The Acquisition of Language-Specific Sound Categories from a Bilingual Input

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1. Introduction

From a global perspective, bilingual language acquisition can be considered the norm rather than the exception. In bilingual communities around the world, infants exposed from birth to two different languages, or even dialects, succeed in the task of simultaneously learning their two native languages. Infants growing up in this type of environments are exposed to a complex input that contains information relative to two different phonological systems. Early in development bilingual-to-be infants must be able to differentiate the sound patterns of their two languages and start building language-specific phonetic categories. Research on young bilinguals' phonetic categorization and perceptual reorganization processes by the end of the first year of life has revealed interesting differences between consonant and vowel categories. Once in the lexical stage, phonetic categories already established will turn into the contrastive categories that form the phonological systems for each of the ambient languages. This is by no means an automatic process. Data from studies with monolingual toddlers participating in word learning tasks have revealed that minimal pair word labels, differing in their initial stop consonant, such as [bih] and [dih], cannot be easily learned at 14 months of age, even though /b/ and /d/ contrastive sounds can be discriminated with no difficulty at the same age (Stager & Werker, 1997). In the case of bilingual toddlers, engaged in the process of establishing two lexicons based on two distinct phonological systems, the situation is even more challenging.

There are still relatively few studies specifically focusing on bilinguals' setting up the phonetic and phonological categories of their native languages (see Werker & Byers-Heinlein, 2008, for a review). Experimental data come mostly from three research groups settled in areas where bilingual populations are available for participation in speech perception studies: J. Werker group at the University of British Columbia in Vancouver (Canada), L. Polka group at McGill University in Montreal (Canada) and the group at the University of Barcelona (Spain) whose main findings will be described in the following sections. Researchers from the above mentioned groups, dealing with bilingual infants and toddlers from various language communities and exposed to different pairs of languages, have all contributed to shed light on the adaptability of the speech processing system to cope with different types of linguistic input.

What previous research in bilingual language development had told us, from a general perspective, was that the pattern of acquisition in bilinguals was rather similar to the pattern of acquisition that had been described for monolingual infants: an early language differentiation was suggested as words in both of the ambient languages were present in their initial expressive lexicons (Genesee, Nicoladis & Paradis, 1995; Pearson, Fernández & Oller, 1995) and they followed the same steps as monolinguals' in reaching the key milestones in the language acquisition process (Oller, Eilers, Urbano & Cobo-Lewis, 1997). From a phonological acquisition perspective, however, input to bilinguals has specific properties and clearly differs from monolingual input, not only in complexity (two lexicons, two phonologies), but also in quantity and quality of exposure to each language. Moreover, the degree of proximity between the specific lexical, phonological and morpho-syntactical properties of the two ambient languages is also a relevant factor to be taken into consideration. The complex and variable nature of the input to bilingual infants and toddlers can determine minor time-course differences in reaching specific sound discrimination abilities or in stabilizing certain phonetic categories when comparing bilingual and monolingual infants. But, more interestingly, similarities or differences in the phonetic and phonological properties of the two languages in the input can result in differences in perception/discrimination abilities observed in groups of bilinguals from different linguistic environments. Language differentiation processes, the setting up of language-specific phonetic categories, phonological representation of sounds in the lexicon, might differ when comparing bilinguals from different pairs of languages.

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There has been an important progress in bilingual infants' speech perception and bilingual language acquisition research in recent years, but the picture is still far from complete. A cross-linguistic approach to bilingual language acquisition is, thus, highly relevant to improve our current understanding of the adaptive processes that characterize bilinguals' coping with their two input languages and their building of the corresponding language-specific phonetic categories and phonological representations.

In this paper, a review of the main results obtained in infants' phonetic discrimination studies, comparing different bilingual and monolingual populations, will be presented and the role of different factors in bilinguals' phonetic categorization and phonological representation processes will be discussed. In the following section, and before reviewing the main results from phonetic categorization and phonological representation studies, data from early language differentiation abilities in bilinguals will be presented, as this ability is relevant for setting up language-specific phonetic categories.

2. Language differentiation abilities in the first months of life

An early language differentiation seems to be crucial in order to avoid delay or confusion in language acquisition processes in bilingual-to-be infants. Language differentiation studies have mainly been done on monolingual populations. It has been established that newborns can distinguish between pairs of languages if they differ in their rhythmic or prosodic structure, but not between languages that belong to the same rhythmic category (Mehler, Jusczyk, Lambertz, Halsted, Bertoncini & Amiel-Tison, 1988; Nazzi, Bertoncini, & Mehler, 1998). For infants in bilingual environments, prosodic information could also be helpful in setting the languages apart after a few months of exposure. However, not all bilingual infants are exposed to languages from different rhythmic categories. It can then be hypothesized that a later differentiation might be characteristic of infants exposed to rhythmically close languages, such as Spanish and Catalan, both belonging to the syllable-timed language category (Ramus, Nespor, & Mehler, 1999). Actually, a possible delay in language differentiation for bilinguals exposed to languages from the same rhythmic class was predicted by the TIGRE (Time and Intensity Grid Representation) model (Mehler, Dupoux, Nazzi, & Dehaene-Lambertz, 1996).

In order to test this hypothesis, a series of experiments with infants from monolingual and bilingual families (Catalan-Spanish bilinguals) were run in the laboratory at the University of Barcelona. Results showed that by four and a half months of age bilingual infants seem to be able to tell apart both languages (Bosch & Sebastián-Gallés, 2001). Using a familiarization-preference procedure, infants were first familiarized to six different utterances in their maternal language (either Catalan or Spanish, depending on the language predominantly spoken by their mother), and when they had accumulated two minutes of attention to this material, they were tested on eight novel utterances, half in the same language of the familiarization phase and half with a switch in the language. Language discrimination was observed in mean attention time differences to switch and same trials, with longer listening time to trials with a switch in the language. The same experiment was run with infants from monolingual homes and similar results were obtained. It was concluded that these two languages can be differentiated rather early in life, independently of the level of exposure and, crucially, simultaneous bilingual exposure did not seem to delay this language differentiation process. From research done on the discrimination between languages from the stress-timed category (such as English and Dutch), it has been established that differentiation is reached around 5 months of age, not earlier (Nazzi, Jusczyk, & Johnson, 2000). If 4 to 5 months of age is the time when monolingual infants reach a within-category language differentiation, our bilingual infants results on the Catalan-Spanish differentiation task at 4 ½ months of age are perfectly in time and no delay can be attributed to bilingual exposure.

This discrimination capacity is considered to be related to the specific characteristics of infants' native language representation, which gradually includes fine-grained details on the specific rhythmic and prosodic information of the language (Nazzi et al., 2000). However, additional experiments run in our lab on infants' ability to differentiate between Spanish or Catalan (maternal language) and Italian (a non-familiar language from the same syllable-timed category), revealed that 4 ½ month-old monolinguals could not distinguish between Spanish and Italian, while succeeding in the Catalan vs. Italian discrimination (Bosch & Sebastián-Gallés, 2000). The failure to reach an Italian vs. Spanish differentiation suggested that information other than (or in addition to) prosody might be more reliably used as a cue for discrimination. It was then hypothesized that frequency and distribution of vowels in the speech signal could yield relevant information at least in this case, as Italian and Spanish show a

more similar distribution of vowel sounds than Catalan, a language in which central vowels /a/ and schwa count for more than half of the total number of vowels present in fluent speech. These results emphasize the importance of distributional cues, segmental rather than prosodic, to help reach finer discriminations between the native language and a non-familiar one. In bilingual exposure, attention to specific prosodic and distributional cues of syllabic or segmental units in the speech signal may help the infant reach an early differentiation between the languages and establish the basis for setting up the different phonetic categories for each of the languages in their environment.

3. Setting up native-language sound categories

This early language differentiation in bilinguals sets the ground for building language-specific files for sound categories in each language. However, there is no clear evidence supporting this hypothetical process. Tuning to the sounds in the native language, a perceptual reorganization process that takes place in the second half of the first year of life, may occur separately for each of the languages of the bilingual or, what seems more plausible, it can begin as a gradual organization of native-sound categories present in the whole linguistic input, initially involving both languages and becoming language-specific later in time. Which of these two options is the best account for the actual perceptual reorganization processes in bilingual infants remains an open question. Early lexical development is probably going to play a significant role in the final organization of categories into language-specific files.

In monolingual language acquisition, these perceptual reorganization processes that occur as a consequence of language experience have been described to take place earlier for vowels than for consonants (Polka and Werker, 1994; Werker and Tees, 1984). Attunement implies not only a decline in sensitivity for non-native contrasts, but also improved sensitivity to native ones (Kuhl, Stevens, Hayashi, Deguchi, Kiritani & Iverson, 2006; Polka, Colantonio & Sundara, 2001). Electrophysiological correlates of this fine-tuning to the sounds in the native language have also been found (Cheour, Ceponiene, Lehtokoski, Luuk, Allik, Alho, Näätänen, 1998; Rivera-Gaxiola, Silva-Preyra & Kuhl, 2005). But, which is the mechanism behind these language-specific changes in phonetic sensitivity? A powerful learning mechanism that is able to extract statistical regularities out of the input has been suggested (Maye, Werker & Gerken, 2002; Maye, Weiss & Aslin, 2008). These authors have proposed a distribution-based model according to which infants' perceptual changes result from their sensitivity to distributional properties of input speech. From this perspective, contrastive categories will eventually be acquired on the basis of how frequently certain sounds can be heard in a given phonetic context. Even acknowledging the important variability present in individual instances of a given speech sound, both within and between speakers, distinct categories can eventually emerge from the input if within-category variability is constrained enough so that clusters of similar sounds can be formed (Vallabha, McClelland, Pons, Werker & Amano, 2007). A distributional learning account has been shown to provide a satisfactory explanation for sound category formation, both in infant and adult studies, when categories are sufficiently distinct (Ashby & Waldron, 1999; Maye et al., 2002). This is an interesting restriction to be taken into account as it can explain certain differences in category stabilization for monolingual infants, but also differences, usually identified as slight delays, for bilingual infants who are dealing with information in a more crowded phonetic space. This possibility has been considered in current models of infant speech perception, even if they have not been designed to specifically deal with bilingual situations. The Native Language Neural Commitment Model (NLNC, by Kuhl, 2004) explicitly mentions the possibility that infants' phonetic distributions will take longer to stabilize in bilinguals due to the complex nature of their input, as they are hearing two languages with distinct statistical and prosodic properties. PRIMIR Model (Processing Rich Information from Multidimensional Interactive Representations, by Werker & Curtin, 2005) makes no specific predictions for bilingual acquisition in terms of differences or delays, but it is acknowledged that input representations and later word learning processes are certainly more demanding from a computational perspective in bilingual contexts.

3.1. Perceptual reorganization processes in bilingual exposure: vowels

The study of perceptual reorganization processes in bilinguals has been addressed at the University of Barcelona infant lab in the last few years. For bilingual children the outcome of these perceptual

reorganization processes should be compatible with the existence of two separate sound systems corresponding to the two languages in their environment. However, due to specific characteristics of the phonetic inventories, number of contrastive categories and acoustic overlap of sounds in both languages, as well as differences in frequency and distributional information in speech input, certain vowel and consonantal categories could show a different developmental time-course in a monolingual bilingual comparison. Differences between Spanish and Catalan sound systems are mainly located in the vowel and fricative categories. These are, then, the most challenging areas for bilinguals, in which specific processes might be found in their building of the corresponding categories for each of the two languages in their environment.

Research was initially focused on mid-front vowels. Spanish has a single mid-front /e/, where Catalan has two distinct /e/ and /ɛ/ categories in this area. Catalan and Spanish /e/ vowel categories do not perfectly match (Bosch, Costa & Sebastián-Gallés, 1994) and their frequency in the input is also very different, with Spanish /e/ being much more frequent than both Catalan /e/ and /ɛ/ vowels taken together (around 30% in Spanish *versus* less than 10% in Catalan). This is, thus, a clear example of a conflicting area in the perceptual space where three categories have to be set up, two of them showing an imperfect match but, at the same time, being heard more often in Spanish-Catalan bilingual environments. Results from an experiment comparing infants form monolingual and bilingual families at 4, 8 and 12 months of age using the familiarization-preference procedure to test for discrimination of the Catalan /e/ and /ɛ/ vowels revealed a particular developmental pattern in bilinguals (see Figure 1). While younger infants were all able to perceive this contrast, independently of the language of exposure (recall that at that young age discrimination is still language-general and no perceptual reorganization processes are active yet), by eight months of age, only infants from Catalan monolingual environments succeeded. When tested at 12 months of age, bilinguals' results indicated that they eventually achieved discrimination and their behavior was similar to that found in monolinguals four months younger (Bosch & Sebastián-Gallés, 2003a).

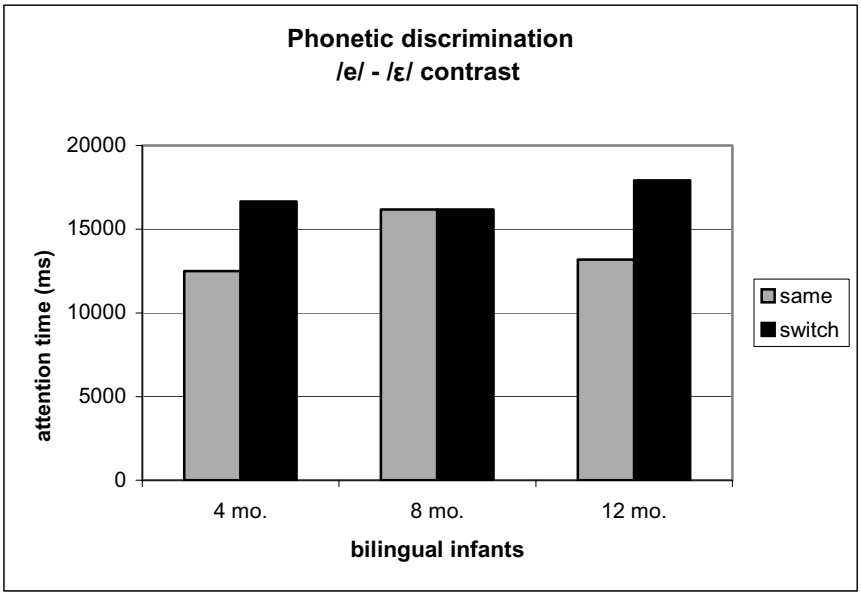

Figure 1: Mean attention time to same and switch trials in the test phase of a phonetic discrimination experiment on the Catalan /e/ - /ɛ/ contrast. Participants were three independent groups aged 4, 8 and 12 months from Catalan-Spanish bilingual homes (adapted from Bosch & Sebastián-Gallés, 2003a).

This U-shaped developmental pattern in bilinguals challenges the view that mere exposure is enough to maintain the capacity to perceive a contrast and suggests specific perceptual reorganization processes that might last longer for infants having to cope with two separate sound systems. This particular pattern may be accounted for by the distributional-based model (Maye et al., 2002), as a unimodal distribution for all these mid-front vowels may initially be formed and only when more

instances of these sounds are experienced, the adequate categorization will eventually be reached. It can be then considered an exceptional situation due to frequency factors and the specific location of these three vowels in the perceptual vowel space. In order to further analyze this possibility, a second series of experiments were run in our lab on the discrimination of a different vowel contrast, this time a common contrast present both in Catalan and Spanish. Using the same procedure as in the previous experiment and also testing bilinguals at three different ages, the capacity to discriminate the high back /o/ - /u/ vowel contrast was explored (Bosch & Sebastián-Gallés, 2005; Sebastián-Gallés & Bosch, 2009). This is a shared contrast between these two languages and, even if an imperfect overlap for both /o/ and /u/ sound categories could be identified, the prediction in this case was that discrimination could follow the standard developmental pattern, that is, maintenance of the discrimination capacity from 4 to 12 months of age. However, this was not the case. Bilinguals showed again the U-shaped pattern, with no evidence of discrimination at 8 months of age; their behavior in the task was similar what had been found for the mid-front vowel contrast in our previous experiment. Only when tested on an acoustically distant vowel contrast (/e/ - /u/) bilinguals showed maintenance of the discrimination capacity already present at 4 months of age (Bosch & Sebastián-Gallés, 2005; Sebastián-Gallés & Bosch, 2009).

Taken together, these results offer valuable information about the challenging task of partitioning the vowel space and beginning to set up language-specific categories that must correspond to the categories in each of the two languages in the bilinguals' environment. From these data on vowel discrimination and categorization a number of factors seem to play a relevant role. First, it is possible that acoustic proximity between categories, a phenomenon often found in crowded vowel space that is characteristic in bilinguals, constrains the initial setting up of the categories. But beyond proximity or crowdedness, specific distributional factors do play a role. Particular distributions may enhance or reduce the distances among vowel elements in the process of building native sound categories. But proximity and frequency factors cannot solely account for the whole set of data just presented. In order to explain results from the experiment on the /o/ - /u/ common contrast, an additional factor must be taken into account, that is, the degree of similarity in the lexical units of the languages of exposure. Why is this additional factor brought into consideration here? Because /o/ and /u/ input frequency differences exist, but they are somehow compensated if counts are done on the whole input information: /u/ is more frequent in Catalan than in Spanish, while the opposite pattern is found for /o/, more frequent in Spanish than in Catalan. While global frequency differences are not substantive in this case, a closer look at the units in which these sounds appear reveals interesting information. Due to vowel reduction in Catalan, /o/ in unstressed syllables turns into /u/. When comparing words from these two languages, with a high number of cognates, the alternation between /o/ and /u/ sounds in final word position can very easily be noticed, for words that are otherwise similar in their segmental and syllabic structure. It can then be hypothesized that this factor may also play a role in explaining the particular developmental pattern found in bilinguals for certain (not all) native vowel categories.

To sum up, bilingual infants seem to follow a slightly different process in setting up their native-languages categories, as far as some specific vowels are concerned. These vowels are elements affected by particular frequency and distributional properties when phonetic inventories of both languages are taken into consideration and when cognate status and form similarity between words in both languages are also considered. By 12 months of age differences between monolingual and bilingual infants are no longer present and this eventual reorganization of categories can be accounted for by both statistical learning and phonological status explanations. Further research is needed in this domain to reach a more complete picture of bilingual infants' vowel categorization processes in the first year of life and to identify all the relevant factors.

3.2. Perceptual reorganization processes in bilingual exposure: Consonants

In the previous section, a review of data from native-vowel categorization processes in bilinguals has been offered. It might be interesting to know how general these particular processes are. Do they also apply to consonants? Are they present in bilinguals exposed to languages other than Catalan-Spanish, that is, languages belonging to a different rhythmic class?

Data from our lab on a Catalan voicing fricative contrast (/s/ - /z/) revealed a similar trend, although at a slightly older age. Three groups of infants from Catalan monolingual, Spanish monolingual and Spanish-Catalan bilingual homes were tested at 4 and at 12 months of age (recall that

perceptual reorganization processes for consonants develop by the end of the first year of life, later than for vowels and for this reason they were not tested at 8 months, as in the previous experiment with vowels). By 12 months of age, only infants exposed to Catalan were able to reach discrimination for this fricative contrast present in their native-language (Bosch & Sebasián-Gallés, 2003b). While absence of exposure could account for the Spanish infants' negative results, bilingual data seemed to replicate the previously found U-shape developmental pattern and suggested again that exposure is simply not enough to maintain initial discrimination capacities. Particular reorganization processes for native-sound categories in bilinguals seem to be active when dealing with sounds that are differently organized in their two languages and show rather different distributional and frequency properties (in this case, the voiceless fricative /s/ is present both in Spanish and Catalan, and its total frequency is much higher than Catalan /z/).

A similar trend was initially observed in a study of French-English bilinguals where the developmental time-course relative to the phonetic VOT category boundaries for French [b] - [p] and English [b] - [p^h] was explored (Burns, Werker & McVie, 2002). When bilinguals and monolinguals were compared, differences were observed by 10-12 months of age. At that age monolinguals had already placed a category boundary in the appropriate location for their native language and bilinguals still did not show a categorization compatible with either one or both of their two native languages. However, in a subsequent analysis with a larger sample of bilinguals, the same group of researchers found that infants actually seemed to have already established both French and English VOT boundaries by the end of the first year of life (Burns, Yoshida, Hill & Werker, 2007). The different pattern finally observed in this group of French-English bilinguals compared to the pattern obtained in our Catalan-Spanish bilingual study deserves some comments. First of all, the target consonants in each study were different (stops and fricatives, respectively). Second, from a methodological perspective, the paradigms and the stimuli also differed (habituation versus familiarization-preference procedure; single token and single speaker versus multi-token and multi-speakers; monosyllabic versus disyllabic items). These differences must not be ignored as they might be, at least in part, responsible for the different pattern of results. In other words, it is possible that with a simplified material (short elements and less variability, as in the French-English study), evidence of language-specific category boundaries for each of the languages in the bilingual can be observed, especially in the case of stop consonants (the different acoustic nature of fricative sounds must not be ignored here). However, the authors of the study suggested a different interpretation for their results. They considered that bilinguals' language-specific categories had successfully been established in this case on the basis of the similarity in frequency and distributional properties of the stop consonants in these two languages, highly frequent in both English and French. In their interpretation, the high frequency of all these consonants in the bilingual input seems to be the crucial factor that would prevent these sounds fom being grouped and organized into a single category.

A similar interpretation has been put forward in a recent paper by Sundara, Polka and Molnar (2008) in which they analyze the abilities of monolingual French, monolingual English and French-English bilingual infants to discriminate de dental (French) and alveolar (English) place of articulation variants of the highly frequent /d/ phoneme in both languages. Having observed no differences in discrimination ability between monolinguals and bilinguals at two age levels (6 to 8 months and 10 to 12 months), they conclude that frequency of occurrence plays a fundamental role in the structuring of the phonetic space in bilinguals.

Even though the number of studies in this domain is still limited, a conclusion can be reached relative to the relevant factors in bilinguals' processes to set up their language-specific sound categories. First, exposure alone, as a unique factor that would maintain initial discrimination capacities, does not seem to be able to account for bilinguals' perceptual reorganization processes. Second, sensitivity to distributional properties and the activity of a powerful mechanism to extract regularities from the input can provide a better explanation for bilinguals' response patterns, in the same way as it has proved to be useful to account for category realignments that have been described in monolinguals. Third, a protracted developmental time-course in setting up native categories does not seem to be universal and it might only be restricted to specific sound categories in which partially overlapping distributions, great frequency differences and acoustic proximity in high density regions in the perceptual space, are present. In these circumstances, infants from bilingual environments might require more information to complete the process of organizing (or re-organizing) their phonetic representations. Exceptionally, bilinguals might temporarily lag behind monolinguals in their

discrimination/categorization capacities, but this behavior merely reflects the adaptive processes that are consequence of the more complex nature of their linguistic input.

4. From phonetics to phonology in bilinguals' early lexicon

From the information just presented, it could be followed that these language-specific categories that have been established by the end of the first year of life are ready to be applied to build the phonological representation of words in the early lexicon. But phonetic category formation, considered as a statistical clustering process, is just the first step in what will later become phonological knowledge as seen in the format of representation of words in the lexicon. Although these early phonetic categories can be considered the building bocks for phonological categories, a direct, automatic link between phonetic categories set up at a pre-lexical stage and contrastive, phonological categories present in the child's system once lexical development has begun, has not been clearly established.

Word recognition studies in monolingual toddlers have offered evidence of a possible "continuity" perspective between phonetic categories and the phonological detail represented in known words, as shown in different research with 18 to 24 month-old children (Swingley & Aslin, 2000; Bailey & Plunkett, 2002; Mani & Plunkett, 2007; 2008), 14-month-olds (Swingley & Aslin, 2002) and even younger children (11-month-olds) at least for word onsets (Swingley, 2005). Although early words' representational format may not yet be adult like, it seems likely that lexical representations for known words contain enough detail to allow detection of phonologically deviant pronunciations.

What about bilinguals? Word recognition studies using mispronunciations are non-existent so far, except for research done at the University of Barcelona with Catalan-Spanish toddlers and young children using vowel mispronunciations for known words. Young children's sensitivity to different vowel contrasts in their first lexicon was analyzed, comparing monolingual and bilingual populations. Children were tested using a visual fixation task: they were presented with sentences that contained nouns for known objects that could be correctly pronounced or mispronounced, while they were shown two pictures simultaneously, but only one was the referent of the utterance.

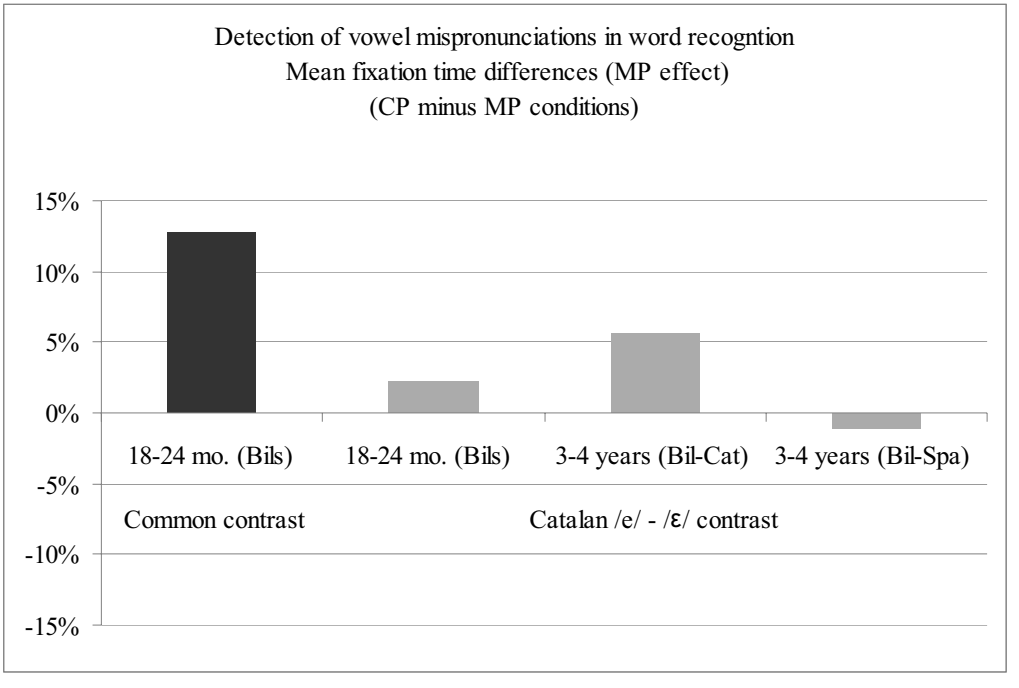

Figure 2: Mispronunciation effect (mean fixation time in Correct Pronunciation conditions minus mean fixation time in MP conditions) in four independent groups of bilinguals tested on a common contrast MP -first left- or on the Catalan /e/-/ɛ/ contrast at two different age levels (adapted from results in Ramon-Casas et al., 2009).

Results from the groups tested at 18-24 months of age revealed interesting differences in fixation time between monolinguals and bilinguals for mispronunciations involving the Catalan /e/ - /ɛ/ vowel contrast, but not for vowels common to both phonological systems. In other words, bilingual toddlers showed a mispronunciation effect only for /e/ - /a/ and /e/ - /i/ vowel replacements, but did not react when /e/ or /ɛ/ vowels were interchanged in known words (Figure 2, left). When older bilinguals (3- to 4-year-olds) were tested with the same procedure and on the same /e/ - /ɛ/ vowel mispronunciations, results were not yet completely satisfactory, even at that age (Figure 2, right). Only the subgroup of 3- to 4-year olds that was identified as Catalan-dominant (greater amount of exposure to Catalan than to Spanish, a Catalan-speaking mother) succeeded in showing the expected mispronunciation effect (Ramon-Casas, Swingley, Sebastián-Gallés and Bosch, 2009).

These results suggest that the Catalan /e/ - /ɛ/ vowel contrast is not clearly specified in the early lexicon. Moreover, even with greater exposure, this language-specific contrast remains inaccessible for a subgroup of bilinguals, those with more exposure to Spanish than to Catalan. Possible factors for this pattern of results have already been mentioned: acoustic proximity of these vowels in a small region of phonetic space, frequency and distribution of vowels in the phonologies of these two languages and high levels of cognates in both lexicons. These factors, linked to the complex nature of bilingual input, can certainly explain why longer processes may be needed in order to reach detailed representations of words in the lexicon. A parallel situation can be found in data from a word learning study with bilinguals who do not succeed at learning minimal-pair words until a later age than monolinguals' (Fennell, Byers-Heinlein & Werker, 2007; but see Mattock, Polka, Rvachew & Krehm, 2009, for a different result). However, it may not be just a matter of time, as suggested by results from the Spanish-dominant subgroup of older bilinguals in our study (Ramon-Casas et al., 2009). Their input language may also contain more variability and even unsystematic productions, especially in the case of vowels, that may hamper the stabilization of these contrastive sounds in the lexicon. Detailed analysis of input language to bilingual infants deserves further consideration in future studies.

5. Final comments

The scarcity of data on phonological specificity of bilinguals' early words limits the discussion of the present results, restricted to a vowel contrast representation in the lexicon of Catalan-Spanish bilingual toddlers. The generality of these results cannot be assumed until further research is carried out. However, one aspect must be underlined: conflicting categories at the phonetic level reappear again when phonological representation of words is being assessed. Bilinguals must learn the intersection of two languages' sound categories and some arrangements of sounds in the phonetic space can pose problems, both at the phonetic and at the phonological levels. Certain language-specific phonemic contrasts may take longer to become fully specified in word representations and may require further readjustments. Form similarity between words in both lexicons may have a negative incidence on the stabilization and detailed representation of some language-specific contrastive categories. Last but not least, input variability (i.e. the range of standard and non-standard pronunciations in input language to bilingual infants) should be more systematically taken into consideration as an additional factor contributing to less precise or perhaps unstable representations. In any case, bilinguals' specific processes, both in phonetic discrimination tasks and word recognition paradigms, must be interpreted as adaptive to the complex and more variable nature of their language input.

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