The influence of initial exposure on lexical representation: Comparing early and simultaneous bilinguals

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Abstract

The representation of L2 words and non-words was analysed in a series of three experiments. Catalan-Spanish bilinguals, differing in terms of their L1 and the age of exposure to their L2 (since birth—simultaneous bilinguals—or starting in early childhood—early sequential bilinguals), were asked to perform a lexical decision task on Catalan words and non-words. The non-words were based on real words, but with one vowel changed: critically, this vowel change could involve a Catalan contrast that Spanish natives find difficult to perceive. The results confirmed previous data indicating that in spite of early, intensive exposure, Spanish-Catalan bilinguals fail to perceive certain Catalan contrasts, and that this failure has consequences at the lexical level. Further, the results from simultaneous bilinguals show: (a) that even in the case of bilinguals who are exposed to both languages from birth, a dominant language prevails; and (b) that simultaneous bilinguals do not attain the same level of proficiency as early bilinguals in their first language.

Keywords: Speech perception; Bilingualism; Spanish; Catalan; Vowel perception; Early exposure; Sensitive period; Lexicon

How early must an individual learn a second language to attain native performance? Popular wisdom has it that puberty is the upper limit for “perfect” second language acquisition. This assumption received support from early models of language development. Lenneberg (1967) formulated the critical period hypothesis which held that language could be learned through some biologically determined mechanisms within a specific time window. Outside this window, learning was only possible through the use of other (non-specific) mechanisms. More recent approaches to this issue no longer assume that there is a more or less sudden end to an individual's ability to master a second language, but hold that the loss of the acquisition capacity is progressive (Bialystok & Hakuta, 1999; Birdsong, 1992, 1999, in press; Birdsong & Molis, 2001; Bongaerts, 1999; DeKeyser & Larsen-Hall, in press; Flege, 2003; Flege & Hillenbrandt, 1984; Flege, Yeni-Komshian, & Liu, 1999; Hyltenstam & Abrahamssoo, 2000; Johnson & Newport, 1989, 1991; Marler, 1991; Mayberry, 1993; Mayberry & Eichen, 1991; Newport, 1990, 1991, 2002; Sebastián-Gallés & Soto-Faraco, 1999; Seliger, 1978; Ullman, 2001). Furthermore, the difficulties in attaining native-level performance are not related solely to individual differences such as age of acquisition or...
amount of exposure. It seems that certain aspects of the language system (such as vocabulary) can be learned at any age, while other aspects (such as the use of prepositions and syntax) remain particularly difficult (Neville & Bavelier, 2000; Neville, Mills, & Lawson, 1992; Weber-Fox & Neville, 1994, 1999).

One domain that seems particularly difficult to master in an L2 is the phonological system (Bosch, 2000; Flege & MacKay, 1999; Sebastián-Gallés & Soto-Faraco, 1999). The difficulties are found in both the production and the perception domains. Many bilinguals are “given away” by their foreign accent and they also tend to experience difficulty in perceiving particular non-native sounds. Most studies of these issues have analysed competence in the second language in relation to variables such as age of acquisition, age of arrival in the foreign country, etc. (for a review see Birdsong, in press). In general, the predominant view is that adults can acquire, with different degrees of success, even the most difficult foreign contrasts, as long as appropriate input is provided (Flege, 2003; Iverson et al., 2003; McCandliss, Fiez, Protopapas, Conway, & McClelland, 2002). On this view, since auditory processing would be unaffected by language exposure, it should be possible, at least theoretically, to acquire any foreign contrast at any moment in life. According to Flege (2003) “the capacities underlying successful L1 speech acquisition remain intact across the life span. These capacities include the ability to accurately perceive featural patterns in speech input.” (p. 327) In this context, the difficulties experienced by adult learners are caused by L1 interference effects and not from normal neural maturation. In fact, as Iverson et al. (2003) suggest, L1 interference effects would become progressively stronger as L1 develops; that is, the earlier L2 is acquired, the less the effects of the L1 will be observed because L1 categories would not be yet fully established. In this way, age of acquisition effects would be just an epiphenomenon of how L1 interference develops in time.

Hardly, any of the empirical data addressing the issue of age of acquisition and its consequences in speech perception mechanisms have analysed simultaneous bilinguals, that is, individuals who, from the very first day of their lives, have been exposed to two languages and have used them continuously. Due to this exposure from birth to both languages, the study of this population represents one of the endpoints in the age of acquisition-L1 interference continuum. Although the literature on adults is scarce, some developmental data are available that suggest that the early setting of phonetic categories in (simultaneous) bilingual infants does not follow the same path as that of monolingual infants (Bosch & Sebastián-Gallés, 2003; Burns, Werker, & McVie, 2002).

As early speech development studies reveal, the first months of life play an important role in the establishment of the native language categories. Research has shown that in the second half of the first year of life infants shape the phonetic categories of their L1 (a development that will continue during childhood). Kuhl and coworkers (Kuhl, 1991; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992) found that before six months of age infants do not show the “perceptual magnet effect,” that is, the difficulty that adults experience in perceiving small acoustic differences close to the prototypes of the phonemes of their native language. This difficulty is specific to the vowels of the maternal language, and is not observed for vowels of other languages. At about six months, infants show a pattern that closely resembles the adult one. Bosch and Sebastián-Gallés (2003) studied the developmental pattern of monolingual Catalan infants, monolingual Spanish infants and bilingual Spanish–Catalan infants in the perception of the Catalan-specific/e/-c/contrast. As expected, at four and a half months, all infants were able to discriminate between different tokens of disyllabic stimuli that differed only in terms of these two contrastive Catalan vowels. Also as expected, by eight months Spanish monolingual infants did not show any sensitivity to the contrast, while Catalan monolingual infants still showed it. Interestingly, bilingual Spanish–Catalan infants no longer showed any discriminative behaviour at this age (regardless of the language of the mother). By 12 months, bilingual infants had “regained” their capacity to discriminate the contrast. This differential pattern between monolingual and bilingual infants shows that the two populations have their own processes of category acquisition. Bosch and Sebastián-Gallés (2003) argued that the recovery of the discrimination behavior in bilingual infants at 12 months was related to their need to represent words in the lexicon in the proper way. It remains to be explored if this particular process of maternal language category development has any consequences in the long-term as regards the representation of the sound system in simultaneous bilingual adults. The main goal of the present series of experiments is to explore the speech perceptual capacities of simultaneous bilinguals by analysing how words are represented in their mental lexicon.

As mentioned above, research in second language speech perception indicates that (non-simultaneous) bilinguals have difficulty in perceiving some non-native contrasts. Several models have been put forward to explain why some segmental contrasts not present in the first language are easier to perceive in the second language than others (Best, 1995; Flege, 1995, 2003). The fact that bilinguals experience perceptual difficulties for some L2 sounds could mean that their lexical representations may not include as much detailed information as the processing and representation of words in the first language. Our previous research has shown that Spanish-dominant bilinguals, in spite of a high degree of linguistic competence, have difficulty in perceiving some
Catalan contrasts, absent in Spanish (Bosch, Costa, & Sebastian-Gallés, 2000; Pallier, Bosch, & Sebastian, 1997a; Pallier, Colomé, & Sebastián-Gallés, 2001; Sebastián-Gallés & Soto-Faraco, 1999). Specifically, Sebastián-Gallés and Soto-Faraco (1999) compared the performance of highly competent Spanish–Catalan bilinguals in an adaptation of the gating task. Two populations were studied: bilinguals who learned only Catalan during the first years of their life (Catalan–Spanish), and bilinguals who learned only Spanish in this period (Spanish–Catalan). The bilinguals in the latter group were selected so that they did not significantly differ from the Catalan–Spanish population in their performance at the last gate, but, even so, they needed a significantly longer fragment of the stimulus (more gates) to identify the correct answer (for converging evidence using the gating task, see Grosjean, 1988 and Schulpen, Dijkstra, Schriefers, & Hasper, 2003).

Recently, it has been shown that these difficulties also extend to the lexicon (Pallier et al., 2001). In that study, Spanish–Catalan bilinguals were asked to perform a lexical decision task. The repetition priming effects between words presenting minimal differences in contrasts existing either in both languages or in Catalan alone were compared. The authors took advantage of the fact that lexical decision times are faster on a repeated word trial than on the first presentation. They observed that Spanish–Catalan participants (L1 Spanish, and unlikely to perceive certain Catalan contrasts) considered the occurrence of the second member of a Catalan-specific minimal pair equivalent to an exact repetition of the first item; that is, the reaction times to a word uttered for the second time in the list (reaction times to the second occurrence of [netɔ] in a list) were equivalent to the reaction times when the word had been preceded by its minimal pair (in this case [netɔ] preceded by [netɔ] in the same list). However, Catalan–Spanish bilinguals whose maternal language was Catalan and who could perceive these contrasts did not show the repetition effect for these pairs. None of the bilinguals showed repetition priming for minimal pairs of words containing phonemes existing in both languages: [pot]-[bot]. These results suggest that Spanish–Catalan bilinguals treat Catalan-specific minimal pairs as homophones, but Catalan–Spanish bilinguals do not.

Another methodological approach has been used to address questions about the lexical representation and activation of non-native words. Spivey and Marian (1999) analysed auditory lexical access in (late) Russian–English bilinguals. In this study, eye movements were recorded while participants were simultaneously presented with four objects. Participants were auditorily asked to pick up one of the objects (the target) and place it at a specific location. In one condition, one of the distractor (non-target) objects had a translation that shared initial phonetic features with the target word (the interlingual distractor); for instance, if participants were instructed, in Russian, to pick up the stamp (“marku” in Russian), one of the distractors was a marker. The results showed that bilinguals glanced more often at the interlingual distractor than at a control object bearing no phonetic relationship to either the target word or its translation. The authors concluded that in spite of being in a totally monolingual mode (the whole experimental session was conducted in only one language), bilinguals activate both auditory lexicons. Weber (2002, Weber & Cutler, 2004) used a procedure similar to Spivey and Marian’s and obtained equivalent results with late Dutch–English bilinguals. In these experiments a very similar procedure was used to explore whether non-natives were as restrictive as natives in using fine phonetic information to access words in their non-dominant language. In one of their experiments, the target object and one of the competitors differed in a vowel pair which is usually difficult for Dutch listeners to perceive, such as the initial vowels in the words “padde” and “pedal.” In this case, after listening to “Click on the pa...” the number of glances at each object was equivalent, indicating that the vowel mismatch was not enough to rule out the distractor object. Crucially, English natives glanced significantly more at the target object.

The experiments of Pallier et al. (2001) and Weber and Cutler (2004) show that because of their insufficiently precise phonetic discrimination ability, bilinguals activate the L2 lexicon in a less restrictive way than native listeners. This means that, provided bilinguals are highly skilled and thus have comparable lexicon sizes to monolinguals, for any given input sequence the chances are that the number of potential lexical candidates will be higher, and, accordingly, one should expect delayed recognition for non-native words because of the existence of more competitors (or homophones) for the second language. While Weber et al. concluded from their data that this less efficient lexical selection for L2 did indeed exist, the results of Pallier et al. indicated that there were no differences in the lexical decision times between Spanish–Catalan and Catalan–Spanish bilinguals; the populations differed in the amount of repetition effects for Catalan-specific minimal pairs, but not in terms of the average reaction times. This difference is probably due to the fact that the bilinguals that participated in the studies were not equivalent: both populations differed in the age of acquisition and context of acquisition. Therefore, it is difficult to directly compare the results of the two studies. Finally, some recent data seem to restrict the scope of the non-selectivity and non-specificity of bilingual lexical access in speech perception. Using the eye-movement paradigm Ju and Luce (2004) observed that the difficulties with L2 words in highly skilled bilinguals can be restricted to words including difficult-to-categorize L2 phonemes.

As we said above, the main goal of the present research is to study the processing of phonetic categories in simultaneous bilinguals. According to the interference
hypothesis, these bilinguals are expected either not to differ from natives or to show only very small differences. In this context, a task showing a clear difference between early, but not simultaneous Catalan–Spanish and Spanish–Catalan bilinguals is needed. Otherwise, the potential lack of differences between Catalan–Spanish and simultaneous bilinguals could be attributable to a lack of methodological power. The aim of our first two experiments, then, is to introduce an approach that is able to distinguish between the performance of the two populations of Catalan–Spanish and Spanish–Catalan bilinguals. This methodology should also provide converging evidence about the consequences at the level of the lexicon of failing to make this discrimination in early bilinguals.

In previous studies (see for reviews Sebastián-Gallés, in press and Sebastián-Gallés & Bosch, in press) we have observed that vowel discrimination is an appropriate context in which to address the present goals. Catalan is a language with eight vowels; Spanish has only five. As prior research has shown, some Catalan-specific contrasts (like /e/-/e/) are particularly difficult for Spanish natives to properly perceive. If Spanish-dominant bilinguals store Catalan words containing either /e/ or /e/ as a single category, they will have great difficulty in discriminating between real words and non-words made by exchanging these vowels. For example, the Catalan word for “window” is “finestra” pronounced [finest]. If these bilinguals do not perceive the contrast /e-/e/, and their lexical representations do not distinguish between the two, they will find it difficult to decide whether [finestra] or *[finestra] is the real word. However, they should not find it difficult when the vowel change involves vowels used in Spanish, as in the Catalan word for “skirt” [fist] when transformed into the non-word *[fist].

Experiment 1

The main goal of this experiment is to establish an experimental situation that can be used with the population of simultaneous bilinguals to analyse their speech processing capacities. To do so, two groups of early Spanish–Catalan and Catalan–Spanish bilinguals will be studied. We expect to find significant differences between early Spanish–Catalan and early Catalan–Spanish bilinguals. As we have just said, the perceptual difficulties previously observed in early Spanish–Catalan bilinguals are likely to impede these subjects’ attempts to discriminate between proper words and their mispronunciations when the only difference between them is a difficult-to-perceive contrast. As it is their lexical knowledge that is being explored, it is of great importance to show that these bilinguals, apart from their difficulty with some foreign contrasts, have a lexical knowledge that is comparable to that of natives; otherwise, the potential difficulty could be attributed to a lack of knowl-

dge of the Catalan words. In this respect, we do not expect to find any difference between the two populations in their capacity to discriminate between words and their mispronunciations when they involve contrasts common to both languages.

Method

Participants

Eighty Spanish–Catalan and Catalan–Spanish early bilinguals participated in this experiment. All of them had been born in Catalonia (most of them in Barcelona or its metropolitan area). Half were raised as Spanish monolinguals until the age of four at the latest (when mandatory schooling started). During the first years of their lives, contact with Catalan was occasional. The other half of the bilinguals was selected according to the reverse criterion, that is, with Catalan as their home language. All participants had received bilingual education and claimed to be very fluent in the two languages, in both listening and reading. Furthermore, all participants had passed the mandatory examination to enter Spanish Universities in Catalonia, meaning that all participants had proven their proficiency not only in oral and written skills, but also in their formal knowledge of both Catalan and Spanish phonology, morphology and syntax (the requirements are the same as those that monolingual Spanish students have to meet in Spanish to gain admission to any Spanish University). Only participants who reported that their current dominant language was the language learned at home participated in this experiment. At the moment of testing, they were all undergraduate Psychology students at the University of Barcelona, where most of the lectures are given in Catalan (according to official statistics, about 60%). Participants were also asked to rate their knowledge of foreign languages. In this experiment, all participants reported having learned English as a foreign language. They rated their knowledge of written English on a ten-point scale. The averages for Spanish-Catalan and Catalan-Spanish bilinguals were 6.7 and 6.6, respectively, (the averages for comprehending spoken English were 4.5 and 4.7, respectively). Some participants reported some knowledge of other languages (French—8—I Italian—3—German—2). None of the participants reported any hearing problems. They participated in the experiment in exchange for course credits.

\footnote{Spanish and Catalan are commonly used in Barcelona. The languages have co-official status. Of the four public TV channels, two broadcast mostly in Spanish and the other two mostly in Catalan. So families have the choice of living in a predominantly monolingual environment, in which contact with the other language is occasional. Education, on the other hand, is to a large extent bilingual. There is no particular privilege in social status for any of the two languages.}
Materials

Sixty-six Catalan words containing the vowel /e/ and sixty-six Spanish words containing the vowel /e/ were selected (experimental words). Because of recording problems, two words from the e-set were discarded. Words varied in length (from one to four syllables). The two sets were matched in word frequency (average tokens per million for e-words: 722.27, SD 1281.77; for e-words, average: 662.19, SD 1270.83, t test <1; Rafel i Fontanals, 1998). The corresponding non-words were created by replacing the vowel /e/ with /i/ and vice versa in each of the words. Thus, the word “galleda” (meaning “bucket”), pronounced [gɔlɛdə], generated the non-word *[gɔlɛdə] and the word “ulleres” (meaning “glasses”), pronounced [uʎəɾəs], generated the non-word *[uʎəɾəs]. The former were called “e-type” stimuli and the latter “e-type” stimuli. Because Catalan features vowel reduction, /e/ and /i/ can only occur in stressed positions, so these changes were restricted to stressed syllables.

To determine the cognate status of the stimuli, following the procedure described in Kroll and Stewart (1994) a group of 10 monolingual Spanish natives from the Canary Islands were presented with the experimental words and asked to guess the corresponding Spanish word. Stimuli were considered to be non-cognates if 6 out of the 10 subjects did not guess the Spanish word. This procedure yielded a total of 52 non-cognates (23 e-words and 29 e-words) and 78 cognates (43 e-words and 35 e-words). There were no significant differences in frequency between cognates and non-cognates (p > .16). A $\chi^2$ test showed that there were no statistical differences in the distribution of cognates and non-cognates across each stimulus type ($\chi^2 = 1.482$, ns). Furthermore, because of the phonological features of the two languages (in particular, vowel reduction in Catalan) cognates in both languages sounded quite different.2

2 Three factors can be advocated here making significant changes between Catalan and Spanish pronunciations. The first one refers to vowel changes. Catalan has eight vowels. Vowels /a/, /e/, /i/, /o/, /u/ appear in stressed positions. In unstressed positions only three vowels are found: /i/, /u/ and schwa. /ə, /e/ and /a/ when in unstressed position are realized like schwa. /ə/ and /u/ when unstressed, are pronounced like /u/. The second factor refers to the differences in the repertoire of consonants. For instance, Spanish has no voiced fricatives, but it has several unvoiced ones appearing in Spanish, and not in Catalan: /f/, /s/. Catalan has both voiced and unvoiced fricatives, some of the unvoiced ones only appearing in this language: /ʃ/. Finally, Catalan, like French, historically went through a process of final-word shortening; while Spanish has a preponderance of trisyllabic words and few monosyllabic words, most Catalan words are disyllabic and many are monosyllabic. This process can be seen in words like “ma” (Cat)—“mano” (Sp) meaning “hand” or “anell” (Cat)—“anillo” (Sp) meaning “ring” (or to see an even more extreme case “cap” (Cat)—“cabeza” (Sp) meaning “head”).

For instance, the Catalan word “convent” is cognate with the Spanish word “convento,” but their pronunciation differs: [kumʃent] in Catalan and [komʃento] in Spanish. Even some cases in which the number of phonemes and orthography is the same in both languages, such as the word “portera” (meaning “concierge” fem.) the pronunciation is different: [purtera] in Catalan and [portera] in Spanish. So, bearing this in mind and even accepting some potential perceptual assimilations made by Spanish speakers (for example, perceiving Catalan /s/ as /ʃ/) there were only 6 e-words and 3 e-words that could be said to sound the same in both languages in the experimental stimuli.

Forty control words were selected. These words also varied in length between one and four syllables and were matched for frequency with the experimental items (average = 378.69, SD 649.81, t test p < .14). Thirty-five non-words were created from words that were similar to the controls (though not exactly the same), produced by replacing their stressed vowel. These changes never involved vowels /e/ or /i/. For example, the word “llencɔl” (meaning “sheet”—bed), pronounced [ʎənʃəl] had its stressed vowel changed to make *[ʎənʃəl]. Two lists were generated, so that one member of each experimental word/non-word pair appeared in each list. Control stimuli were the same for all participants.

Stimuli were recorded by a male native speaker of Catalan, digitalized and down-sampled to 16 KHz. All stimuli were recorded in a single session. Stimuli were edited with Cool Edit © and individual stimulus files were created for each word. No silences were left at the beginning or end of each file.

Procedure

Participants were tested in individual sound-attenuated booths, seated in front of a computer screen where instructions were displayed. They were asked to press a button labelled “yes” immediately on hearing a word stimulus and a button labelled “no” on hearing a non-word. In the instructions they were specifically warned that the stimuli would be very similar to words, and had been made by changing a single vowel; participants were told that, in many cases, the change would involve the replacement of a sound /e/ by a sound /i/ and vice versa. Feed-back was provided during the training phase, in which some words and non-words containing the /e/-/i/- exchange were included. Each trial started with an asterisk (fixation point) displayed for 300 ms in the centre of the computer screen. Immediately, after the asterisk offset, the stimulus was played binaurally. The onset of the auditory stimulus triggered the timing mechanism. The asterisk reappeared to start the next trial 750 ms after the subject had answered. Subjects had a 3500 ms response deadline; if they had not answered within this time, the asterisk appeared indicating the onset of the following trial. The order of
presentation was fully randomized for each subject. Participants were encouraged to respond as quickly as possible and to keep their response fingers over the response buttons. Half of the participants were tested with one of the lists and the other half with the other.

The presentation of the stimuli was controlled by personal computers, equipped with Pro-Audio 16 sound cards. Auditory stimuli were presented through Sennheiser HMD224x headphones. The experimental situation was controlled by the program EXPE (Pallier, Dupoux, & Jeannin, 1997b). Reaction times were measured from stimulus onset.

Results

Error rates for the experimental stimuli (e-type and e-type ones) were very high, particularly for participants with Spanish as their first language (see Fig. 1). In fact, these participants showed a functional breakdown in the capacity to discriminate experimental words and non-words. Indeed, they showed a strong bias to consider most experimental non-words as real words. Because of this high error rate and bias, it was decided to carry out the accuracy analyses using the A’ statistic for both test and control items. Each subject’s performance was converted to an A’ score, which is a non-parametric unbiased index of sensitivity with 0.5 corresponding to chance performance and 1.0 to perfect discrimination (McNichol, 1972). Reaction times were only analysed from stimulus onset.

Error analyses

Table 1 shows the average A’ statistic for each bilingual group. Separate ANOVAs by subjects and by items were performed for the three categories of stimuli with type of bilingual as a between subjects variable. The analyses showed a significant effect of type of bilinguals (F1(1,78) = 201.051, p < .0001, F2(1,167) = 389.498, p < .0001) and a significant effect of stimulus type (F1(2,156) = 206.458, p < .0001, F2(2,167) = 156.781, p < .0001). The interaction of these two factors was also significant in both analyses (F1(2,156) = 89.650, p < .0001, F2(2,167) = 72.7, p < .0001). A t test comparison of means showed that the differences were significant for Catalan-dominant bilinguals (.974 vs. .967, respectively) and for Spanish-dominant ones (.947 vs. .967, respectively). Other ANOVAs restricted to the two experimental conditions were also performed. In these analyses, the type of bilingual factor was also significant (F1(1,78) = 203.438, p < .0001, F2(1,128) = 513.528, p < .0001), as well as the stimulus type (F1(1,78) = 14.530, p < .0001, F2(1,128) = 17.110, p < .0001). The interaction between the two factors was also significant (F1(1,78) = 12.318, p < .001, F2(1,128) = 5.673, p < .02). T test comparisons between the two populations were carried out for each stimulus type. For both types of stimulus, Catalan-dominant bilinguals performed better than Spanish-dominant ones (.974 vs. .967, respectively). Contrasting results were also found between the populations for types of experimental stimuli (e- and e-stimuli). The difference was significant for Catalan-dominant bilinguals (t1(39) = 11.309 and t2(128) = 6.382, p < .0001), but not for Spanish-dominant ones (t1 < 1 and t2(128) = 1.389, p < .167).3

Reaction time analyses

A group of analyses was performed to explore the differences between the groups of bilinguals in their knowledge of Catalan. As mentioned above, this was

Table 1

<table>
<thead>
<tr>
<th>Type</th>
<th>Early Catalan</th>
<th>Early Spanish</th>
<th>Simultaneous</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>e-type</td>
<td>.874 (.058)</td>
<td>.684 (.103)</td>
<td>.798 (.112)</td>
<td>.984 (.015)</td>
</tr>
<tr>
<td>e-type Control</td>
<td>.953 (.046)</td>
<td>.687 (.116)</td>
<td>.813 (.147)</td>
<td>.984 (.015)</td>
</tr>
<tr>
<td>e-type Control</td>
<td>.974 (.013)</td>
<td>.967 (.014)</td>
<td>.967 (.013)</td>
<td>.984 (.015)</td>
</tr>
</tbody>
</table>

Fig. 1. Average correct responses (percentages) in Experiment 1 for each stimulus type and bilingual group.

3 The potential contribution of the cognate status of the stimuli was systematically explored. Two ANOVAs, by items and by subjects with bilingual group, stimulus type (e-type/e-type) and cognateness (cognate/non-cognate) were carried out. No main effect or interaction involving the cognate status of the words approached significance; the average values for cognates and non-cognates were .812 and .807, respectively.
done by analysing their performances in the control stimuli. Reaction times above 3000 ms and below 200 ms (which together represented less than 4% of all data) were discarded. Two ANOVAs, one by subjects and one by items, were carried out on the reaction times of the control condition. The analyses showed that words were responded to faster than non-words; $F(1,78) = 174.73$, $p < .0001$ and $F(2,73) = 40.43$, $p < .0001$ (words = 1004 ms, non-words = 1160 ms). Differences between Catalan- and Spanish-dominant bilinguals did not reach significance in the subject analysis ($F(1,78) = 2.458$, $p > .12$), but they were significant in the item analysis ($F(2,73) = 70.203$, $p < .0001$) (Catalan = 1055 ms, Spanish = 1108 ms).

The interaction of these two factors was significant in both analyses ($F(1,78) = 4.131$, $p < .045$ and $F(2,73) = 13.59$, $p < .0001$). Post hoc analyses showed that Catalan–Spanish participants responded faster to words than Spanish–Catalan participants ($t(78) = 2.149$, $p < .04$, $t(39) = 8.748$, $p < .0001$). The difference between the two populations for non-words was only significant in the item analyses ($t(78) = 0.823$, ns, $t(34) = 3.248$, $p < .003$). Table 2 shows the mean and standard deviations for each group and condition.

### Discussion

The results of this experiment are clear. They show that in spite of a high command of their second language, Spanish-dominant bilinguals are far behind Catalan-dominant bilinguals in terms of their accuracy in recognizing stimuli including vowels /e/ and /ɛ/. The results also show that while the direction of the change that transformed real words into non-words has no influence on Spanish-dominant bilinguals, it makes a difference for Catalan-dominant ones: Spanish-dominant bilinguals showed no differences in their scores for e- and e-stimuli, but Catalan-dominant ones performed significantly better with e-stimuli. We will analyse this divergence between the populations in the general discussion.

Although the error rates for control stimuli were very low in both populations, the fact that there were significant differences between them (although only in the items analysis) in the reaction times (and in the accuracy data -A’) could be taken as evidence that, in fact, Spanish–Catalan bilinguals had poorer lexical knowledge than their Catalan–Spanish counterparts. Though this may be the case, the situation in which the two populations were tested cannot be considered fully equivalent. In most of the trials (and it has to be remembered that the instructions gave participants prior warning) Spanish–dominant bilinguals were asked to distinguish between Catalan sounds that are particularly difficult for them, and so it is not surprising that they were more cautious when making their decisions and that their responses in all conditions were slower. Furthermore, because of their false recognition of experimental non-words as words, the percentage of “no” responses was much lower for Spanish–Catalan bilinguals than for Catalan–Spanish ones. This may have influenced their general criteria for giving a positive or a negative response, a bias that may also have influenced their responses to the control stimuli. If these are the reasons for the differences observed between the two populations, testing equivalent participants with just the control stimuli should make the differences disappear.

### Experiment 2

The goal of this experiment was to test whether the differences in the control stimuli observed in the previous experiment were due to a lower command of Catalan in Spanish-dominant bilinguals than in their Catalan–dominant peers, or whether the differences were experimentally induced. This experiment is a replication of the previous one, but using only the control stimuli.

### Method

Forty new participants from the same population as in the previous experiment were tested. Half of them had been exposed only to Spanish during the first years of their lives and half of them only to Catalan.

Materials and experimental procedure were the same as in the previous experiment, except that only the control stimuli were used. Therefore, only one list was used (all participants were tested with the same stimuli).

### Results and discussion

The analysis of the accuracy data (A’) showed no significant differences between the two groups ($t(38) = 1.644$, $p > .10$ and $t(39) = 1.335$, $p > .19$, by items); the mean A’ were .988 for the Catalan-dominant group and .982 for the Spanish-dominant group.

Reaction times above 3000 ms. and below 200 ms. (together representing less than 3% of all data) were discarded. Two ANOVAs were carried out on the reaction times, one by subjects and one by items. The analyses showed that words were responded to faster than non-words; $F(1,38) = 55.285$, $p < .0001$ and $F(2,1,73) = 38.425$, $p < .0001$. Differences between Catalan–Spanish

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Mean reaction times for each control condition and bilingual population (standard deviation in parentheses): Experiment 1</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Words</td>
</tr>
<tr>
<td>Catalan dominant</td>
<td>965 (118)</td>
</tr>
<tr>
<td>Spanish dominant</td>
<td>1043 (196)</td>
</tr>
</tbody>
</table>
and Spanish–Catalan bilinguals did not reach significance in any of the analyses (both $F < 1$).

The interaction of these two factors was only significant in the item analysis ($F(1,38) = 2.831$, $p > .10$ and $F(1,73) = 16.085$, $p < .0001$). Post hoc analyses of means showed no differences between populations for either words or non-words in the subject analyses (both $t$s <1), although the analysis by items showed significant differences both for words ($t(39) = 2.395$, $p < .03$), where Catalan-dominant participants were faster than Spanish ones, and for non-words ($t(34) = 3.208$, $p < .003$); here Spanish–Catalan bilinguals responded faster than Catalan–Spanish ones. Table 3 shows the mean and standard deviations for each population and condition.

These data show that the differences observed in the previous experiment in the control stimuli between Spanish and Catalan-dominant bilinguals were due to the experimental situation. The only partially significant effect concerning the two groups of bilinguals was the interaction between group and lexicality, and it was only significant in the items analysis. This result is difficult to explain, especially since the post hoc comparison of means did not show reliable differences between groups either for words or for non-words. Summarizing, on the strength of the present pattern of results, it seems safe to assume that populations can be considered as on the strength of the present pattern of results, it seems safe to assume that populations can be considered as

Table 3

<table>
<thead>
<tr>
<th>Condition</th>
<th>Words</th>
<th>Non-words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalan dominant</td>
<td>934 (190)</td>
<td>1058 (170)</td>
</tr>
<tr>
<td>Spanish dominant</td>
<td>906 (114)</td>
<td>1103 (193)</td>
</tr>
</tbody>
</table>

imments for e-type and e-type stimuli in the Spanish-dominant bilinguals could not be attributed to a poor language command by this group of bilinguals.

**Experiment 3**

The two previous experiments tested the ability of highly proficient early bilinguals to discriminate between words and non-words differing in a particular Catalan-specific vowel contrast that is difficult for Spanish natives to perceive. The reason for this difficulty may be the differential exposure to Catalan and Spanish during the first years of life in the two populations. The fact that these early bilinguals were exposed to their second language when the foundations of the L1 phonological system had already been laid, along with their continuous use of their L1, may have contributed to the persistence of these difficulties. The importance of this early exposure could be tested more conclusively in simultaneous bilinguals. As noted in the introduction, the early setting of phonetic categories does not follow the same path in simultaneous bilinguals as in monolingual individuals. In fact, there seems to be a period, around eight months of age, where bilingual infants are not sensitive to certain vowel contrasts. It may be that in bilingual adults, words may be represented in the lexicon in an idiosyncratic way, because of this period of non-differentiation. One potential scenario is that their discrimination pattern will be intermediate, somewhere between those of Catalan–Spanish and Spanish–Catalan early bilinguals (like those tested in the previous experiments); that is, their performance may be moderate, and their scores somewhere between those of the early exposure populations. This possibility is supported by the data from simultaneous English–French bilinguals studied by Caramazza, Yeni-Komshian, Zurif, and Carbone (1973), who compared differences in the VOT production of monolingual and bilingual individuals. The results showed that bilinguals produced intermediate values, between those of French and English natives. However, Mack (1989) only partially replicated these results. In that study simultaneous bilinguals were able to perform like monolinguals in the VOT distinction (although they showed intermediate values for other phoneme contrasts).

Still another possibility is that although Bosch and Sebastián-Gallés (2003) did not observe differences
between bilingual infants as a function of the language of the mother (which we will assume, in most cases, is the dominant language in the environment for infants) simultaneous bilinguals, as adults, may show a language dominance pattern. In the present case, those mostly exposed to Catalan in their first one or two years of life show a pattern that is more consistent with the data of Catalan-dominant early bilinguals, while those mostly exposed to Spanish show a pattern closer to that of Spanish-dominant early participants. Some of the data in the speech perception literature with simultaneous bilinguals point in this direction. As already noted, few studies have analysed the speech perception capacities of simultaneous bilinguals. In some, the results are consistent with this type of hypothesis. Cutler and colleagues (Cutler, Mehler, Norris, & Segui, 1989, 1992) studied the segmentation capacities of simultaneous English–French bilinguals. Though the results were complex, they were interpreted by the authors as indicating that even in the case of highly proficient simultaneous bilinguals, a language dominance was to be found. This explanation was also suggested in the study of simultaneous bilingual infants by Sebastián-Gallés and Bosch (2002). In this study, the acquisition of phonotactic constraints in monolingual Catalan and Spanish 10-month-old was compared with that of bilingual infants. The results showed that simultaneous bilingual infants with Catalan as the dominant language in the environment showed a pattern of behaviour indistinguishable from that of Catalan monolingual infants, and clearly different from that of Spanish monolinguals. However, simultaneous bilinguals mostly exposed to Spanish showed an intermediate pattern between infants mostly exposed to Catalan (monolingual and bilingual) and monolingual Spanish ones.

Summarizing, the goal of this experiment is to explore the processing and representation of lexical items in simultaneous Spanish–Catalan bilinguals and to compare it with the performance of early Spanish–Catalan and Catalan–Spanish ones.

Method

Participants

Forty new participants were tested. All of them were raised in a bilingual environment from the first day of their lives. Half of them had a Catalan-speaking mother and a Spanish-speaking father, and the other half had the reverse pattern. All of them were undergraduate Psychology students who participated in the experiment in exchange for course credits. In addition, all of them had been born in Catalonia (most of them in Barcelona or its metropolitan area). None reported any hearing deficits. They were extracted from the same pool as that used in the previous two experiments. Like the early bilinguals, they all had attended bilingual schools and grew up in a bilingual society. Their knowledge of foreign languages was equivalent to that of participants in the preceding experiments; in this case as well, all participants reported having learned English as a foreign language and the self-rates of their ability to understand written and spoken English were 6.5 and 4.5, respectively. Although participants were classified according to the language spoken by their mother, they filled in a questionnaire designed to gather information about the percentage of use of each language in different contexts. Crucially, both groups did not differ in the amount of use of each language at home or outside it. The information from this questionnaire was also used to analyse the results. As the two analyses yielded convergent patterns of results, the data concerning these questionnaires, as well as the statistics performed with them, are presented in Appendix A.

We use the terms Simultaneous-Catalan and Simultaneous-Spanish refer to simultaneous bilinguals whose mother’s language was either Catalan or Spanish. “Catalan–Spanish” and “Spanish–Catalan” refer to bilinguals who were raised as monolinguals in the first years of their lives, but who acquired their L2 early in life (the type of bilinguals tested in the first two experiments).

The materials and experimental procedure were the same as in Experiment 1.

Results and discussion

Error analyses—maternal language

Four different groups of analyses were carried out. First, all simultaneous bilinguals, as a single group, were compared to both groups of early bilinguals. Second, the two subgroups of simultaneous bilinguals were compared to each other. Third, performance in each experimental condition was compared across the four groups. Finally, the asymmetry observed for early Catalan–Spanish bilinguals but not for early Spanish–Catalan ones when both types of experimental stimuli were compared, was also assessed here for each group of simultaneous bilinguals.

Simultaneous bilinguals vs. early bilinguals

Separate ANOVAs were performed (by subjects and by items) on the A’ statistic. The analyses showed significant effects of bilingual type (Catalan–Spanish, Spanish–Catalan, and simultaneous) (F1(2,117) = 75.123, p < .0001; F2(2,334) = 252.315, p < .0001), type of stimulus (F1(2,234) = 299.144, p < .0001; F2(2,167) = 214.984, p < .0001) and the interaction of these two factors (F1(4,234) = 43.367, p < .0001; F2(4,334) = 47.373, p < .0001). Table 1 shows the means for each group of bilinguals in each condition. Comparisons of means
showed significant differences between simultaneous bilinguals and each group of early bilinguals for all stimulus types. For control stimuli, the comparison between Catalan–Spanish bilinguals and simultaneous bilinguals was significant ($t_{(78)} = 3.138$, $p < .002$; $t_{(39)} = 2.043$, $p < .05$), simultaneous bilinguals performing better than Catalan–Spanish ones (.984 vs. .974). The comparison between Spanish–Catalan bilinguals and simultaneous bilinguals yielded the same pattern, simultaneous bilinguals performing better (.984 vs. .967; $t_{(78)} = 4.964$, $p < .0001$, $t_{(39)} = 4.903$, $p < .0001$). For both experimental stimulus types, the performance of simultaneous bilinguals was between that of the two groups of early bilinguals. For $\varepsilon$-type stimuli Catalan–Spanish bilinguals performed better than simultaneous ones, (.874 vs. .798; $t_{(78)} = 4.236$, $p < .0001$; $t_{(39)} = 6.227$, $p < .0001$). And simultaneous bilinguals performed better than Spanish–Catalan bilinguals (.798 vs. .684; $t_{(78)} = 5.062$, $p < .0001$; $t_{(39)} = 8.589$, $p < .0001$). For $\varepsilon$-type stimuli the same pattern was obtained: Catalan–Spanish bilinguals outscored simultaneous bilinguals (.953 vs. .813; $t_{(78)} = 7.041$, $p < .0001$; $t_{(39)} = 12.573$, $p < .0001$); Spanish–Catalan bilinguals performed worse than simultaneous bilinguals (.687 vs. .813; $t_{(78)} = 4.857$, $p < .0001$; $t_{(39)} = 13.871$, $p < .0001$).

**Simultaneous Catalan vs. Simultaneous Spanish bilinguals**

Another set of analyses was carried out to compare the two simultaneous bilingual subgroups. Table 4 shows the mean $A'$ statistics of these populations. The analyses showed significant effects for type of stimulus factor ($F_{(2,76)} = 112.809$, $p < .0001$; $F_{(2,167)} = 144.542$, $p < .0001$), type of bilingual ($F_{(1,38)} = 13.410$, $p < .001$, $F_{(2,167)} = 122.01$, $p < .0001$) and the interaction of these two factors ($F_{(2,76)} = 8.542$, $p < .0001$, $F_{(2,167)} = 19.746$, $p < .0001$). The comparison of means showed that the groups differed on the control stimuli, but only in the item analysis (.986 vs. .981; $t_{(38)} = 1.132$, $p > .26$, $t_{(2)} = 5.333$, $p < .0001$). The two populations differed in both varepsilon-type and $\varepsilon$-type responses in the subjects and items analyses (for $\varepsilon$-type: $t_{(38)} = 3.449$, $p < .001$, $t_{(65)} = 7.349$, $p < .0001$; for $\varepsilon$-type: $t_{(38)} = 3.363$, $p < .002$, $t_{(63)} = 13.414$, $p < .0001$).

**Comparison of all four groups: Differences in each experimental condition**

To further assess the effect of early exposure, the four groups of bilinguals were compared in each experimental condition. For $\varepsilon$-type stimuli, the type of bilingual factor reached significance in both analyses ($F_{(3,116)} = 38.427$, $p < .0001$, $F_{(3,195)} = 75.595$, $p < .0001$). Scheffé multiple comparisons of means found no differences between the two groups of maternal–Catalan bilinguals (Catalan–Spanish and Simultaneous-Catalan), while all the other comparisons were significant (all $ps < .05$ both in the subject and item analyses). Both groups of maternal–Catalan bilinguals performed better than the other groups with this type of stimuli, while simultaneous-Spanish were between Spanish–Catalan and both groups of Catalan–maternal bilinguals. For $\varepsilon$-type of stimuli, the type of bilingual factor also reached significance in both analyses ($F_{(3,116)} = 58.263$, $p < .0001$, $F_{(3,189)} = 227.314$, $p < .0001$). The comparison of means showed that all means were significant at least at $p < .016$, except the comparison between the two Spanish–maternal groups which failed to reach significance in the subject analysis ($p < .057$). Overall, there were differences between all types of bilinguals as a function of their initial exposure to Catalan.

**$\varepsilon$-type vs. $\varepsilon$-type across groups**

The performance of the four groups of bilinguals in the two experimental conditions was also compared. The interaction between group of bilinguals and stimulus type was significant in both the subject and the item analyses ($F_{(3,116)} = 5.731$, $p < .001$, $F_{(3,384)} = 2.710$, $p < .045$). The differences between $\varepsilon$-type and $\varepsilon$-type stimuli were .079 and .003 for Catalan–Spanish and Spanish–Catalan bilinguals and .023 and .008 for Simultaneous-Catalan and Simultaneous-Spanish bilinguals. The comparison of means showed significant differences between the types of stimuli for Simultaneous-Catalan bilinguals ($t_{(19)} = 2.437$, $p < .025$, $t_{(128)} = 7.202$, $p < .0001$). However, the difference failed to reach significance in the subject analysis ($t_{(1)} < 1$), although it reached significance in the item analysis ($t_{(2)} = 3.984$, $p < .0001$) for the Simultaneous-Spanish bilinguals.

**Reaction times analyses**

Although error rates were not as high as in the Spanish–Catalan early bilinguals tested in Experiment 1, we performed the same analyses so as to be able to compare the results.

6 Two new ANOVAs by subjects and by items were performed adding the cognate status of the stimuli to the factors declared in the previous analyses. No main effect or interaction including it was observed.
Reaction times above 3000 ms and below 200 ms (together representing less than 3% of all data) were discarded. Mean reaction times were 1106 ms for control words and 1174 ms for control non-words. Two ANOVAs, one by subjects and one by items, were carried out on the reaction times of the control condition for the three groups of participants (Early Catalan–Spanish, Early Spanish–Catalan, and Simultaneous). The analyses showed no effect of language group in the subject analysis, but a highly significant effect in the item analysis \((F(1,217) = 1.483, p > .23; F(2,146) = 66.272, p < .0001)\), the effect of lexicality was highly significant in both analyses \((F(1,177) = 200.698, p < .0001; F(2,173) = 45.650, p < .0001)\): words were responded to faster than non-words. The interaction between group and lexicality was significant only in the item analysis \((F(1,217) = 1.596, p > .20; F(2,146) = 9.148, p < .0001)\).

The group of simultaneous bilinguals was divided into two subgroups according to the language of the mother, and the data were analysed separately. The mean reaction times for words and non-words were 963 and 1049 ms, respectively, for the Simultaneous-Catalan participants, and 1135 and 1206 ms for the Simultaneous-Spanish ones. The ANOVA showed that the Simultaneous-Catalan participants were faster than their Simultaneous-Spanish counterparts \((1049 \text{ vs. } 1127 \text{ ms}; F(1,38) = 5.385, p < .03; F(2,173) = 215.350, p < .0001)\), but that the maternal-language factor did not interact with the lexicality factor \((F(1 < 1; F(2,173) = 2.451, p > .122))\).

**Discussion**

This third experiment assessed a population of simultaneous Spanish–Catalan bilinguals with three types of analyses. In the first place, all simultaneous bilinguals were evaluated as a single group and compared to each group of early bilinguals. The results showed significant differences between this population and the two groups of early bilinguals. Regarding the experimental stimuli, simultaneous bilinguals showed an intermediate behavior between Catalan–Spanish and Spanish–Catalan early bilinguals. This pattern could reflect the fact that some participants behaved like Catalan–Spanish and others like Spanish–Catalan bilinguals. One possibility was that daily exposure, in particular in the first months/years of life, was responsible for these differences. One way of classifying simultaneous bilinguals in this respect is according to the language spoken by their mother; so new analyses were performed separating simultaneous bilinguals into two subgroups, Simultaneous-Catalan and Simultaneous-Spanish.

When these two subgroups were compared, differences were observed for both experimental stimulus types: Simultaneous-Catalan performed better than Simultaneous-Spanish bilinguals. Also, when both stimulus types were compared in each population, Simultaneous-Catalan subjects showed a small but significant asymmetry, while Simultaneous-Spanish bilinguals did not.

When the four groups of bilinguals were compared, the results showed that, for e-type stimuli, both Catalan–Spanish and Simultaneous-Catalan bilinguals performed better than Spanish–Catalan and Simultaneous-Spanish, but Spanish-simultaneous subjects performed better than the Spanish–Catalan group. For e-type stimuli, the analyses showed significant differences between all groups of bilinguals, in the following order: Catalan–Spanish better than Simultaneous-Catalan, better than Simultaneous-Spanish, better than Spanish–Catalan.

Taken together, the results of this experiment provide support for the idea that in simultaneous bilingual acquisition, exposure to a contrast is not enough for an individual to attain the same level of proficiency as bilinguals exposed to a single language during the first year/s of life; that is, even Simultaneous-Catalan bilinguals (as a group) did not perform at the same level as Catalan–Spanish bilinguals. Moreover, significant differences were observed between the populations of simultaneous bilinguals. Those bilinguals whose mother spoke Catalan, and who presumably had greater exposure to that language than to Spanish in the first years of life, performed better than simultaneous bilinguals who were exposed mostly to Spanish in the same period. They also showed a significant asymmetry when both experimental stimuli were analysed, a pattern not observed in the Spanish-dominant simultaneous bilinguals. This suggests that differences in the amount of initial exposure may be responsible for speech processing differences that may persist throughout life.

**General discussion**

This series of three experiments studied Spanish–Catalan and Catalan–Spanish bilinguals who were first

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7 Because of the relatively high error rates of Simultaneous-Spanish participants, and to increase the statistical power of the analyses, the cognate status of the stimuli was analysed pooling together the data of Catalan–Spanish and Simultaneous-Catalan bilinguals (the analyses performed including Simultaneous-Spanish participants did not yield any significant effect or interaction involving the cognate status factor). Two ANOVAs including lexical and cognate status as well as experimental type were performed on the reaction times. They showed a significant effect of cognate status \((F(1,59) = 9.695, p < .003, F(2,118) = 5.991, p < .02)\), non-cognates being faster than cognates \((1158 \text{ ms vs. } 1211, \text{ respectively})\). No interaction involving the cognate status yielded significant results.
exposed to Catalan at different points in their lives, and in whom the amount of initial exposure also differed. The results of the first two experiments indicated that highly skilled Spanish–Catalan (early) bilinguals had great difficulty in distinguishing between mispronounced and properly pronounced words that differed in a Catalan-only contrast. This difficulty was restricted to this contrast and was not observed for other (common) contrasts. The last experiment explored simultaneous bilinguals, and found significant differences between individuals exposed to both languages from birth but whose maternal language was Spanish and those also exposed to both languages from birth but whose maternal language was Catalan: the language used by the mother was a good predictor of the participants’ ability to perform the task. From the questionnaire that participants filled in, this variable seems to be crucial. As already mentioned, there were no differences between both groups of simultaneous bilinguals in the amount of exposure to Catalan at home. Also, an estimation of the percentage of use of each language outside home was also assessed. This variable did not correlate with any of the experimental conditions.

Though there is a possibility that Simultaneous-Spanish bilinguals may have had less exposure to Catalan during childhood and adolescence than their Simultaneous-Catalan peers due to the social environment in which they grew up, this is in fact highly unlikely. Taken together, the results of the experimental series, and in particular those of the last experiment, support the notion that early exposure has a profound influence on the way first and second language sounds are perceived.

As a summary, Fig. 2 illustrates the results of Experiments 1 and 3. This figure plots individual scores of the four types of bilinguals for the contrastive vowel categories. When individual data are considered, the results show different distributions for each type of bilingual. It could be said that there is a boundary line that separates individuals who were exposed mostly to Catalan or Spanish in the first years of life. For instance, while no early Catalan-Spanish bilinguals or simultaneous Catalan-dominant bilinguals had a score of less than .80 for the e-type stimuli, only seven simultaneous (40%) and eight early (20%) Spanish-dominant bilinguals scored above it. These results are in agreement with previous results reported with simultaneous bilinguals; as mentioned in the introduction, Cutler et al. (1989, 1992) observed that simultaneous French–English bilinguals behaved differentially in a fragment detection task and in a word spotting task depending on the language spoken by the mother.

However, it would be wrong to conclude that the performance of simultaneous bilinguals’ performance is equivalent to that of early bilinguals. Both subgroups of simultaneous bilinguals differed significantly from the early bilingual groups.

One factor that has not been commented upon so far is the amount of exposure participants had to “mispronunciations” of Catalan words. It could be argued that in the present experiments, participants were asked to decide whether or not certain stimuli were mispronunciations of real words. Spanish–Catalan bilinguals, when pronouncing Catalan words, mostly use the phonetic categories of Spanish, so the Catalan contrast /e-æ/ is assimilated to the Spanish phoneme /e/. This could account for the asymmetry in the perception of experimental stimuli for Catalan–Spanish bilinguals: exposure to mispronounced words containing vowel /æ/ by Spanish–Catalan bilinguals, which would be mispronounced as having vowel /e/, but not the other way around. That is, because of the assimilation to the Spanish vowel system, a word like [gaλeðə] is likely to be mispronounced by Spanish-dominants as *[gaλæðə], but a word like [finestra] is less likely to be mispronounced as *[finestra]. So, because of the bilingual nature of Catalan society, individuals (regardless of their home language) hear, for example, instances of [gaλeðə], *[gaλæðə] and [finestra], but never *[finestra]. In this way, Catalan–Spanish bilinguals may tend to misidentify *[gaλæðə] as a real word, but not *[finestra], since they have never been exposed to these mispronunciations. Spanish–Catalan bilinguals do not show the asymmetry because they have difficulty in perceiving the /æ/e/ contrast; thus, to their ears there are no differences between [gaλæðə] and *[gaλæðə] and [finestra] and *[finestra].
However, this explanation cannot easily account for the pattern of results of simultaneous bilinguals. If we consider that simultaneous bilinguals are exposed to both languages from birth, it is quite likely that simultaneous bilinguals are exposed to more mispronunciations of e-e words than Catalan–Spanish ones (they might have heard the mispronunciations from the Spanish-speaking parent and siblings). Thus, simultaneous bilinguals should show a stronger asymmetry than early Catalan–Spanish ones, as they would have been exposed both earlier and more intensely to mispronounced stimuli (from one of the parents), but this is not in fact the case. The difference between the two categories was .079 for Catalan-Spanish bilinguals and .023 for Simultaneous-Catalan bilinguals (and .008 for Simultaneous-Spanish ones, and .003 for Spanish–Catalan ones). At present, it is unclear why simultaneous bilinguals do not behave like early bilinguals. Because no data about perceptual abilities of simultaneous bilinguals were collected, it might be that the lack of asymmetry, in particular for the Simultaneous-Spanish, could be the consequence of poor perceptual discrimination capacities in these individuals. As mentioned in the introduction, simultaneous bilingual infants do not follow the same developmental path as monolingual ones (at least for the contrast and population under study here). One way of testing this possibility would be to compare early and simultaneous bilinguals in more perceptual tasks. In fact, a closer look at the data may be taken as supporting this explanation. Simultaneous-Catalan bilinguals showed less asymmetry because they perform worse for e-stimuli than do Catalan–Spanish ones, while their performance for e-stimuli is similar. That is, in spite of having heard few mispronunciations of e-stimuli, they confuse words and non-words in this category, a potential indication of some perceptual problems. However, these comments are merely speculative at present and further research into the matter is needed.

The results reported here have important consequences for theories of the acquisition of L2 phonological properties. According to the influential view proposed by Flege (2003, see also Iverson et al. 2003) the difficulties posed by learning a new L2 phonological system occurs at the same time as that of the L1, interference should not be present or should be greatly reduced. Since there is no phonological system in place that can affect the way in which the second one is represented, this suggests that the simultaneous acquisition of two languages should be achieved without major difficulty. However, our results demonstrate that this is not the case and that simultaneous exposure to two languages does have an effect on how the phonological system develops. The present pattern of results suggests that initial exposure plays a crucial role in the way the brain encodes phonological information. Its influence can be considered to lie in two directions. On the one hand, initial exposure is particularly relevant in the case of simultaneous bilinguals. Indeed, these individuals did not differ in terms of overall exposure to Catalan, but showed striking differences in performance: Simultaneous Spanish bilinguals showed significant difficulty in performing the task, while the performance of Simultaneous Catalan bilinguals was only slightly worse than that of early Catalan–Spanish bilinguals. So, the initial differences between the populations seem to be responsible for important differences in adult performance. Further, the differences between early Catalan–Spanish bilinguals and simultaneous bilinguals, along with the developmental data showing different paths for bilingual infants acquiring the vowel system (Bosch & Sebastián-Gallés, 2003) may be taken as an indication that simultaneous bilinguals follow a different developmental path. Whether this path can be accounted for in terms of a very precocious interference between a (to be established) dominant L1 and a (less established) L2 language (note that this hypothesis implies the assumption that infants give preference to one language over the other, for which conflicting evidence is available, see Sebastián-Gallés & Bosch, in press, for a review) or by the inherent dynamics of simultaneously establishing the categories of both languages, remains an open question.

Finally, the data also indicate that late exposure plays a significant role in the way phonological information is represented. Indeed, the asymmetry observed between the types of experimental stimuli, in Catalan-dominant bilinguals, suggests that, at least with respect to the way words are represented in the lexicon, different realizations (such as dialectal variations) are stored. Whether this information at the level of the lexicon feeds down and modifies the way phonetic categories are represented is something that the present study cannot answer; research is currently being carried out in our laboratory to explore this question. Data with short-term training in laboratory conditions (Norris, McQueen, & Cutler, 2003) indicate that this might be the case. To explain the present pattern of data, any model of the L2 phonological system must take into consideration not only the age of acquisition (understood either as a maturational issue or as an interference effect), but also the amount of experience. Furthermore, these two factors interact. The speech perception system does not seem to be able to compensate for the difference in initial exposure between Simultaneous Catalan and Simultaneous Spanish bilinguals.
Table 5
Mean and standard deviations for each group of simultaneous bilinguals on the variable home and correlations with scores with each experimental condition

<table>
<thead>
<tr>
<th></th>
<th>Home exposure</th>
<th>Correlation with e-stimuli</th>
<th>Correlation with e-stimuli</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simultaneous Catalan-dominant</td>
<td>1.125 (.393)</td>
<td>.193 **</td>
<td>.302 **</td>
</tr>
<tr>
<td>Simultaneous Spanish-dominant</td>
<td>.975 (.580)</td>
<td>.682 **</td>
<td>.794 **</td>
</tr>
</tbody>
</table>

** p < .01 bilateral.

Acknowledgments

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Appendix A. Language dominance and use

Participants filled in a questionnaire concerning the percentage of use of each language in different contexts, to establish the language dominance in their infancy and childhood as well as their current dominance. A first measure reflected the language use at home. This information included the language in which both parents communicate to each other and the language spoken by brothers, sisters and other relatives that might be living with the family. With this information an estimation of the use of Catalan was calculated. If both parents talked to each other in Catalan, the participant was assigned 1 point, if both parents talked to each other in Spanish, the participant was assigned 0 points, if they used both languages, 0.5 points were assigned. The same criteria were used for the language of communication of siblings or other relatives. If the participant was an only child, the score corresponding to the language of communication between the parents was multiplied by two. Scores could vary from 0 to 2. Table 5 shows the average for each bilingual group and the correlation between this variable and the A’ scores for each experimental condition. There were no differences between the two groups as a function of use of Catalan at home (t < 1).

Language exposure at home correlated significantly with the performance of Simultaneous-Spanish bilinguals, but not of Simultaneous-Catalan ones. These results suggest that Simultaneous-Catalan bilinguals had a sufficient amount of exposure to this language to develop the phonetic categories of Catalan, so that differences in the amount of exposure at home do not seem to be important. However, the performance of Simultaneous Spanish bilinguals, because of a greater variation in the amount of exposure to Catalan, appears to be more sensitive to this variable. Nevertheless, we should not automatically conclude that Simultaneous Catalan bilinguals’ exposure at home did not have any significant impact; it may well be the case that in this population the range of data was not large enough to observe any correlation. Indeed, it has to be remembered that while Simultaneous-Spanish bilinguals had a standard deviation close to .6, Catalan-dominant ones showed a standard deviation of .4. However, it seems safe to conclude from this analysis that the performance of simultaneous bilinguals is greatly affected by the amount of exposure at home. It should be borne in mind that this variable was estimated in a rather coarse way (assuming, for instance, that each parent contributed equally to the participants’ input).

A second measure reflected their use in social contexts outside home (college, friends, work,...). Information about amount of use and language used with friends (or at work, in case participants worked) was gathered. It was estimated that, on average, participants slept 8 h everyday, spent 4 h (awake) at home and attended lectures, seminars... 6 h every day. Because all students attended the same courses, this last exposure could not contribute to differentiate both groups of bilinguals. So, 6 h were left for socializing where differences might arise. Simultaneous-Catalan bilinguals spent 2.90 h (SD .79) and Simultaneous-Spanish bilinguals spent 3.05 h (SD .88) listening to Catalan. This difference did not approach significance. In addition, correlations between this measure and the performance with both types of experimental stimuli were performed. In all cases the correlations were extremely low, r < .10.

References


