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SHORT REPORT

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Bilingual infants excel at foreign-language talker recognition

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Abstract

Bilingual and monolingual infants differ in how they process linguistic aspects of the speech signal. But do they also differ in how they process non-linguistic aspects of speech, such as who is talking? Here, we addressed this question by testing Canadian monolingual and bilingual 9-month-olds on their ability to learn to identify native Spanish-speaking females in a face-voice matching task. Importantly, neither group was familiar with Spanish prior to participating in the study. In line with our predictions, bilinguals succeeded in learning the face-voice pairings, whereas monolinguals did not. We consider multiple explanations for this finding, including the possibility that simultaneous bilingualism enhances perceptual attentiveness to talker-specific speech cues in infancy (even in unfamiliar languages), and that early bilingualism delays perceptual narrowing to language-specific talker recognition cues. This work represents the first evidence that multilingualism in infancy affects the processing of non-linguistic aspects of the speech signal, such as talker identity.

KEYWORDS
bilingualism, cognitive development, infant speech perception, language acquisition, talker recognition

1 | INTRODUCTION

Growing up in a bilingual environment has a dramatic effect on how children process language. Even before they can speak, monolingual and bilingual infants differ in how they distinguish languages, perceive speech sounds, and learn novel words (e.g., Byers-Heinlein, Burns, & Werker, 2010; Byers-Heinlein & Fennell, 2014; Pons, Bosch, & Lewkowicz, 2015; Sebastián-Gallés, Albareda-Castellot, Weikum, & Werker, 2012). But while it is widely recognized that monolinguals and bilinguals process linguistic properties of speech differently, no research to date has asked whether bilingualism affects infants' perception of non-linguistic aspects of speech. Here, we address this question by asking whether exposure to multiple languages in infancy leads to enhanced performance in a challenging talker recognition task.

The acoustic speech signal is a rich source of information, transmitting multiple layers of information in parallel (e.g., Kreiman & Sidtis, 2011). Upon hearing an utterance, listeners extract not only what is being said but also information about who is saying it – including indexical information such as the talker's identity, age, gender, origins, social background, and emotional state. Many studies have shown that humans are highly adept at extracting both linguistic and indexical information from speech (e.g., Sheffert, Pisoni, Fellowes, & Remez, 2002). However, to date no work has addressed whether diverse linguistic experiences affect infants' processing of indexical speech information. One study indicates that bilingual 6- to 11-year-old children outperform their monolingual peers in a talker processing task (Levi, 2018; see Yow & Markman, 2011, for related work on emotion detection), but we do not know when in development these differences emerge.

Here, we tested the hypothesis that these differences already emerge in infancy by examining monolingual and bilingual infants' talker recognition abilities using a face-voice matching task. We tested infants on an unfamiliar language because, first, this leveled the playing field between monolinguals and bilinguals, ensuring that all infants were equally unfamiliar with the test language. And second, using an unfamiliar language decreased the likelihood that we would find a ceiling effect in infants' performance (and thus increased the likelihood that we would observe a performance difference between groups), because we know from previous work that listeners generally struggle with identifying talkers in an unfamiliar language (e.g., Fecher & Johnson, 2018a,b; Johnson, Bruggeman, & Cutler, 2018; Levi, 2018; Perrachione, Del Tufo, & Gabrieli, 2011). If exposure to multiple languages in infancy enhances the processing of indexical speech cues, then bilinguals should outperform monolinguals in learning to identify foreign-language talkers.

Research highlights

- Monolingual and bilingual 9-month-old infants were tested on a face-voice matching task in an unfamiliar language.
- Bilingual 9-month-olds were successful at learning face-voice pairings in an unfamiliar language, but monolingual 9-month-olds failed at the same talker recognition task.
- We conclude that bilingualism likely affects infants' non-linguistic (indexical) – and not just linguistic – processing of the speech signal.

2 | METHOD

2.1 | Participants

Forty-eight healthy full-term 8.5- to 9.5-month-old infants from the Greater Toronto Area were tested. The monolingual infants (n = 24) were exposed to English on average 98% of the time (SD = 3, range: 90–100) and they had no regular exposure to any other language. The bilingual infants (n = 24) heard English on average 53% of the time (SD = 15, range: 30–70) and they were, since birth, frequently exposed to at least one other language in their homes (see Table A11 in the Appendix for details on infants' language backgrounds). Critically, none of the infants had prior experience with Spanish or Spanish-accented English. The data for 17 additional infants were excluded prior to data analysis due to failure to habituate (n = 11), fussing (n = 3), parental interference (n = 2), or failure to reach posttest criterion (n = 1). Infants' age and gender were well balanced across the monolinguals (M_{age} = 276 days, range = 260–291; 12 female) and bilinguals (M_{age} = 272 days, range = 259–289; 12 female). An estimate of the socioeconomic status (SES) of participating families, indicated by family income and parental education, revealed no differences between groups. Family income was measured in Canadian dollars on a 4-point scale (<$45,000; $45,000 to $89,999; $90,000 to $140,000; and >$140,000). Eighteen caregivers of monolingual infants and 17 caregivers of bilingual infants provided this information. A Mann–Whitney U test indicated that family income did not differ between the monolingual group (Mdn = $90,000–$140,000) and the bilingual group (Mdn = $90,000–$140,000), U = 132.0, p = 0.459. Parental education was measured on a 5-point scale (some high school education, high school graduate, some college or university education, college or university graduate, and postgraduate education).[1] Twenty-one caregivers of monolingual infants and 18 caregivers of bilingual infants provided this information. Values for both parents were summed, providing a parental education score with a value between 2 and 10. Parental education did not differ between the monolingual group (Mdn = 8) and the bilingual group (Mdn = 8), U = 148.0, p = 0.232. This lack of a difference in SES between monolingual and bilingual participants reflects the typical pattern seen in the linguistically diverse neighborhood surrounding our laboratory.

2.2 | Stimuli

Auditory stimuli consisted of 40 unrelated sentences in Spanish (drawn from Paquette-Smith & Johnson, 2015), which were read in an adult-directed manner with a neutral tone of voice by two native Spanish-speaking females (aged 18 and 23 years at time of recording). Both speakers learned Spanish from birth in South America, and both were non-smokers with no particularly distinctive voice quality. The sentences were recorded in a double-walled, sound-attenuated Industrial Acoustics Company (IAC) booth (using a sampling rate of 48 kHz; later normalized to 69.5 dB). Visual stimuli consisted of images of two simple cartoon characters, which differed in hair color and style but otherwise looked identical (see Figure 1, panel A). The characters' mouths opened and closed in synchrony with the amplitude envelope of the speech signal, thus giving the impression that the characters were talking (the images were otherwise still; for sample movies see Supporting Information).

2.3 | Procedure

We tested infants using a version of the 'switch' habituation paradigm (Werker, Cohen, Lloyd, Casasola, & Stager, 1998). Infants were first exposed repeatedly to two novel face-voice pairings (face A and voice A, and face B and voice B; see Figure 1, panel A). As long as infants were interested in the characters (as indicated by their looks to the screen), we continued to present them with the same face-voice pairings. Over time, as infants lost interest in the stimuli, their looks to the characters gradually decreased. Once infants' looking time had decreased to a preset criterion (i.e., infants were habituated), they were presented with one *same* test trial, where the original face-voice pairing was preserved (face A and voice A, or face B and voice B), and one *switch* test trial, where a pairing violation was presented (face A and voice B, or face B and voice A). Critically, once infants reached the test phase of the experiment, all faces and voices were familiar, but they were now paired differently on *switch* trials (but not *same* trials). Thus, in the current task infants were not simply tested on whether they could tell the voices apart (as per the talker discrimination tasks used in Fecher & Johnson, 2018b; and Johnson, Westrek, Nazzi, & Cutler, 2011), but infants were additionally required to learn to associate voices and concurrently presented faces. We predicted that if infants detected the mismatch between the previously learned faces and voices at test, then they would be

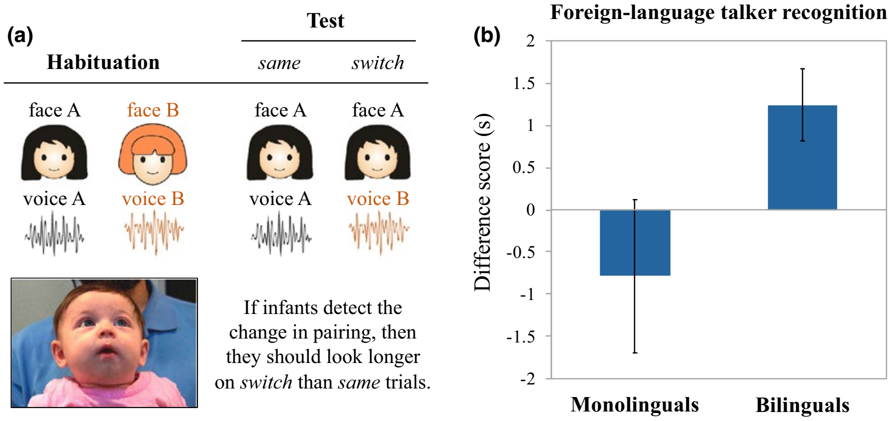

FIGURE 1 Examples of habituation and test stimuli used in the 'switch' habituation procedure (panel a). Mean difference score (in seconds) as a function of language group (panel b). Difference scores were calculated by subtracting mean looking times on *same* trials from mean looking times on *switch* trials. Importantly, monolinguals and bilinguals differed with respect to their language background, but the language used for habituation and test was unfamiliar to all infants. The monolinguals showed no evidence of dishabituation. The bilinguals listened significantly longer on *switch* than on *same* trials, indicating that infants had dishabituated (and were thus sensitive to the novel face-voice pairing). Error bars represent standard errors of the mean

more interested again and their looks to the visual display would increase (i.e., infants would dishabituate to the *switch* trial).

Infants sat on their caregiver's lap in a double-walled IAC booth facing a 21.5-in. computer monitor. Auditory stimuli were played through Alesis M1 Active 520 loudspeakers at a constant, comfortable listening level. The experimenter monitored infants' looking behavior on a separate monitor outside the booth and relayed looking data to a computer using Habit 2000, Version 2.2.4 (Cohen, Atkinson, & Chaput, 2000). At the end of each trial, a blinking red star served to center the infant. Once the infant oriented toward the star, the experimenter initiated the next trial. Caregivers wore close-fitting noise-canceling headphones and listened to masking music intermixed with speech stimuli used in the experiment to prevent them from biasing their child's performance.

All infants (regardless of language background) completed exactly the same task. The procedure consisted of a habituation phase and a test phase. During each infant-controlled habituation trial (each maximum 16 s long), one of the two face-voice pairings was repeated in a cyclic manner (minimum look time = 1 s, minimum look-away time = 2 s). The two pairings were presented in quasi-random order such that each pairing was presented twice within a 4-trial block, with no more than two consecutive trials of the same pairing. The test phase began once infants' looking time had decreased to 50% or less of the initial duration or infants had completed the maximum number of habituation trials (24). At test, infants were exposed to one *same* trial (i.e., a matched face-voice pairing) and one *switch* trial (i.e., a mismatched face-voice pairing). Because the design of habituation and test trials was identical, caregivers and experimenter were unaware of test phase commencement. During a pretest trial (before habituation) and a posttest trial (after test), infants were exposed to a colorful spinning windmill, which acted as a control for whether infants had become uninterested in the stimuli or generally fatigued. If the looking time during posttest (windmill) was at least 80% of the looking time during pretest (windmill), then we would infer that infants were still attentive to the task (and that the data were therefore usable). Across infants, we counterbalanced the order of presentation of the two types of test trials (*same–switch* or *switch–same*), the nature of the switch trials (A–B or B–A), and which sentences were used for habituation and test. This study was approved by the University of Toronto's Social Sciences, Humanities and Education Research Ethics Board. All caregivers of participating infants provided informed written consent for their child's participation prior to taking part in the study.

3 | RESULTS

Monolinguals and bilinguals did not differ in the number of trials completed before reaching habituation criterion and proceeding to test ($M_{monolinguals}$ = 13.7, SD = 3.9; $M_{bilinguals}$ = 14.2, SD = 3.3), $t(46) = -.48$, p = 0.635; they also did not differ in their total looking time during habituation ($M_{monolinguals}$ = 136.0, SD = 46.5; $M_{bilinguals}$ = 145.2, SD = 36.5), $t(46) = -0.76$, p = 0.452. This suggests that both groups of infants were equally interested in listening to the Spanish samples, that is, they showed no difference in attention paid to the talkers during habituation.

To assess infants' face-voice matching abilities, we compared mean looking time (in seconds) during *same* trials to mean looking time during *switch* trials. If infants noticed the new combination of faces and voices at test, then their mean looking times during *switch* trials should have been longer than their mean looking times during *same* trials. Figure 1 (panel b) shows the difference score (calculated by subtracting looking times on *same* trials from looking times on *switch* trials) as a function of language group. Data were analyzed using a repeated-measures analysis of variance (ANOVA) with trial type (same, switch) as a within-subjects factor and group (monolinguals, bilinguals) as a between-subjects factor.

Our analysis revealed no significant main effects of trial type or group (*F*s < 1), but crucially, the trial type × group interaction was statistically significant, $F(1,46) = 4.10$, $p = 0.049$, $\eta_p^2 = 0.08$. For the monolinguals, the difference between looking time during *same* trials and looking time during *switch* trials was not significant ($M_{same} = 5.34$, $SD = 3.82$; $M_{switch} = 4.55$, $SD = 3.65$), $t(23) = 0.87$, $p = 0.394$. This indicates that the monolinguals did not detect the mismatch between the face and voice at test, suggesting that these infants had difficulty with learning to associate previously unfamiliar faces and voices in an unfamiliar language. For the bilinguals, however, the difference between looking times during *same* and *switch* trials was significant, with longer looks during *switch* than during *same* trials ($M_{same} = 4.44$, $SD = 3.31$; $M_{switch} = 5.68$, $SD = 3.40$), $t(23) = -2.91$, $p = 0.008$, $d = 0.37$. This significantly longer looking time to the novel face-voice pairing (relative to the familiar pairing) suggests that the bilinguals did indeed notice when the faces and voices were paired differently at test. That is, the bilinguals were able to detect and remember the perceptual speech cues that distinguished one talker from the other, and in addition, successfully linked these talker-specific speech cues to concurrently presented facial representations of the talkers.

Taken together, we found that infants with exposure to only one language (English) in their home environment showed no evidence of successful talker recognition in an unfamiliar language (Spanish). This conforms with previous work showing that monolingual 7- to 8-month-old infants are better at discriminating between talkers in their native language than in a foreign language (Fecher & Johnson, 2018b; Johnson *et al*., 2011). In comparison to the monolinguals, infants growing up with more than one language from birth (English plus at least one other language) succeeded at foreign-language talker recognition. This finding supports the hypothesis that bilingual infants are more sensitive to talker identity information encoded in the acoustic speech signal than are monolingual infants, suggesting that bilingualism may affect indexical processing in infancy. Future work will be needed to determine whether the strength of this effect differs in children learning different pairs of languages (e.g., languages from the same rhythm class versus different rhythm classes).

4 | DISCUSSION

As predicted, bilingual 9-month-olds excelled in a talker recognition task, supporting our hypothesis that bilingualism may affect infants' processing of non-linguistic aspects of the speech signal. Notably, our results cannot be explained by group differences in age, gender, socioeconomic status, attention during habituation (as measured by looking time), or experience with the test language. So how can we explain the performance difference between monolinguals and bilinguals in the current talker recognition task?

There are various possible explanations for our findings, some of which involve more general effects on infants' processing of the speech signal and some of which involve changes specifically to how bilinguals learn face-voice pairings. Bilingual infants exhibit an advantage in processing of auditory and visual stimuli, even beyond the language domain (e.g., Brito & Barr, 2014; Kovács & Mehler, 2009; Liu & Kager, 2017; Sebastián-Gallés *et al*., 2012; Singh, Fu, Meaney, & Rifkin-Graboi, 2015). Hence, domain-general cognitive and perceptual benefits due to exposure to linguistic diversity could also promote infants' ability to identify talkers. For example, it is possible that the bilinguals simply had a competitive edge at remembering the face-voice pairings. Additionally, it seems plausible that bilinguals are more efficient at encoding and remembering talker identity because they use this information in their daily lives to help distinguish their native languages, thus potentially facilitating the acquisition of and/or switching between languages. This notion is supported by research showing that adult early bilinguals associate interlocutor identity with their native languages, leading to adaptations in their spoken language comprehension strategies (Molnar, Ibáñez-Molina, & Carreiras, 2015).

Alternatively, perhaps talker recognition was superior in bilinguals because early bilingualism heightens acoustic sensitivity (e.g., pitch perception; Liu & Kager, 2017) and/or because it enhances perceptual attentiveness specifically to talker-specific acoustic-phonetic detail. The latter possibility is supported by studies showing that bilinguals maintain sensitivity to non-native speech sound contrasts longer than do monolinguals (e.g., Best, 1994; Byers-Heinlein & Fennell, 2014). If the bilinguals in our study succeeded because they attended to phonetic detail in the test language that the monolinguals were no longer attentive to, then our findings could be conceptualized as delayed perceptual narrowing in bilinguals (see also Sebastián-Gallés *et al*., 2012). Evidence that access to language-specific phonology facilitates talker processing in children and adults supports this idea (Fecher & Johnson, 2018a,b; Johnson *et al*., 2018; Levi, 2018; Orena, Theodore, & Polka, 2015; Perrachione *et al*., 2011). Future work will help to clarify whether the monolinguals and bilinguals performed differently in our study because bilinguals have a specific talker processing advantage or because bilinguals have a more general cognitive or perceptual advantage that also facilitates the task of identifying individuals by their voices (e.g., greater sensitivity to acoustic detail, or better executive function). Two interesting avenues for future research would be, first, to examine whether monolinguals and bilinguals also perform differently in a face recognition task, and second, to investigate the role of visual speech cues in talker recognition. The possibility that access to visual cues from the talker's articulating face contributes to bilinguals' success in talker processing gains support from earlier findings indicating that bilingual infants are better than monolingual infants at visually distinguishing between languages (Sebastián-Gallés *et al*., 2012).

In conclusion, this work represents the first empirical evidence that bilingual exposure affects infants' processing of indexical – and not just linguistic – aspects of the speech signal. Our findings contribute to an increased understanding of the mechanisms linking bilingualism to infants' cognitive, linguistic, and social development.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

ENDNOTE

[1]We originally used a 7-point scale (with 'some college education' and 'some university education', as well as 'college graduate' and 'university graduate', as separate categories, respectively). However, since the distinction between college and university was not meaningful to a large number of our participants, we combined these two categories.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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APPENDIX

TABLE A1 Percentage of exposure to English and other language(s) as reported by caregivers of bilingual infants

Infant	English exposure	Exposure to other language(s)
1	30%	70% French
2	30%	70% Polish
3	30%	70% Portuguese
4	30%	70% Tagalog
5	35%	50% Hindi, 15% Punjabi
6	40%	60% Arabic
7	50%	40% Arabic, 10% French
8	50%	50% French
9	50%	50% Russian
10	50%	50% Tamil
11	50%	30% Tamil, 20% Sinhalese
12	50%	50% Urdu
13	50%	45% Urdu, 5% Punjabi
14	55%	40% Kashmiri, 5% Urdu
15	60%	40% French
16	60%	40% Punjabi
17	60%	40% Punjabi
18	70%	30% Cantonese
19	70%	30% Cantonese
20	70%	30% Polish
21	70%	30% Portuguese
22	70%	15% Russian, 15% Urdu
23	70%	30% Serbian
24	70%	20% Vietnamese, 5% Polish, 5% Cantonese