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A Bilingual Advantage in Visual Language Discrimination in Infancy

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Abstract

The origins of the bilingual advantage in various cognitive tasks are largely unknown. We tested the hypothesis that bilinguals' early capacities to track their native languages separately and learn about the properties of each may be at the origin of such differences. Spanish-Catalan bilingual and Spanish or Catalan monolingual infants watched silent video recordings of French-English bilingual speakers and were tested on their ability to discern when the language changed from French to English or vice versa. The infants' performance was compared with that of previously tested French-English bilingual and English monolingual infants. Although all groups of monolingual infants failed to detect the change between English and French, both groups of bilingual infants succeeded. These findings reveal that bilingual experience can modulate the attentional system even without explicit training or feedback. They provide a basis for explaining the ontogeny of the general cognitive advantages of bilinguals.

Keywords

bilingualism, infant development

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Bilingual experience has important consequences for how the cognitive system operates. Bilinguals outperform monolinguals in tasks involving the executive-control network. They are better than monolinguals at selecting relevant information while ignoring irrelevant distractions. They are also better at updating response criteria in a changing context. These advantages have been observed in adults, children, and even infants (for reviews, see Bialystok & Craik, 2010, and Kovács, 2012).

The favored explanation for the cognitive advantages of bilinguals is the additional computations that they must constantly make to inhibit one of their two languages, so that only one is used even though both are active and potentially available whenever they speak (Bialystok & Craik, 2010; Costa, Alario, & Sebastián-Gallés, 2009). Although at present there is no dispute about the existence of such cognitive benefits, their precursors remain to be established. Recent findings that preverbal infants who are learning two languages outperform those who are learning one language in both multiple-rule learning (Kovács & Mehler, 2009b) and inhibitory-control tasks (Kovács & Mehler, 2009a) indicate that some precursors are already in place before infants start to speak, and hence before competing lexicons need to be inhibited. This raises the question of what may underlie these early cognitive advantages. One possibility is that they arise from the additional computations that infants who are growing up in bilingual environments must perform to separate their languages of exposure and simultaneously learn the properties of each.

Before they can learn the words or structure of their native language, infants become attuned to its acoustic properties and regularities. A child growing up bilingual must keep track of the regularities in the speech signal for each of the two native languages. An essential prerequisite is the ability to separate the two languages and keep them distinct. Although many parents still worry that raising their children in a bilingual environment may cause language confusion and therefore hinder or delay language acquisition, research has demonstrated that bilingual acquisition proceeds apace with monolingual acquisition (for reviews, see Sebastián-Gallés, 2010; Werker, Byers-Heinlein, & Fennell, 2009) and—more specifically—that infants growing up in bilingual homes do not confuse their two native languages. Bilingual infants are as adept as monolingual infants at differentiating languages both at birth (Byers-Heinlein, Burns, & Werker, 2010) and at 4.5 months of age (Bosch & Sebastián-Gallés, 1997, 2001). Similarly, infants

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growing up in bilingual homes show as much preference for the two languages in their environment (Bosch & Sebastián-Gallés, 1997; Byers-Heinlein et al., 2010) as monolingual infants show for their single native language (Moon, Cooper, & Fifer, 1993).

Despite their similarity in spoken-language discrimination, infants growing up in monolingual and bilingual homes differ in their capacity to differentiate languages visually. In the previously mentioned studies, infants listened to audio files. However, visual information in talking people's faces also plays a fundamental role in the way both adults and infants perceive and learn speech (regarding adults, see McGurk & McDonald, 1976; Soto-Faraco et al., 2007; regarding infants, see Kuhl & Meltzoff, 1982; Kushnerenko, Teinonen, Volein, & Csibra, 2008; Patterson & Werker, 2003; Pons, Lewkowicz, Soto-Faraco, & Sebastián-Gallés, 2009; Vouloumanos, Druhen, Hauser, & Huizink, 2009; for a review, see Soto-Faraco, Calabresi, Navarra, Werker, & Lewkowicz, 2012).

Weikum et al. (2007) explored the capacity of young infants to discriminate languages when the only available source of information was silent video clips of talking faces. These authors reported that 4- and 6-month-old monolingual infants were able to discriminate their native (English) language from an unknown (French) language. At 8 months, the monolingual infants no longer succeeded. In contrast, infants from French-English bilingual homes succeeded at both 6 and 8 months, discriminating between the same visual English materials and the same visual French materials that the 8-month-old monolingual infants could not discriminate. Weikum et al. interpreted these results as showing perceptual narrowing from initial broad-based sensitivities, followed by a decline in the ability to discriminate nonfamiliar stimuli in the 1st year of life. Such results would parallel similar developmental trajectories observed in a wide variety of domains (discrimination of, e.g., consonants, vowels, faces, audiovisual speech, and musical rhythms; see Scott, Pascalis, & Nelson, 2007). For example, monolingual infants begin life with the ability to discriminate different speech sounds, both in their native language and in nonnative languages; by the end of the 1st year of life, they maintain sensitivity to only those speech-sound differences within their native language (Werker & Tees, 1984). Bilingual infants maintain sensitivity to the speech-sound differences within each of their native languages (Albareda-Castellot, Pons, & Sebastián-Gallés, 2011; Burns, Yoshida, Hill, & Werker, 2007).

Our alternative hypothesis is that the superior performance of the 8-month-old French-English bilingual infants (in comparison with monolingual infants of the same age) in the visual language discrimination task (Weikum et al., 2007) could have been due to enhanced perceptual attentiveness in the bilingual infants, rather than (or in addition to) perceptual narrowing. Specifically, we propose that bilingual infants' need to simultaneously track perceptual information from two languages not only maintains their sensitivity to the visual cues distinguishing their two familiar native languages, but also heightens their attentional system's ability to detect and remember even visual cues not used in either of their native languages (perceptual attentiveness). According to this hypothesis, babies growing up with two languages that are not English and French should maintain the ability to discriminate visual French from visual English, even though neither language is familiar to them.

The goal of the present study was to test these competing hypotheses: that bilingual acquisition attunes the perceptual system to the cues in each of the familiar languages exclusively (perceptual narrowing) and that bilingual acquisition leads to more general perceptual attentiveness to cues, regardless of which language they come from. To do this, we investigated whether bilingual infants are able to notice differences between two unfamiliar visually presented languages at an age at which monolingual infants no longer can. We tested 8-month-old Spanish and Catalan monolingual and bilingual infants with the same materials and procedure used in the study by Weikum et al. (2007; visual-only video clips of bilingual women reciting French and English sentences). Then we directly compared our results with the original data from Weikum et al.

If the success of the French-English bilingual 8-month-olds was due solely to their previous exposure to, and hence learning about, the specific properties of their two native languages, then the 8-month-olds in our study, who were bilingual in a different pair of languages, would not be expected to succeed on this task. That is, according to the perceptual-tuning hypothesis, both monolingual and bilingual 8-month-olds who have been exposed to Spanish, Catalan, or both should perform as did the English monolingual 8-month-olds that Weikum et al. tested and should fail to discriminate visual English from visual French. However, if bilingual language exposure results in a more general ability to attend to any cues that might distinguish two languages, even two unfamiliar ones, then Spanish-Catalan bilingual 8-month-olds, but not Spanish or Catalan monolingual 8-month-olds, should be able to discriminate visual French from visual English, as did the French-English bilingual 8-month-olds that Weikum et al. tested.

Method

Participants

Forty-eight 8-month-old infants were included in the final sample. All were healthy and full term. Twenty-four of these infants were from a monolingual environment that was either Spanish ($n = 21$) or Catalan ($n = 3$; mean age = 238 days, range = 226–254 days). The other 24 were from Spanish-Catalan bilingual families (mean age = 243 days, range = 226–262 days). We tested 7 additional infants but excluded them from the sample because of failure to habituate (i.e., they reached the maximum of 24 trials; 1 monolingual, 3 bilinguals), parental interference (1 bilingual), and failure to look at the video display on at least one test trial (2 monolinguals).

Infants were recruited by visiting maternity rooms at the Hospital Sant Joan de Déu and the Clínica Sagrada Família, Barcelona, Spain. We required parental consent before running the experiment. A questionnaire (Bosch & Sebastián-Gallés, 2001) was administered to determine infants' language background and familiarity. Monolingual infants' average exposure time to their home language relative to all speech heard was 96.5%, ranging from 85% to 100%. For bilingual infants, the average exposure time to the less-used language was 39.25%, ranging from 25% to 50%.

Stimuli

The stimuli were the same as those in the study by Weikum et al. (2007). They comprised silent video clips of three female French-English bilingual speakers reciting sentences from the *Le Petit Prince* (by Antoine de Saint-Exupéry) and its English translation. Each clip showed the face of one bilingual speaker uttering a different sentence in either English or French. To attract infants' attention to the screen, we had the screen display a colorful expanding and contracting ball before every trial.

Procedure

The procedure was the same as the one employed by Weikum et al. (2007). Infants' discrimination performance was assessed with a visual habituation paradigm using Habit 2000 software (Cohen, Atkinson, & Chaput, 2004). In the habituation phase, infants were shown trials containing clips from one of the languages until they habituated. Each trial comprised a clip of a unique sentence recited (silently) by one of three bilingual speakers. The same order of speakers was repeated for each block of 3 trials. The preset criterion for habituation was a 60% decrease in looking time at the video on the screen across 3 trials relative to looking times on the block of 3 trials with the longest looking times. A maximum of 24 trials was presented during habituation. Following habituation, infants were presented with 6 test trials. For the *same* group, test trials were clips of new sentences from the same language that was used in the habituation phase. For the *switch* group, test trials consisted of new sentences from the language that was not used during habituation.

The experimenter recorded each infant's looking times on-line, pressing a key while the infant looked at the screen and releasing it when the infant looked away. The experimenter was blind to the change from the habituation phase to the test phase. The maximum duration of each trial was 16 s, but any particular trial was terminated if the infant looked away for more than 2 s (indicating boredom with the clip). If the infant looked at the screen for less than 1 s on any given trial, the trial was repeated. The video records of infant looking were coded off-line frame by frame (25 frames/s) by a trained coder who was unaware of the condition (*same* or *switch*). Coded looking times were used in all analyses.

Setup and apparatus

During the experiment, each infant sat on his or her caretaker's lap in a dimly lit, sound-attenuated laboratory room measuring 178 × 150 cm. A 99- × 86-cm screen was 75 cm from the infant. A Mitsubishi XL8U projector projected the images onto the screen. The caretaker wore a sleep mask to prevent him or her from watching the visual clips. The experimenter controlled the study from a separate room through Habit 2000 software (Cohen et al., 2004), using an Apple Power Mac G5. We recorded the infant's gaze using a closed-circuit Canon MV750i video camera mounted under the screen and watched the recorded gaze using a Panasonic BT-S1460Y TV monitor. Later, the video record was used to code looking time.

Results

An analysis of variance (ANOVA) on data from our two language groups plus the two in Weikum et al. (2007) revealed that the groups did not differ in the number of trials before infants reached the habituation criterion, $F(3, 80) = 1.120$, $p > .34$.

We computed ANOVAs to compare average looking time for the six test trials with average looking time for the last three habituation trials for each infant (as in Weikum et al., 2007). Because data from the French-English bilinguals (Weikum et al., 2007) were available only for the *switch* condition, two separate ANOVAs were carried out. In the first ANOVA, the three available groups' looking times in the *same* condition were compared. The goal of this analysis was to assess the comparability of the data obtained in the two laboratories. A 3 (language background: English monolingual vs. Spanish or Catalan monolingual vs. Spanish-Catalan bilingual) × 2 (trial type: habituation vs. test) mixed ANOVA was carried out on infants' looking times. No statistically significant effects or interactions were found, all Fs < 1, except that there was a marginal effect of trial type, $F(1, 33) = 3.446$, $p < .072$. All language groups showed an identical tendency to slightly increase their looking times in the test phase: Group averages for the habituation and test trials, respectively, were 3.99 s and 4.59 s for the monolingual English infants, 3.72 s and 4.38 s for the monolingual Spanish or Catalan infants, and 3.53 s and 4.85 s for the Spanish-Catalan bilingual infants.

The crucial analysis was the comparison of all language groups in the *switch* condition. To directly test the hypothesis that bilingual infants are able to notice differences between visually presented languages independently of their familiarity with the languages, we defined two between-subjects factors: number of languages (monolingual vs. bilingual) and familiarity with the test stimuli's language, as indicated by home language or languages (French-English vs. Spanish-Catalan). Additionally, because the analysis in the preceding paragraph did not show any relevant difference in the patterns of responses between the infants tested in the present study and those tested by Weikum et al. (2007), the crucial analysis was carried out on the looking-time difference between the test phase and the habituation phase (*discrimination score*). Therefore, the ANOVA had a between-participants design with two variables: number of languages and familiarity.

Only the number of languages had a significant effect, $F(1, 44) = 7.774$, $p < .008$. Figure 1 shows discrimination score as a function of language group. Post hoc comparison of means showed that both groups of bilingual infants discriminated the two languages. Group averages for the habituation and test trials, respectively, were as follows—French-English bilinguals: 4.07 s and 5.84 s, $t(11) = 2.147$, $p < .055$; Spanish-Catalan bilinguals: 3.23 s and 5.03 s, $t(11) = 3.109$, $p < .01$. Neither of the two monolingual groups showed discriminating behavior: For habituation and test trials, respectively, the mean looking times were 4.53 s and 3.78 s for English monolinguals, $t(11) = -1.535$, $p < .1$, and 5.75 s and 6.33 s for Spanish and Catalan monolinguals, $t(11) = 0.798$, $p > .44$.

Discussion

The goal of the present research was to test the hypothesis that bilingual experience leads to an increase in perceptual sensitivity to only those cues that distinguish one familiar language from another (perceptual narrowing) against the hypothesis that bilingual experience heightens attentional sensitivity to, and memory for, cues that distinguish any two languages, including unfamiliar ones (perceptual attentiveness). Weikum et al. (2007) argued for the perceptual-narrowing hypothesis. However, it is impossible to distinguish perceptual narrowing from perceptual attentiveness when testing French-English bilingual infants on French-English stimuli. Therefore, in the current study, we tested two groups of 8-month-old monolingual and bilingual infants who had no previous exposure to French and English and compared their ability to discriminate visual French from visual English with that of the same-aged English monolingual and French-English bilingual infants tested by Weikum et al.

The results are very clear. The Spanish-Catalan bilingual infants showed discrimination behavior equal to that of their French-English bilingual peers. In contrast, the two groups of monolingual infants (English monolinguals, Spanish and Catalan monolinguals) did not; their looking times hovered around chance levels. These results cannot address whether perceptual narrowing contributed to the performance of the French-English bilinguals tested by Weikum et al. (2007), but they do indicate that there is something more to bilinguals' language-discrimination abilities than perceptual narrowing.

But is there a way in which perceptual narrowing might have played a role in the visual discrimination by Spanish-Catalan bilingual infants? Perceptual narrowing occurs not only for heard speech but also for the correlated visual-articulatory phonemes (Pons et al., 2009). According to a perceptual-narrowing explanation, the Spanish-Catalan bilingual infants discriminated the visual English from the visual French because the visual phonetic cues that distinguish English and French overlap with the visual phonetic cues that distinguish Spanish and Catalan. If this explanation is right, perceptual attunement results in optimized discrimination of the two native languages and allows discrimination of additional languages "for free" if the differentiating cues overlap.

However, we think this interpretation is unlikely for the language pairs under consideration. The visual articulatory properties that distinguish phonemes such as /b/, /p/, and most

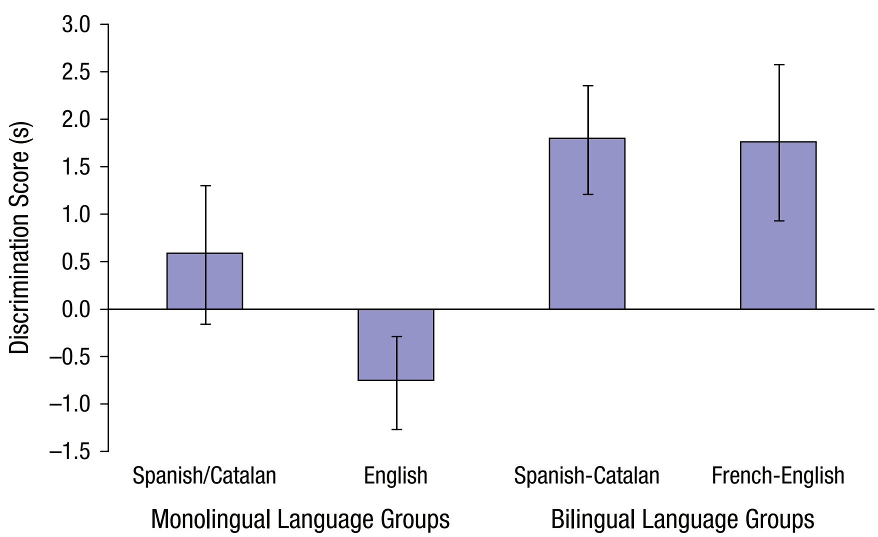

Fig. 1. Mean discrimination score as a function of language group. Discrimination scores were calculated by subtracting mean looking time on the last three habituation trials from mean looking time on the six test trials. Error bars represent standard errors of the mean.

of the vowels in French from the corresponding phonemes in English are quite different from the visual articulatory properties that distinguish these phonemes in Spanish from those in Catalan. For instance, in both French and English, the vowel-onset time (VOT; i.e., the time between the consonant's closure and its release) of /b/ is different from the VOT of /p/, whereas there is no such VOT difference between Spanish and Catalan. Thus, sensitivity to VOT might be a very relevant, visually available cue for French-English bilinguals (Burns et al., 2007), but it is not so for Spanish-Catalan bilinguals. Another example involves differences in salient lip shape. Compared with English, French has more lip rounding and less interdental articulation (with the tongue on the teeth). Again, in comparison with English and French, Spanish and Catalan are more similar in these respects: Neither language uses lip rounding, and both use interdental articulations. Analogous arguments can be proposed for other relevant phonemes. Therefore, although we cannot absolutely rule out the possibility that overlapping discriminatory cues contributed to our results, they are more consistent with the hypothesis that bilingualism generally enhances the attentional system's ability to detect and remember perceptual information in talking people's faces.

Up to now, the origins of the cognitive advantages seen in prelinguistic bilingual infants have remained unexplained. The bilingual advantages observed in adults and children have been considered the consequence of the executive-control mechanisms that bilinguals need to select only one of their two languages prior to speaking. The fact that bilingual advantages have been seen as early as the age of 7 months (Kovács & Mehler, 2009a, 2009b), long before an infant has productive language, makes it unlikely that these advantages stem from the need to cognitively inhibit one of the two active languages. Current knowledge of the structure and functioning of the executive-function components is incomplete. Although research on bilingual advantages was initially focused on the control of attention, recent studies have expanded the focus to other components of the executive-function system. Hernández, Costa, and Humphreys (2012) reported a bilingual advantage in handling the contents of working memory. In their study, bilinguals were better than monolinguals at detecting a target in a visual search array only when they had to hold in memory an irrelevant object (bilinguals' attention was less captured by the irrelevant information). Those authors argued that bilinguals were better at keeping separated (compartmentalized) the different types of information needed to perform the task. We suggest that in infants who are learning two languages simultaneously, the challenge of keeping the two languages distinct may trigger a precursor to the advantage reported by Hernández et al.

This study provides, for the first time, data showing that bilingual infants are more able than monolingual infants to detect and remember those perceptual cues that distinguish one unfamiliar language from another. Not only are bilingual infants able to discriminate two languages with which they have no previous experience, but they are able to do so without feedback from secondary cues, such as the pairing of the visual stimulus with the corresponding sound. Thus, we have identified enhanced perceptual attentiveness as a bilingual advantage. The current data do not allow determination of whether their greater perceptual attentiveness enabled the bilingual infants to be better at noticing the differences between the two languages, remembering both the information extracted at the habituation phase and the information present at the test phase, and comparing the two. Also, the current data do not allow determination of whether only one of these last two processes—remembering and comparing information—is privileged in bilinguals. But the data clearly indicate cognitive enhancement in bilingual infants and support the notion that the advantage is related to the need to keep the two languages separate.

The current work does not indicate whether this perceptual attentiveness is specific to visual speech, to any cues that might distinguish two languages, or even to perceptual information outside of the language domain. However, our finding raises the possibility that in the process of separating two languages, bilingual infants establish a transferable skill set that triggers the more general cognitive advantages they have. Just as Marcus, Fernandes, and Johnson (2007) showed that rule learning in speech contexts can facilitate learning in nonlinguistic contexts, we suggest that the transfer of speech-based computations to other domains may constitute one important precursor to bilinguals' cognitive advantages both in infancy and across the life span.

In conclusion, we have shown that at the age of 8 months, bilingual infants maintain an overall advantage in visually discriminating one language from another, even if they have never before seen either language spoken. Thus, not only are bilingual infants not at risk for confusing their two languages, but also they are better prepared than monolingual infants to discriminate two unknown languages. That bilingual infants can do so with complex, naturalistic stimuli and without any feedback provides the strongest support yet for bilinguals' processing advantage in infancy. Finally, our results provide the first direct evidence that bilinguals' general cognitive advantages originate from the specific abilities involved in language separation.

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The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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