Babic, Chloé Lehoucq, Thierry Nazzi and Lionel Granjon
Integrative Neuroscience and Cognition Center, CNRS and Université Paris Descartes

Address for correspondence: Ranka Bijeljac-Babic. Integrative Neuroscience and Cognition Center (INCC), Language and Cognition Team. CNRS - Université de Paris. 45 rue des Saints Pères. 75270 Paris cedex 06. e-mail : ranka.bijeljac-babic@parisdescartes.fr

Acknowledgments: This work was supported by the LABEX Empirical Foundations of Linguistics (ANR-10-LABX-0083), as a contribution to the IdEx Université de Paris (ANR-18-IDEX-0001). We would like to thank Géraldine Legendre, Professor of Cognitive Science at Johns Hopkins University, who helped us recruit monolingual and bilingual families and allowed us to carry out the experiment with monolingual adults. In addition, we would like to thank Vicky Bouche for her collaboration in testing adults in Baltimore, to Jonathan El Methni for his advise on the Elo ranking test and Christelle Dodane for the acoustic analyess. Finally, special thanks to the children and their parents for their kindness and cooperation.

Jacques Mehler was a great scientist and visionary in the field of cognitive science. He was extremely cultured and a polyglot who was proficient in Spanish, French, English, Italian, Yiddish and German. He switched languages with ease but spoke all of them with a “foreign” accent. Native and nonnative speakers of the languages he spoke were always aware of his “foreign” accent. It gave him a certain charm that made him unique.

Our paper is a modest contribution to one of many questions concerning “foreign accent”: do children, bilinguals from birth, speak without an accent just like monolinguals?

Abstract

In a previous study, Dodane and Bijeljac-Babic (2017) found that French/American English children aged 3;6 to 6;0, bilingual from birth, produced disyllabic words which had acoustic properties for lexical stress (*f0*, syllable duration and intensity) that differed from those of monolingual peers, showing cross-linguistic influences. In order to check whether these acoustic differences between the productions of bilingual children and those of their monolingual French- or American English-speaking peers were perceptible by native monolingual adults, we investigated the perception of these words by French and American English native speakers. Using an Elo rating task, participants were asked to indicate in each trial which word out of two competitors was produced by a bilingual child. Words were produced by French- or American English-speaking monolingual children and by two groups of bilinguals, one dominant in French and the other in American-English . The results clearly show that both French and American English monolingual adults were successful in distinguishing the bilingual children from their monolingual peers, but only if they were not dominant in the language of the raters. The relationship between the acoustic correlates of word stress produced by children and the perception of some "accent" by native adult speakers seems more intricate than expected and is further discussed.

Keywords: bilingual children's accents, native adults' perception

1. Introduction

In studies of accent and dialect processing and representation (Floccia et al., 2009; Cristia et al., 2012), these authors propose different definitions of what we call "accent" and more specifically what the terms *regional* and/or *nonnative* accents cover. From a listener's perspective, if a talker is a native speaker of a variety of a language that does not match his/her own variety, the talker's speech would be considered to have a *regional accent*. Moreover, if a talker is a native speaker of a different language and he speaks in a language acquired later in life, his speech would be considered to have a *non native accent*. In both cases, *accented* speech differs from the "standard" variety along phonetic, phonotactic, phonological, lexical and suprasegmental levels, though evidence suggests that the cues to accentedness differ for the two types of accents. Yet, when a listener is faced with speech that differs from his/her standard, he/she can perceive the difference in accent. However, the perception of unfamiliar regional and nonnative accents is fundamentally different (Adank et al., 2009; Clarke & Garrett, 2004; Goslin, Duffy & Floccia, 2012). It was also found that adults process unfamiliar accent-related variations relatively quickly. For instance, listeners are able to distinguish native from nonnative speakers with input as short as a stop burst (Flege, 1984) or detect a nonnative accent in speech samples played backwards, which removes the availability of segmental, grammatical, and lexical cues (Munro et al., 2010). The ability to identify a talker as nonnative has also been observed in nonnative listeners (Munro et al., 2006) and even in listeners who are completely unfamiliar with the target language (Major, 2007). Similar results were found with 7-year-old English-speaking children (Floccia et al. 2009) and 5-year-old French-speaking children (Girard, Floccia, & Goslin, 2008), both groups being significantly better at detecting a foreign accent in adult speech samples than a regional accent in adult speech samples.

All the above-mentioned studies concern the perception of accented speech produced by adults, either bilingual adults with a nonnative accent or adults speaking in their native language with a different regional accent. What about the way children's productions are perceived by adults, when the children are producing speech in a different regional accent, or have more than one language? At present, there are no studies exploring this issue. The main aim of the present study is to investigate whether monolingual French and American English adult speakers perceive differences between monolingual French children, American English children and bilingual children speaking these two languages from birth. To start addressing

this issue, the present study focuses on the word level, thus presenting the afults with productions of disyllabic words produced by these children. Therefore, this study will, first, address the issue of whether bilingual children separate their two languages very early on, speaking both languages as monolinguals, or whether the interaction between their two linguistic systems makes their productions in each language different from the productions of monolinguals.

Second, it will also investigate whether bilinguals' mastery of each of their two languages is modulated by their relative experience with each language, contrasting children raised in France, in which French is the predominant language, with those in the US, in which American English is the predominant language. Previous studies have suggested that dominance (which can be defined in different ways, and is a multidimensional construct, see Birdsong, 2014; Bedore at al., 2012) influences relative mastery of bilinguals' languages, both in adulthood (Cutler, Mehler, Norris & Segui, 1989, 1992; Dupoux, Peperkamp & Sebastián-Gallés, 2010; Sebastián-Gallés, Echeverria & Bosch, 2005; but see Boll-Avetisyan et al., 2020, for lack of an effect), and in infancy/childhood (Bijeljac-Babic et al., 2012; Paradis et al., 2003; Pearson, Fernandez, Lewedeg & Oller, 1993; Hoff, Core, Place, Rumiche, Señor & Parra, 2012; Marchman, Fernald & Hurtado, 2010; Sebastián-Gallés & Bosch, 2002; but see Abboub et al., 2015; Bijeljac-Babic et al., 2016; Polka, Orena, Sundara & Worrall, 2017, for lack of an effect).

Third, the present study will contribute to the issue of the link between perception and production, as perception of speech sounds is not exclusively based on acoustics. At the phonetic/phonological level, it has been shown that it is difficult for adults to discriminate and acquire vowel and consonant contrasts that do not exist in their native language (Best, Halle, Bohn, & Faber, 2003; Best & Tyler, 2007; Flege & MacKay, 2004; Kuhl, 1993). Similarly, at the suprasegmental level, the perception of lexical stress appears modulated by the prosodic system of the native language. For example, Spanish adults, who use stress when recognizing Spanish words, outperform French adults in their sensitivity to stress information, a property that is not lexically contrastive in French, in particular at the phonological level (Dupoux, Pallier, Sebastián-Gallés & Mehler, 1997; Dupoux, Peperkamp & Sebastián-Gallés, 2001). Similar effects were found when comparing the perception of lexical tones by adult speakers of Mandarin, a tonal language, and speakers of French, a non tonal language (Hallé, Chang & Best, 2004). Regarding accent perception, several studies have shown that certain acoustic measurements of non-native speech correlate with listeners' ratings of accentedness, fluency,

comprehensibility, and intelligibility (Derwing, Rossiter, Munro, & Thomson, 2004; Pinget, Bosker, Quene, & de Jong; 2014). However, Munro & Derwing (2015) underline that without listeners' data, acoustic measures themselves cannot predict whether listeners will notice the accent change. This question is well illustrated in Birdsong's (2007) study of Anglophone speakers' production of French voice onset times (VOT). While some speakers' VOTs were clearly more nativelike than others, the study failed to show a statistical relationship between the values of this dimension and the accent judgments from a group of native French listeners.

In the present study of the perception of bilingual children's productions, we relied on the existence of a corpus of production of disyllabic words by French/American English bilinguals for which the prosodic correlates have been measured (Dodane & Bijeljac-Babic, 2017). This will allow us to explore the extent to which perception of a foreign, bilingual accent in these productions is related to how lexical stress is marked. This corpus was constructed with the goal of investigating how bilingual children acquire the prosodic lexical properties of their two languages. French and English differ on many dimensions (Ladefoged, 1995) but the main motivation for choosing these two languages was that at the word level, they have clearly contrastive prosodic, lexical stress properties. French does not have stress at the word level, but at the phrase level (Féry, Hörnig & Pahaut, 2011). Primary stress in French has a fixed position on the final full syllable of the last lexical item of a stress group (Di Cristo, 1998) and is thus completely predictable (Delattre, 1965). In contrast, English words receive lexical stress, and the position of lexical stress is variable but tends to fall on the first syllable of lexical words (trochaic stress; Cutler & Carter, 1987). Concerning the acoustic correlates of stress, primary stress in French is created mainly through temporal cues, final syllables being approximately twice as long as unstressed syllables, with no increase in *f*0 or intensity (Rossi, 1980; Vaissière, 1991). In contrast, in English, lexical stress is made salient by the use of higher *f*0, greater intensity and longer duration on stressed syllables, which makes it more salient than in French.

In terms of the acquisition of the production of these properties, Vihman, DePaolis and Davis (1998) showed that English and French monolingual children, between 13 and 20 months, produce disyllabic words that have the acoustic realization of stress (*f*0, intensity and duration) characteristic of their respective languages. For bilinguals, it is well known that while French-English bilingual adults can speak both of their languages fluently, mastering word level stress appears problematic for a long time during childhood (Flege, 1984). Indeed, LaBelle (2000) argued for a trochaic bias in the English and French productions of a young

English-French bilingual learner (aged 1;6-2;4). Yet, on the basis of data from another English-French bilingual child (aged 2;0-4;02), Rose and Champdoizeau (2008) argued that this child had mastered both basic metrical properties and the main acoustic correlates of stress for each of the target languages. These conflicting results point to the fact that studies on these issues should go beyond the analysis of single cases.

Dodane & Bijeljac-Babic (2017) thus investigated the acoustic correlates of the lexical stress of disyllabic words (mean duration ratio S2/S1, mean *f0* interval S1-S2, and relative S1-S2 intensity) produced by groups of French monolinguals (Mono-FR), American-English monolinguals (Mono-US), and French/American-English bilinguals living in France (Bil-FR). Each group consisted of 8 children (mean age: 4;6, range: 3;3-6;0). To complete the experimental design and to compare bilinguals' production in both languages as a function of the ambient language, a group of 8 American-English/French bilingual children living in Baltimore, US (Bil-US), was later recorded under the same conditions as the other 3 groups (see Appendix for methodological details used in that study).

Table 1. Acoustic properties of lexical stress realization (from Dodane & Bijeljac-Babic, 2017) in the production of disyllabic words produced by monolingual and bilingual children in French (left panels) and in English (right panels): means (and standard deviations) for duration ratio Syllable 2/ Syllable 1 (S2/S1), mean *f*0 (in Hz) on S1-mean *f*0 on S2 (in semi tones) and relative intensity.

.

	MONO FR	BIL-US-FRENCH	BIL FR-FRENCH	MONO-US	BIL-US-ENGLISH	BIL-FR ENGLISH
S2/S1 Duration Ratio	1.73 (0.02)	1.71 (0.03)	2.29 (0.03)	0.78 (0.06)	0.97 (0.03)	1.31 (0.03)
f0 S1-S2 1/2 tons	0.22 (0.52)	0.51 (0.54)	1.33 (0.63)	0.98 (0.82)	0.21 (0.53)	0.41 (0.40)
Relative intensity S1-S2	0.02 (0.01)	0.01 (0.03)	0.04 (0.01)	0.05 (0.02)	0.01 (0.03)	0.05 (0.02)

The most important results can be summarized as follows : First, although the age range of the participants was large (3;6 to 6;0), there was no effect of age in the multivariate (ANCOVA) analysis of variance for each acoustic parameter tested (mean S2/S1 duration ratio, mean *f0* interval, and mean S1-S2 RMS) in each language (French and English).

Second, for the French productions, the final syllable lengthening characteristic of French disyllabic words in monolinguals was found in the productions of the two groups of bilingual children: the S2/S1 ratio was higher for the Bil-FR compared to both the Mono-FR

and the Bil-US, with no difference between the latter groups. The analyses of *f*0 differences in semitones and intensity differences between S1 and S2 were not significant. These results show that the second syllable lengthening expected for French is observed in both groups of bilinguals. Moreover, there were some differences between the two groups of bilinguals, as only the bilingual children living in France lengthened the second syllable more than the French monolinguals.

Third, for the English productions, results on duration revealed that S1 was significantly longer than S2 in Mono-US, S1 and S2 were equivalent in Bil-US, and S2 was significantly longer than S1 in Bil-FR. For pitch, *f0* tended to be higher for S1 compared to S2 in all groups, but none of these differences reached significance. For intensity, the intensity of S1 was higher than that of S2 and the group factor was close to significance, with Mono-US being significantly different from Bil-US and Bil-FR, while the two groups of bilinguals did not differ from each other. These findings establish that the acoustic parameters that mark lexical stress in English, i.e. the longer duration and higher intensity of the initial syllable, are acquired by the monolingual children in our group. This lexical stress mastery is less clear for the bilinguals. Moreover, for duration, once again a difference is found between Bil-FR and Bil-US.

2. The present study

To obtain perceptual ratings, we used the Elo rating system, a method that rates chess and other competitive game players. In this task, each player starts with a rating of a 1000. This rating increases if she/he wins and goes down if she/he loses. Over time a player's rating becomes a true reflection of his/her ability - relative to the entire player population. In our study, each group of monolingual adults participated in a “game” in which they heard the same word produced by two “players” and had to assess which of the two was bilingual. The Elo ranking for each child reflected his/her probability of being considered bilingual by any new judge in comparison to any other child (see Procedure for more details).

3. Hypotheses

We first predicted that adult monolingual speakers can make differences between monolingual and bilingual children speaking French and American English from birth on the basis of the production of disyllabic words. Bilingual children should thus have higher mean Elo scores and be in the upper part of the Elo rankings, compared to monolingual children whose Elo scores should be lower and in the bottom part of the Elo rankings. Second, we

suppose if adult listeners can differentiate bilingual from monolingual children, they are presumably influenced by the bilingual child's ambient language in their assessment. If so, they would rate the productions of bilingual children living in their own country as closer to those of monolinguals than to those of bilinguals living in the other country. Accordingly, Bil-US children speaking French should be perceived by French-speaking participants as more bilingual (higher Elo scores) than Bil-FR children; conversely, Bil-FR children speaking English should be perceived by American English-speaking participants as more bilingual (higher Elo scores) than Bil-US children. Third, we surmise that if the acoustic differences in stress pattern realizations presented above contribute to the monolingual/bilingual ratings, then the Elo scores should correlate with some of the acoustic parameters measured.

4. Methods

4.1 . Participants

Twenty-four French-speaking adults (17 women, age: 19-40 years, M = 27.71, SD = 6.8) participated in Experiment 1, conducted in Paris; 23 American English-speaking adults (15 women, age: 28-60 years, M = 38.9, SD = 13.56) participated in Experiment 2 conducted in Baltimore, U.S. None of the participants had oral or written language impairment or neurological or psychiatric problems and all adults stated they did not have any hearing problems. All participants had a high level of education. Their language level was evaluated through a Linguistic Background Questionnaire. (Marian, Blumenfeld & Kaushanskaya, 2007). French-speaking participants started to learn foreign languages in school at the age of 10-11 years (in the 6th grade). Two of them had spoken French and another language in early childhood, but all of them only used French in their daily life at the time of testing. All American English-speaking participants, except two, had learned another language in school, but all used English in their daily life at the time of testing.

Participants gave written informed consent and were paid around 10 euros for their participation.

4. 2. Materials

Disyllabic words produced by 4 groups of 8 children (mean age 4;6, range: 3;3-6;0) were recorded during a word elicitation task while looking at a picture book in the presence of one experimenter and one parent (for details see Dodane & Bijeljac-Babic, 2017). Two groups were recorded in France: French-speaking monolinguals (Mono-FR) and French/American English bilinguals (Bil-FR) and two (groups were recorded) under similar conditions in

Baltimore : American English-speaking monolinguals (Mono-US) and American English/French bilinguals (Bil-US). As described in Dodane & Bijeljac-Babic (2017), only well produced disyllabic words, produced spontaneously looking at the picture book (thus excluding repetitions after parent's production) were segmented. Among the disyllabic words analyzed in this study for Elo ranking, we only selected words produced by most children, which reduced the number of words to 11 in French and 15 in English (see Appendix for the list of words).

4.3. Procedure

Participants sat in front of a computer in a quiet room and listened to the audio recordings through headphones. Each trial presented a pair of identical words (e.g., *carrot* in English) pronounced by two different children from the 3 groups producing words in the same language (for French: Mono-FR, Bil-FR and Bil-US; For English: Mono-US, Bil-FR and Bil-US). The participants had to determine for each pair which child was bilingual by responding to the question "Who is bilingual?" The instructions given to the French and American listeners were similar. The answers were given on a keyboard by pressing the left arrow to select the first child and the right arrow to select the second one. The trials were set up in such a way that over the entire experiment, every child was compared to every other child: each was compared to another child for one of the words they had in common. Thus, the bilingual children were compared to the monolingual children, but also to the other bilinguals. Similarly, the monolinguals were compared to the bilinguals but also to the other monolinguals of the same language.

The available words were used to create 248 trials in English and 271 trials in French. Six additional trials were used for training, to familiarize the participants with the procedure. The list of trials can be considered a "bilingualism competition" in which each trial represents a "match" between two children. The outcome of these matches is determined by the participants (referred to as "judges").

To avoid biased judgment, participants were not informed that the trials could present two bilingual or two monolingual children. For the same reason, the second language spoken by the children was not specified.

The task consisted of a forced choice after each listening of a pair: the next trial could not be launched until the participant had given an answer. However, a break could be taken after a trial, at any time during the test.

All participants were tested with a different list of trials: the pairs of children not being introduced in the same order and the words for which they were compared not always being the same. At the end of the test for each judge, a program (coded in R — using the package Player Ratings- Stephenson & Sonas, 2016) assigned an Elo score to each child, following the procedure developed by the authors.

In our experiment, the Elo score was calculated based on the number of wins and losses during the competition: a win meant that the child was considered a bilingual after a "match." The Elo rating for each child reflects the probability it will be considered bilingual by a different judge when compared with any other child of the list. Every child started the competition with an Elo score of a 1000 (this score was chosen arbitrarily). When a child "won a match," he/she gained the same number of points as that withdrawn from the score of the losing child. The number of points gained/lost varied depending on the Elo score of the adversary at the time of the competition: the greater the difference of the Elo ratings, the higher the number of points at stake.

$$E_{n+1} = E_n + K\big(W - p(D)\big)$$

$p(D) =$ expected outcome based on both children's current Elo
W = actual outcome
K = multiplier coefficient.

5. Results

A mean value of the Elo scores attributed to each of the 24 evaluations was computed for each of the 24 judges in Experiment 1; the same was done for the 23 evaluations in Experiment 2. Then a ranking of the children was established from the one most often judged as bilingual (with the highest mean Elo scores) to the one least often judged as bilingual (with the lowest mean Elo scores). There is a direct link between the difference in the Elo ratings and the probability of success:

$$p(Success) = \frac{1}{1 + 10^{\frac{-Diff}{400}}}$$

For example, a difference of 50 points between two adversaries indicates that the one with the higher score has a probability of 57% to win a new match.

After each competition, the Elo scores of the winner and the loser are adjusted according to a factor called “K-factor” fixed at 10 in our study. However, Elo scores presented as bilingual evaluations are the results of all competitions (all assessments of the same judge) played over and over until the scores for all children converge. The value of the K-factor does not change the value of the final scores, only the speed of convergence.
Example of Elo points exchanged from loser to winner:

Child#1 Elo rating	**Opponent Elo rating**	**If Child#1 wins**	**If Opponent wins**
REF	REF+10	5.1	4.9
REF	REF+200	7.6	2.4

If REF was equal to 1000, then that child winning against an opponent with an Elo of 1200 would gain 7.6 points (and his/her opponent would lose 7.6 points accordingly). A win against an opponent with an Elo of 1010 would only reward 5.1 points. The more unlikely the outcome, the more points exchanged.

Perception of French productions

The Elo rankings are presented in Figure 1, showing that 7 of the 8 Bil-US children occupy the first place in the ranking which means that in most competitions these children were considered bilinguals. The mean Elo scores for the three groups were: Bil-US = 1063 (SD = 39), Bil-FR = 966 (SD = 78), and Mono-FR = 971 (SD = 47). The participants’ responses were consistent through all 3 groups according to Cronbach’s alpha coefficients: Bil-US = 0.73; Bil-FR = 0.89; and Mono-FR = 0.77.

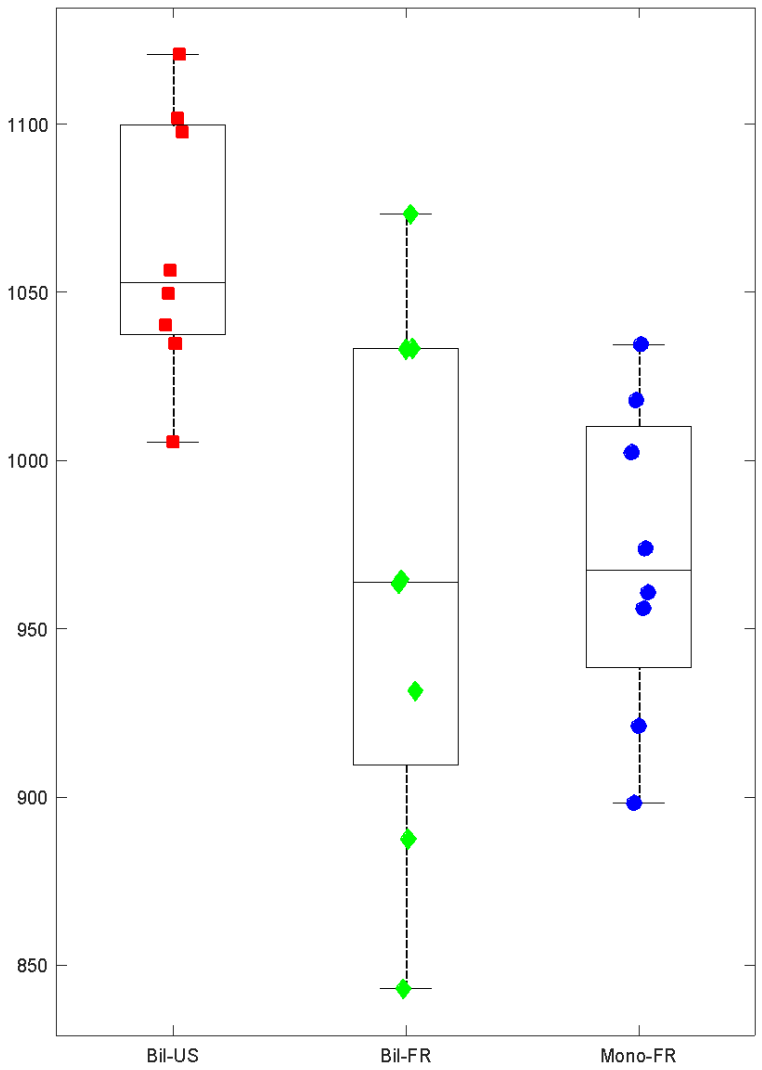


Figure 1. Plots representing the median Elo scores (and SDs) by the **French judges** for the three groups of children: Mono-FR (monolinguals French), Bil-FR (bilinguals French/American English) and Bil-US (bilinguals American English/French). Dots represent Elo scores of individual children

An analysis of covariance (ANCOVA) with Group (Mono-FR vs. Bil-FR vs.BIL-US) as main factor and Age as covariate revealed a significant effect of Group (F (2,18) = 11.53; $p < .001$; $\eta^2 = .38$), which means differences in Elo scores between the 3 groups. Contrast comparisons revealed a significant difference between the Bil-US group and the other two groups (Mono-FR and Bil-FR; $t(18) = 4.78$, $p = .0001$), while the comparison between the Mono-FR and Bil-FR groups failed to reach significance ($t(18) = .52$, $p = .61$). French-speaking adults clearly differentiated bilingual children growing up in a dominant American-English background (Bil-US) from the other 2 groups of children growing up in a dominant French background (whether Bil-FR bilinguals or Mono-FR monolinguals). Yet, they did not discriminate between the Bil-FR bilinguals and the Mono-FR monolinguals.

There was also a significant effect of Age (F (1,18) = 8.81; p = .008; η^2 = .15), older children having lower Elo scores. Moreover, the Group*Age interaction was significant (F (2,18) = 5.06; p = .018; η^2 = .17). This is due to the fact that the effect of Age was significant for the Mono-FR (t(6) = -2.5; p = .04) and the Bil-FR (t(6) = -2.8; p = .03) groups, but not for the Bil-US group (t(6) = 0.8; p = .48).

Perception of English productions

The Elo rankings are presented in Figure 2. Four of the 6 bilingual children dominant in French occupy the first positions in the ranking. Mean Elo scores for the three groups: Bil-FR = 1066 (SD = 117), Bil-US = 978 (SD = 83) and Mono-US = 965 (SD = 55). The participants' responses were consistent across all 3 groups according to Cronbach's alpha coefficient: Bil-FR = 0.96; Bil-US = 0.92 and Mono-US = 0.84.

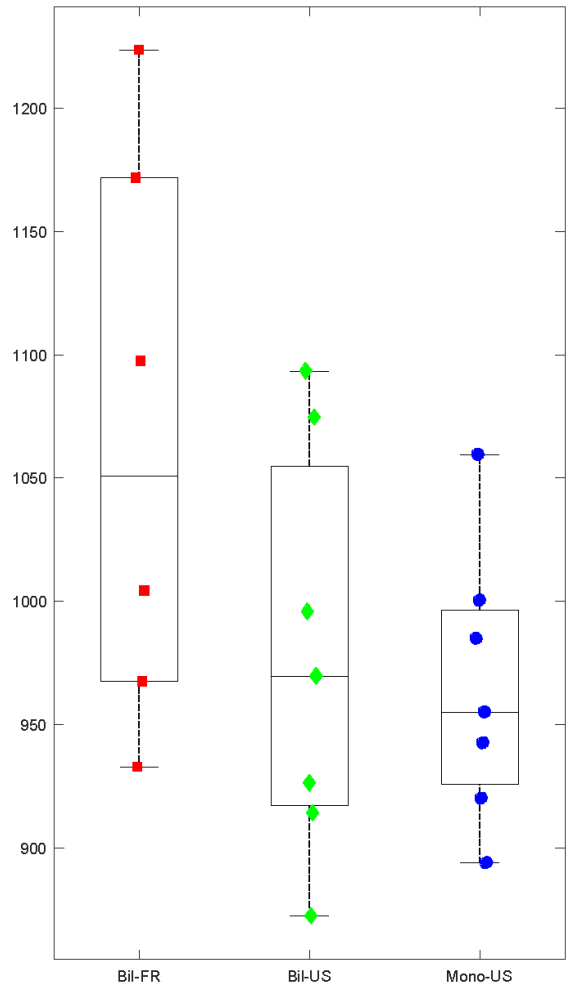


Figure 2. Plots representing the median Elo scores (and SDs) by the **American English** judges for the three groups of children Bil-US (bilinguals American English/French), Bil-FR (bilinguals French/American English) and Mono-US (monolinguals American/English). Dots represent individual children.

An analysis of covariance (ANCOVA) with Group (Mono-US vs. Bil-Us vs. Bil-FR) as main factor and Age as covariate was conducted. None of the effects or interactions reached significance (Group: $F(2,14) = 2.43$; $p = .12$; $\eta^2 = .24$; Age: $F(1,14) = 1.79$; $p = .20$; $\eta^2 = .09$; Group*Age interaction: $F(2,14) < .01$; $p = .99$; $\eta^2 = .00$).

Although there was no Group effect, we performed contrast comparisons between the groups, as done for the analyses on French productions. The contrast between the Bil-FR group and the two other groups (Mono-US and Bil-US) was significant ($t(14) = 2.15$; $p = .05$), while the difference between Mono-US and Bil-US failed to reach significance ($t(14) = 0.51$, $p = .62$). American-English adults differentiated the bilingual children with dominant French background (Bil-FR) from the other group dominant in American-English (whether Bil-US bilinguals or Mono-US monolinguals). Nonetheless, they did not discriminate between Bil-US bilinguals and Mono-US monolinguals.

Impact of language dominance

In order to explore the impact of dominant language background in both experiments, we conducted repeated ANOVA measures with bilingual Group (Bil-FR vs. Bil-US) and language of production (French vs. English) as factors. Although the effects of Group, ($F(1,11) = 0.157$, $p = .69$, and language of production, $F(1,11) = 0.103$, $p = .75$) failed to reach significance, the interaction was significant, $F(1, 11) = 12.8$, $p = .004$. This interaction reflects the fact that when speaking French, Bil-FR are considered less bilingual then Bil-US by French judges (M = 966 vs. M = 1063), and conversely that when speaking English, Bil-US are considered less bilingual then Bil-FR by English-speaking judges (M = 978 vs. M = 1066).

Perception-Production links

In order to compare the data from the acoustic analyses of stress pattern realization (ratio duration, difference *f*0 S1-S2 and relative amplitude) and the Elo scores in both languages for the 4 groups, Pearson correlations were conducted. Only the correlation between the Elo score in French and the duration ratio approached significance ($r = 0.39$, $p = .065$).

6. General discussion

The present study examined how monolingual French and American English adults perceive productions of disyllabic words by monolingual French (Mono-FR), monolingual American-English (mono-US) and bilingual French/American-English children, aged 3;6-6;0. The bilinguals were growing up in bilingual French/American-English families, either in France or in the US, so that the predominant ambient language was French for half of them (Bil-FR), and American English for the other half (Bil-US). The productions had been recorded and acoustically analyzed for lexical stress production by Dodane & Bijeljac-Babic (2017), the group of French/American-English bilinguals living in the US being later recorded and analyzed for the purpose of the current study. There were 8 children in each group.

To assess perception, we used an Elo competition task in which monolingual adult speakers were asked to assess which of two words presented in their native language were pronounced by a bilingual child. Overall, results first demonstrated that in both languages, the bilingual children reached higher Elo scores and were in the upper part of the Elo rankings, compared to monolingual children whose Elo scores were lower and in the bottom part of the Elo rankings. These results thus clearly established that both the French and American-English monolingual adults succeeded in distinguishing the bilingual children from their monolingual peers. Our findings are in line with previous results suggesting that the simultaneous acquisition of two languages by children creates a competition between two different phonological systems. Our perception results further show that when bilingual children start to speak, the cross-linguistic influences that are apparent in their word productions in each language, found before 2 years (Vihman, 2016) but also later, up until at least 6 years of age (Dodane & Bijeljac-Babic, 2017), are salient enough to be perceived and used to determine the monolingual/bilingual status of a child. Since our children were bilingual from birth, our results somehow challenge the idea that the earlier in life a language is acquired the less accented it will be (Piske, MacKay, & Flege, 2001), at least for the early years of acquisition and for the word level evaluated here. Note that for the French productions, we find an effect of age for the French monolinguals and the bilinguals living in France, with lower bilingual ratings with age, suggesting that mastery of the French productions improves with age in these two groups, while it does not in the bilinguals living in the US.

Second, by presenting the raters in our study with stimuli produced by two groups of bilingual French/English children, one living in France and the other living in the US, our study allowed us to investigate whether the predominant ambient language of the society in which the children are being raised (French in Paris, American English in Baltimore) plays a role in how their productions are assessed in each of their languages. We hypothesized that the Bil-US children should be perceived as more bilingual by the French participants rating their French productions, and the Bil-FR should be perceived as more bilingual by the American English participants rating their English productions. This hypothesis was confirmed by our results. Indeed, Bil-US children speaking French were perceived by French-speaking participants as more bilingual (higher Elo scores) than Bil-FR children; conversely, Bil-FR children speaking English were perceived by American English-speaking participants as more bilingual (higher Elo scores) than Bil-US children. In addition, monolingual adults did not differentiate monolingual from bilingual children growing up in their country. In French, the Elo scores for Bil-FR (966) were similar to those for Mono-FR (971), and in English, the Elo scores for Bil-US (978) were similar to those of Mono-US (965). Therefore, our results establish that the bilinguals were better differentiated from the monolinguals in the language that was not the predominant language in the country in which they grew up. These findings are compatible with studies showing that bilingual acquisition is modulated by environmental factors that affect language balance and relative proficiency or dominance (see Höhle, Bijeljac-Babic & Nazzi, 2020, for a discussion of these issues for early development; Mueller Gathercole & Thomas, 2009, for later development). The factors that define dominance are under debate in the literature and may differ depending on the language domain/ability considered. For example, studies of individual variability in simultaneous bilingual adults revealed that speech segmentation is modulated by the bilinguals' preferred language (the one they would like to keep if they were to lose one; Cutler et al., 1989, 1992), phonotactic acquisition by the mother's language (Sebastián-Gallés et al., 2005), lexical stress perception by some measure of early input (Dupoux et al., 2010), whereas rhythmic grouping appeared unmodulated across bilinguals (Boll-Avetisyan et al., 2020). Here, it appears that the language of the country of residence of the bilingual children played an important role in how their productions were evaluated.

Several explanations could be offered for the fact that acoustic differences between bilinguals' and monolinguals' productions were not perceived by the monolingual adults when the bilinguals were dominant in their language. It could be that the adult listeners' perceptual system could accept some degree of deviation from native-accented speech, and/or

could adapt very quickly to the accented speech, as observed for example by Clark & Garrett (2004). Another explanation might concern more general adaptation processes related to higher cognitive and/or social processes, linked to characteristics of the listeners' group. Perception of "foreign" accent in children's productions depended on the extent to which the variations in perceived speech matched the judge's accentual representations. It remains difficult to distinguish between these two possibilities because it is impossible to isolate the effect of linguistic (segmental and suprasegmental) deviations from social and cognitive effects related to the listener's origin.

Finally, to start exploring how variability in the assessment of the two groups of bilinguals relates to specific acoustic properties of their productions, we performed correlation analyses between the Elo scores and the acoustic measures that were available to us, measures that evaluated how the prosodic properties of the words were realized by the children in the 4 groups. No correlation reached significance, failing to reveal links between the perceptual scores by the adults and prosodic correlates of the productions, even though the acoustic analyses had revealed both differences between the productions of the monolingual and bilingual children, and between the productions of the two groups of bilinguals. Additional analyses or new studies will be needed to evaluate the potential contribution of other factors, in particular factors related to the production of the phonemes making up the words.

In conclusion, previous results of the acoustic analyses of word productions by monolingual and bilingual children had suggested that French-English bilingual children produced words that had different lexical stress patterns in each language, but that were also acoustically different from the same words produced by monolinguals (Dodane & Bijeljac-Babic, 2017). The present accent perception study shows that the bilingual children's word productions were perceived differently from those of the monolingual children by both groups of judges, both for their productions in French and those in English. Moreover, the assessment of the children's linguistic status (bilingual vs. monolingual) appeared to be influenced by the predominant ambient language in the society in which they grow up. Given that this is the first study on the perception of bilingual children's accent by adult speakers, further studies will be needed to explore the link between the acoustic characteristics of the productions, at all relevant linguistic levels (phonetic, prosodic, …), and accent perception, and to go beyond the lexical level tested here. Additional studies will be also needed to investigate these phenomena in children acquiring other pairs of languages, that differ on different linguistic dimensions, and who are more or less linguistically related (see Havy, Bouchon & Nazzi,

2016, and Höhle et al. 2020, for a discussion on linguistic distance). Lastly, it would also be important to carry out the same perception study with bilingual adult speakers, dominant in one or the other language, to determine how accent is perceived by bilinguals themselves.

7. References

Abboub, N, Bijeljac-Babic, R, Serres, J. & Nazzi, T. (2015). On the importance abilities in infants from bilingual environments. *Infancy, 2*, 29–49.

Adank, P., Evans, B., Stuart-Smith, J., & Scotti, S. (2009). Comprehension of familiar and unfamiliar native accents under adverse listening conditions. *Journal of Experimental Psychology: Human Perception and Performance, 35*, 520–529.

Bassano, D., Labrell, F., Champaud, C., Lemétayer, F., & Bonnet, P. (2005). Le DLPF : un nouvel outil pour l'évaluation du développement du langage de production en français. *Enfance*, *2*, 171-208.

Best, C. T., Hallé, P. A., Bohn, O.-S., & Faber, A. (2003). Cross-language perception of nonnative vowels: Phonological and phonetic effects of listeners' native languages. In M. J. Solé, D. Recasens & J. Romero (Eds.), *Proceedings of the 15th International Congress ofPhonetic Sciences* (pp. 2889-2892). Barcelona: Causal Productions.

Best, C.T. & Tyler, M.D. (2007). Nonnative and second-language speech perception: Commonalities and complementarities. In: Bohn, O.; Munro, MJ., editors. *Language experience in second language speech learning:* In honor of James Emil Flege. Amsterdam: John Benjamins; pp. 13-34.

Bijeljac-Babic, R., Höhle, B. & Nazzi, T. (2016). Early prosodic acquisition in bilingual infants: The case of the perceptual trochaic bias. *Frontiers in Psychology*, 7, 210. doi:10.3389/fpsyg.2016.00210

Bijeljac-Babic R, Serres J, Höhle B & Nazzi T (2012). Effect of bililngual- ism on lexical stress pattern discrimination in French-learning infants. *PLoS ONE*, 7(2), e30843. doi:10.1371/journal.pone.0030843

Birdsong, D. (2007). Nativelike pronunciation among late learners of French as a second language. In O.-S. Bohn & M. J. Munro (Eds.), *Language experience in second language speech learning* (pp. 99‑116). Amsterdam: John Benjamins. DOI: 10.1075/lllt.17.12bir

Birdsong, D. (2014). Dominance and Age in Bilingualism, *Applied Linguistics , 35/4*, 374–392, 2014doi:10.1093/applin/amu031

Boersma, P., & Weenink, D. (2009). Praat, a system for doing phonetics by computer. (version 5.0), https://www.fon.hum.uva.nl/praat/download_win.html.

Boll-Avetisyan, N., Bhatara, A., Unger, A., Nazzi, T. & Höhle, B. (2020). Rhythmic grouping biases in simultaneous bilinguals. *Bilingualism: Language and Cognition*, 1–12. https://doi.org/10.1017/S1366728920000140

Bosch, L., & Sebastián-Gallés, N. (2001). Evidence of early language discrimination

Clarke, C. M., & Garrett, M. F. (2004). Rapid adaptation to foreign-accented English. *The Journal of the Acoustical Society of America, 116*(6*)*, 3647–3658.

Cristia,A., Seiddl, A., Vaughn, C., Schmale, R., Bradlow, & Floccia, C. (2012). Linguistic processing of accented speech across the lifespan. *Frontiers in psychology, 3*, 2-14. https://doi.org/10.3389/fpsyg.2012.00479Cutler & Carter, 1987

Cutler, A., & Carter, D. (1987). The prosodic structure of initial syllables in English. In J. Laver, & M. Jack (Eds.), *Proceedings of the European Conference on Speech Technology*: Vol. 1 (pp. 207-210). Edinburgh: IEE.

Cutler, A, Mehler, J, Norris, D & Segui, J. (1989). Limits on bilingualism. *Nature*, *340*, 229–230.

Cutler, A, Mehler, J, Norris, D & Segui, J (1992). The monolingual nature of speech segmentation by bilinguals. *Cognitive Psychology, 24*, 381–410.

Delattre, P. (1965). *Comparing the Phonetic Features of English, French, German and Spanish*. Heidelberg: Julius Gross Verlag.

Derwing, T.M., Rossiter,M.J., Munro, M.J. , & Thomson, R.I. (2004). Second Language Fluency: Judgments on Different Tasks. *Language Learning, 54 (4)*, 655–679.

Di Cristo, A. (1998). Intonation in French. In D. Hirst. & A. Di Cristo (Eds.). *Intonation Systems: A survey of Twenty Languages* (pp. 195-218). Cambridge: Cambridge University Press,

Dodane C &. Bijeljac-Babic R. (2017). Cross-language influences in the productions of French-English bilingual children: Separation or interaction? in M. Yavas, M. Kehoe et W. Cardoso (éds.), *Romance-Germanic Bilingual Phonology* (pp. 38-55). Sheffield, Equinox Publishing Ltd,.

Dupoux, E, Peperkamp, S & Sebastian-Gallés, N. (2010). Limits on bilingualism revisited: stress ‘deafness’ in simultaneous French–Spanish bilinguals. *Cognition, 114*, 266–275. doi:10.1207/S15327078IN0201_3

Dupoux, E., Pallier, C., Sebastián-Gallés, N. and Mehler, J. (1997). A destressing ‘deafness’ in French? *Journal of Memory and Language, 36*, 406–421. doi:10.1006/jmla.1996.2500

Dupoux, E., Peperkamp, S. & Sebastián-Gallés, N. (2001). A robust method to study stress 'deafness'. *The Journal of the Acoustical Society of America*, 110, 1606–1618. doi:10.1121/1.1380437

Dupoux, E., Peperkamp, S. & Sebastián-Gallés, N. (2010) Limits on bilingual- ism revisited: Stress 'deafness' in simultaneous French-Spanish bilinguals. *Cognition*, 114, 266–275. doi:10.1016/j.cognition.2009.10.001

Fenson, L., Dale, P., Reznick, S., Thal, D., Bates, E., Hartung, J., Pethick, S. & Reilly, J. (1993). *MacArthur Communicative Development Inventories: User's guide and technical manual*. San Diego, CA: Singular Publishing.

Féry, C., Hörnig, R., & Pahaut, S. (2011). Correlates of phrasing in French and German from an experiment with semi-spontaneous speech. In C. Gabriel and C. Lleó (Eds.), *Intonational Phrasing in Romance and Germanic: Cross-linguistic and Bilingual Studies* (Amsterdam: John Benjamins Publishing Company), Vol. 10, pp. 11–42.

Flege, J.E. & MacKay, 2004. Perceiving vowels in a second language. *Studies in Second Language Acquisition, 26*, 1-34.

Flege, J. E. (1984). The detection of French accent by American listeners. *Journal of the Acoustical Society of America*, *76*(3), 692‑707.

Floccia, C., Butler, J., Girard, F., & Goslin, J. (2009). Categorization of regional and foreign accent in 5- to 7-year-old British children. *The International Journal of Behavioral Development, 33*, 366–375.

Girard, F., Floccia, C., & Goslin, J. (2008). Perception and awareness of accents in young children. *British Journal of Developmental Psychology*, *26*(3), 409–433.

Goslin, J., Duffy, H., & Floccia, C. (2012). An ERP investigation of regional and foreign accent processing. *Brain and Language*, *122*, 92–102,

Hallé, P., Chang, Y-C., & Best, C. (2004). Categorical perception of Taiwan Mandarin Chinese tones by Chinese versus French native speakers. *Journal of Phonetics, 32*, 395-421.

Havy, M., Bouchon, C. & Nazzi, T. (2016). Phonetic processing when learning words: The case of bilingual infants. *International Journal of Behavioral Development, 40*, 41–52. doi:10.1177/0165025415570646

Hoff, E, Core, C., Place, S., Rumiche, R., Señor, M. & Parra. M. (2012). Dual language exposure and early bilingual development. *Child Language, 39*, 1–27. doi:10.1017/S0305000910000759

Höhle, B, Bijeljac-Babic, R., & Nazzi, T. (2020). Variability and stability in early language acquisition: Comparing monolingual and bilingual infants' speech perception and word recognition. *Bilingualism: Language and Cognition, 23,* 56-71. https://doi.org/10.1017/S1366728919000348

Kuhl P. (1993). Innate predispositions and the effects of experience in speech perception: The native language magnet theory. In B. de Boysson-Bardies, S. de Schonen, P. Jusczyk, P. McNeilage and J. Morton (Eds.), *Developmental Neurocognition: Speech and Face Processing in the First Year of Life*. Dordrecht: Springer.

LaBelle, C. (2000). A longitudinal study of lexical and prosodic differentiation by simultaneous French/English bilingual child. In C. Howell, S. Fish & T. Keith-Lucas (Eds.), *Proceedings of the 24th Annual Boston University Conference on Language Development,* Somerville, MA: Cascadilla Press.

Ladefoged, P. (1975). *A Course in Phonetics*. New York: Harcourt Brace Jovanovich.

Major, R.C., (2007). Identifying a foreign accent in an unfamiliar language. *Studies in Second Language Acquisition. 29,* 539–556.

Marian, V., Blumenfeld, H. K. & Kaushanskaya, M. (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech, Language, and Hearing Research, 50,* 940–967.

Marchman, V.A., Fernald, A. and Hurtado, N. (2010). How vocabulary size in two languages relates to efficiency in spoken word recognition by young Spanish-English bilinguals. *Journal of Child Language, 37,* 817–840. doi:10.1017/S0305000909990055Mueller

Munro, M.J., Derwing, T.M. & Morton, S.L. (2006). The mutual intelligibility of l2 speech, *Studies in Second Language Acquisition, 28,* 111-131.

Munro, M.J., Derwing, T.M & C.S. Burgessa (2010). Detection of nonnative speaker status from content-masked speech. *Speech Communication, 52,* 626–63.

Munro, M.J., & Derwing, T.M. (2015). A prospectus for pronunciation research in the 21st century. *Journal of Second Language Pronunciation 1,* 11–42. doi 10.1075/jslp.1.1.01mun

Mueller- Gathercole, V. C. & Thomas, E. M. (2009). Bilingual first-language development: Dominant language takeover, threatened minority language take-up *Bilingualism: Language and Cognition 12,* 213–237.

Paradis, J., Crago, M., Genesee, F., & Rice, M. (2003). Bilingual children with specific language impairment: How do they compare with their monolingual peers? *Journal of Speech, Language,and Hearing Research, 46,* 1–15.

Pearson, B.Z., Fernández. S.C. & Oller, D.K. (1993). Lexical development in bilingual infants and toddlers: Comparison to monolingual norms. *Language Learning, 43,* 93–120. doi:10.1111/j.1467-1770.1993.tb00174.x

Pinget, A.F., Bosker, H.R., Quene, H. & de Jong, N.H. (2014). Native speakers' perceptions of fluency and accent in L2, *Langauge Testing, 3,* 349–365.

Piske,T., MacKay, J. R. A. & Flege, J. E. (2001). Factors affecting degree of foreign accent in an L2: a review. *Journal of Phonetics, 29,*191-215. http ://doi:10.006/jpho.2001.0134.

Polka L, Orena A.J, Sundara, M. & Worrall, J. (2017). Segmenting words from fluent speech during infancy – challenges and opportunities in a bilingual context. *Developmental Science, 20,* e12419. doi:10.1111/ desc.12419

Rose, Y. & Champdoizeau, C. (2008). There is no trochaic bias: Acoustic evidence in favor of the neutral start hypothesis," In A. Gavarro and M.J. Frietas (Eds.), *Language Acquisition and Development: Proceedings of GALA 2007* (pp. 359 - 369). Newcastle: Cambridge Scholars Publishing.

Rossi, M. (1980). Le français, langue sans accent? [French: A non-stressed language?]. In I. Fonagy & P. Léon (Eds.), *L'accent en français contemporain* [Stress in modern French] (pp. 13–51). Paris: Didier.

Sebastián-Gallés, N. & Bosch, L. (2002). Building phonotactic knowledge in bilinguals: Role of early exposure. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 974–989. doi:10.1037/0096-1523.28.4.974

Sebastián-Gallés, N., Echeverria, S. & Bosch, L. (2005). The influence of initial exposure on lexical representation: Comparing early and simultaneous bilinguals. *Journal of Memory and Language, 52,* 240–255.

Stephenson, A. & Sonas, J. (2016). *PlayerRatings: Dynamic Updating Meth-ods for Player Ratings Estimation.* URLhttps://CRAN.R-project.org/package=PlayerRatings. R package version 1.0-1.

Vaissière, J. (1991). Rhythm, accentuation and final lengthening in French. In: J. Sundberg, L. Nord, & R. Carlson (Eds.), *Music, Language, Speech and Brain :* Macmillan Press, pp.108-120.

Vihman, M.M., and DePaolis, R.A. (1998). Perception and production in early vocal development: Evidence from the acquisition of accent. In M. C. Gruber, D. Higgins, K. S. Olson, & T. Wysocki (Eds.), *Chicago Linguistic Society 34, Part 2: Papers from the panels* (pp. 373‑386). Chicago, IL: CLS.

Vihman, M.M. (2016). Prosodic structure and templates in bilingual phonological development. *Bilingualism: Language and Cognition*, *19*, 69-88. http://dx.doi.org/10.1017/S1366728914000790

Appendix

1. Participants

Eight French-English bilingual children (Bil-FR) born and living in Paris or the surrounding region (4 girls and 4 boys, mean age: 4;8, range: 3;5-6;0). These children have been regularly exposed to both languages, their mothers being native American English speakers and their fathers, native French speakers; 8 French-English bilingual children (Bil-US) born and living in Baltimore, US or the surrounding region (4 girls and 4 boys, mean age: 4;8, range: 3;5-6;0). These children have been regularly exposed to both languages, their mothers being native French speakers and their fathers, native American-English speakers; 8 monolingual French children born and living in Poitiers, France (Mono-FR), all with monolingual parents (4 girls and 4 boys, mean age: 4;5, months, range: 3;3-6;0); 8 monolingual English children born and living in Baltimore, US (Mono-US), all with monolingual parents (5 girls and 3 boys, mean age: 4;6 months, range: 3;7-5;5).

To assess the vocabulary of the bilingual children, we asked parents (or teachers for the French monolingual group) to complete the CDI (Communicative Development Inventory) for English (Fenson, Dale, Reznick, Bates, Thal, Pethik & Reilly, 1993) and a version of the same questionnaire adapted to the vocabulary of French children (Bassano, Labrell, Champaud, Lemétayer & Bonnet, 2005) in order to be certain that the children know the words that we included in the picture book.

A child's language exposure was measured by an adapted version of the Language Exposure Questionnaire (Bosch & Sebastián-Gallés, 2001) to obtain specific estimates of the child's exposure to each language from all possible language partners (e.g., parents, grandparents). Average French exposure for the American- English/French bilingual group from Baltimore was 42%, average American-English, exposure for the French-American-English bilinguals was 52%.

2. Stimuli and recording procedure

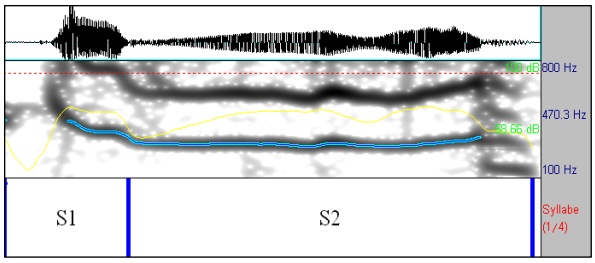
The words illustrated in the picture book are presented in Table 1. The words in BOLD are the words which are used for the current Elo experiment.

Bébé-baby	Lion-**lion**	**Carotte-carrot**	Roche-rock	Robe-dress	Bouche-mouth	Maison-house
Table-**table**	Singe-**monkey**	**Orange-orange**	Trou-hole	Voiture-car	Cheveux-hair	**Garage-garage**
Fourchette-fork	**Tigre-tiger**	**Tomate**-tomato	Parachute-parachute	**Docteur-doctor**	Brosse-hairbrush	Guitare-**guitar**
Verre-glass	Zèbre-**zebr**a	Pomme-**apple**	**Camion**-truck	Bleu-blue	Nez-nose	Sandale-sandal
Biscuit-cookie	Serpent-snake	Vert-green	Coquillage-shell	Chemise-shirt	Pyjama-pyjamas	Porte-door
Fromage-cheese	Renard-fox	**Poulet-chicken**	Panier-basket	Chaussette-sock	Lavabo-washbowl	Douche-**shower**
Biberon-baby bottle	Crocodile-crocodile	Patate-potato	Livre-book	Pantalon-trousers	Robinet-tap	Parapluie-umbrella
Fleurs-flowers	**Girafe-giraffe**	Chien-dog	Poupée-doll	Montre-watch	Peigne-comb	Tracteur-tractor

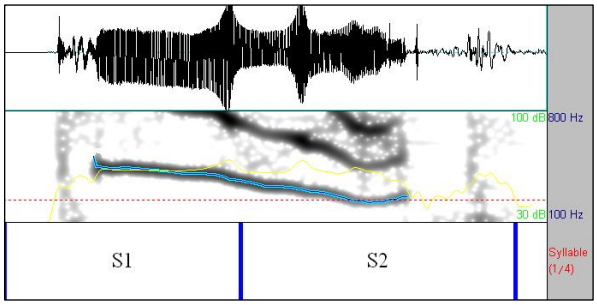
The recording of the children's production occurred during the word elicitation task in which the children had to produce 40/32 disyllabic words in French/English while looking at a picture book. Out of the 40 disyllabic words in French and 32 in English, bilingual French-American/English (Bil-FR) children produced 16 to 23 words (mean: 19.2) in French and 13 to 27 words (mean: 18.9) in English. The French monolinguals (Mono-FR) produced 24 to 39 words (mean: 29.2). The American-English-French (Bil-US) produced 6-15 words (mean: 12. 4) in French and 6-25 (mean: 18.8) in English. The American-English monolinguals (Mono-US) produced 12 to 22 words (mean: 14.3). Overall, 510 tokens of disyllabic words were analyzed.

3. Segmentation and acoustic measurements.

Each disyllabic word was manually segmented from 25-30 minutes of continuous recording with the Praat software (Boersma & Weenink, 2009), using the simultaneous display of the sound waveform and a wideband spectrogram (frequency range: 0-8000 Hz, analysis bandwidth: 260 Hz, pre-emphasis: 6dB/octave, dynamic range: 50 dB). One annotation sheet was created, which corresponded to syllabic segmentation (see Figure 1 for an example).



(a)



(b)

Figure 1. Waveforms (upper panels) and spectrograms (lower panels) of disyllabic words: (a) “carotte” produced by a bilingual child in French and (b) “carrot” produced by a bilingual child in English with *f*0 contour (in Hz, scale 100-800 Hz) indicated in the blue line and intensity contour (in dB) indicated in the yellow line.

The acoustic analyses were based upon the segmented syllables and included measures of duration (in ms), fundamental frequency (*f*0 in Hertz) and intensity (in dB) for a total of 510 words. The duration was extracted for all syllables. Then, we calculated the syllabic duration ratio to determine the presence of final lengthening on S2 or on the contrary, a lengthening on S1. The mean *f*0 was extracted for each syllable and subsequently, we computed the mean interval between S1 and S2 in semitones, using the following equation to calculate for each syllable (Semitone = 39.86 $\log_{10}$ (*f0* S1 or S2/*100*). A negative value indicated higher *f*0 on the second syllable, but the most important fact was the value of the interval: the higher the value, the greater the perceptual distance between syllables. The intensity values were extracted for each syllable (in dB), and the relative intensity was determined by computing the ratio of the Root-Mean Square energy (RMS in dB) of the selected syllable (S1 or S2) to the RMS energy of the loudest point in the selected word.

Measures of reliability were carried out to evaluate the segmentation made by the two authors for 10 % of the words chosen randomly (50 words in French and 50 words in English). The percentage of exact agreement between the authors was 89,5 %.

The means for the three acoustic parameters, broken down by language of production and child group, are given in Table 1 of the paper, and the main results and statistical analyses are presented in the introduction of the paper.