The early bilingual influence on speech and music processing

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Abstract

Previous studies report incongruent findings whether bilingual infants face delays when perceiving native speech contrasts compared to monolinguals. We present three experiments targeting monolingual and bilingual infant vowel, linguistic pitch, and musical pitch perception in the first year after birth. Bilingual infants outperformed their monolingual peers in each experiment, contrasting previous findings. We propose a heightened acoustic sensitivity hypothesis: facing a complex language environment, bilingual infants pay more attention to input acoustic details than monolinguals crossing linguistic and musical domains.

Index Terms: infant, bilingualism, perception, language, music

1. Introduction

Human experience to sounds and languages begins before birth. Speech perception is essential for the mastery of an infant's native sound system and subsequently her native language. In the first year after birth, infants tune in from their initial sensitivities towards the patterns from their ambient environment, a process known as perceptual attunement [1]. This process is not restricted to the linguistic domain but applies to other fields such as musical [2] and face [3] perception. Some experiments have shown a delay in the vocabulary comprehension and production of a single language [4] among infants growing up learning two languages. Though under debate [5,6], discrepancies lead to the question whether the pace of sound acquisition may be delayed among bilingual infants. Since native sounds and words are acquired in a parallel fashion, the delay of one domain may affect the acquisition of the other.

Debates in bilingual speech perception begin with the study reporting the perception of a native vowel contrast during the language-specific perceptual attunement process. Spanish-Catalan bilingual infants of 8 months fail to discriminate Catalan-specific /e/-/ɛ/ and Catalan/Spanish /o/-/u/ contrasts [7,8]. Nevertheless, other studies have found that monolingual and bilingual infants are both sensitive to native contrasts [9,10]. Several accounts have been proposed for the observed bilingual delay, including, but not limited to, acoustic properties and salience, input frequency and distributional properties, rhythmic similarity or segmental variation (cognate words) between languages, phonetic space (the density of phonetic categories), segmental processing differences, task effects (tokens in use, number of talkers, paradigm, etc.), and social-indexical factors [7-10].

Despite the debates on the similarities and differences between monolingual and bilingual infants along the language developmental trajectory, recent studies illustrate advantages among bilingual infants, such as inhibition control [11] and attentional factors [12], in the cognitive domain. These advantages are attributed to the bilingual environment, even though no clear advantage has been shown in the linguistic domain for bilingual infants. The existence of such potential advantage is worth exploring.

Just like the language-specific perceptual attunement, infants present initial sensitivity to music [13], followed by the perceptual tuning process towards their native music conventions [2]. No previous research has tested the influence of bilingualism on music perception. We propose the following research question: do monolingual and bilingual infants differ in the discrimination of linguistic and non-linguistic distinctions between acoustic stimuli in the first year of life? To answer these questions, we tested infants on a native vowel, a non-native linguistic pitch, and a non-linguistic violin contrast before 12 months after birth.

2. Experiments

2.1. Exp.1 – Vowel perception

As the debate of speech perception between monolingual and bilingual infants begins with vowel perception, a native vowel contrast was selected in Exp.1.

2.1.1. *Participants*

Seventy-four 8-9-month-old Dutch monolingual and bilingual infants participated in the study. Data from 16 participants were excluded from analysis, the reasons being: fussiness (6), unable to habituate (1), inattentive (4), looking time (LT) less than 2 seconds for both trials in the test phase (2), and individual average LT for each sound category in the test phase more than 2 SD from the mean (3). Data from 58 participants were included for analysis, with 29 infants per language condition.

2.1.2. *Stimuli*

The Dutch /I/ and /i/ (e.g., rit 'ride' vs. riet 'reed') vowels were selected. The two vowels differ in the spectrum (first (F1) and second (F2) formant) but not duration [14,15]. This differs from the English /i:/-/i/ distinction in which both spectrum and duration differ. We hypothesized that limited acoustic cues in the Dutch contrast may increase infants' perceptual and learning difficulties. The syllables /bIp/ and /bip/ spoken by a female Dutch speaker were recorded in a sound-isolated booth with a DAT Tascam DA-40 recorder and a Sennheiser ME-64 microphone. The voice onset time values of syllable onsets and offsets /b/ and /p/ were set around 72ms and 1ms, respectively. The other natural properties of the contrast were maintained. The F1 and F2 values of the contrast are 409 and 2280 Hz for /I/ and 370 and 2597 Hz for /i/.

2.1.3. *Procedure*

Infants went through habituation and test phases. The habituation phase consisted of randomly presented tokens from one category. One trial ended when infants looked away for more than two seconds, and then the next trial began. The habituation criterion was set as infants' mean looking time of three consecutive trials dropping below 65% of the first three trials in the habituation phase. When habituated, the test phase started and infants heard two trials from the other category. Discrimination was indicated by a looking time recovery hearing the new stimuli. The stimuli presentation order between the two phases was counter-balanced.

During the experiment, infants sat on their parents' lap facing the screen, with the camera in front of them. Parents were blind to the testing stimuli and heard music from a headphone. No visual or audio interference could be observed in the test booth other than the stimuli used in the test. The test was conducted by a computer program [16]. A tester observed the experiments through a closed TV circuit and used a button box to record infants' looking times in the testing room adjacent to the testing booth. The inter-stimulus interval (ISI) was set as 1sec in all phases. If infants' looking time per trial was less than 2sec, the trial was considered ineffective and was excluded from the analysis [17].

2.1.4. Results

A Repeated Measures analysis of variance (RM ANOVA) was conducted with the mean of infant recovery looking time between the test trials and the end of habituation trials looking time as the within-subject variables and 2-level (monolingual vs. bilingual) language background as the between-subject factor. The effect of the phase change was significant, $F(1,56) = 7.202$, $p = .010$, $\eta2 = .114$. The interaction between language background and the phase change was also significant, $F(1,56) = 6.784$, $p = .012$, $\eta2 = .108$. Splitting the data by language background, paired samples t-test shows that the phase change was significant for bilingual, $t(28) = -3.041$, $p = .005$, but not monolingual group, $t(28) = -0.080$, $p = .937$. Hence, bilingual but not monolingual infants discriminated the contrast (Figure 1).

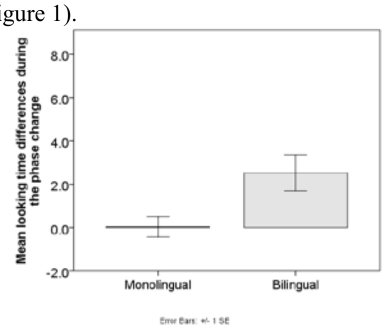

Figure 1: *Mean looking time differences in the phase change*

2.2. Exp.2 – Linguistic pitch perception

Exp.1 showed unexpected results that may be influenced by the sound categories of the native languages. To avoid such potential influence, we tested a linguistic pitch contrast novel to monolingual and bilingual infants in Exp.2.

2.2.1. Participants

Sixty-eight 11-12-month-old Dutch monolingual and (non-tone language learning) bilingual infants participated in the study. All bilingual infants were exposed to Dutch and another non-tone or pitch accent language. Data from 12 participants were excluded from the analysis for the following reasons: fussiness (1), unable to habituate (2), LT less than 2 seconds for both trials in the test phase (5), and individual average LT for each sound category in the test phase more than 2 SD from the mean (4). Data from 56 participants were included for analysis, with 28 infants per language condition.

2.2.2. Stimuli

The high-level (T1) and high-falling (T4) Mandarin Chinese tones were selected to create the stimuli. The tone-bearing syllable was /ta/. The productions of a Mandarin female speaker were recorded using the same device as in Exp.1. The natural Mandarin T1-T4 pair was further manipulated to avoid potential ceiling performance in non-native perception [18]. Considering the role of acoustic salience in non-native tone perception, the pitch distance between T1 and T4 was reduced to two fundamental frequency (F0) values occurring at 3/8 and 3/4 of the pitch distance of the original contrast, respectively, by introducing four interpolation points along the pitch contours (at 0%, 33%, 67% and 100%, see Fig.4). The new contrast shares the same acoustic properties with the T1-T4 contrast except for featuring a narrower distance between the pitch contours. The acoustic salience of this phonetic contrast is weakened by a pure manipulation of F0 (Contrast B, Figure 2).

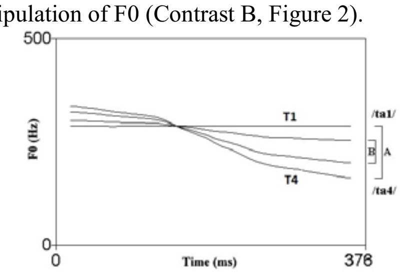

Figure 2: *The reduced T1-T4 [B] contrast shrunk from T1-T4 [A] to reduce the acoustic salience.*

2.2.3. Procedure

The same procedure as in Exp.1 was adopted.

2.2.4. Results

An RM ANOVA was conducted with the same within- and between-subject variables as Exp.1. The effect of the phase change was significant, $F(1,54) = 4.976$, $p = .030$, $\eta2 = .084$. The interaction between language background and the phase change was also significant, $F(1,54) = 6.126$, $p = .016$, $\eta2 = .102$. Splitting the data by language background, paired samples t-test shows that the phase change was significant for bilingual, $t(27) = -2.655$, $p = .013$, but not monolingual group, $t(27) = 0.263$, $p = .794$. Hence, bilingual but not monolingual infants discriminated the contrast (Figure 3).

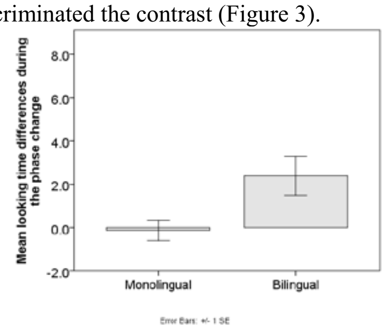

Figure 3: *Mean looking time differences in the phase change*

2.3. Exp.3 – Musical pitch perception

Exps.1 and 2 tested two contrasts in language. Results showed a bilingual perceptual advantage. In Exp.3, we explore monolingual and bilingual infant perception of a violin contrast in order to test the domain specificity of the effect observed in previous experiments.

2.3.1. Participants

Forty-eight 8-9-month-old Dutch monolingual and (non-tone language learning) bilingual infants participated in the study. Data from 12 participants were excluded from the analysis, the reasons being: fussiness (3), crying (3), inattentiveness (2), unable to habituate (1), and tone or pitch accent language exposure after birth (3). Eventually, data from 36 participants were included for analysis, with 18 infants per language condition.

2.3.2. Stimuli

To ensure the cross-domain comparison, the musical (violin) tonal stimuli were generated from the same contrast used in Exp.2. The F0 tiers of the contrast in Exp.2 were extracted and replaced the F0 tiers of a violin tone, creating novel violin stimuli. The violin contrast shared the exact same pitch contour as the tonal contrast in Exp.2 but differed in timber.

2.3.3. Procedure

The same procedure as in Exp.1 was adopted.

2.3.4. Results

An RM ANOVA was conducted with the same within- and between-subject variables as Exp.1. The effect of the phase change was significant, $F(1,34) = 4.371$, $p = .044$, $\eta2 = .114$. The interaction between language background and the phase change was also significant, $F(1,34) = 4.565$, $p = .040$, $\eta2 = .118$. Splitting the data by language background, paired samples t-test shows that the phase change was significant for bilingual, $t(17) = -2.274$, $p = .036$, but not monolingual group, $t(17) = 0.062$, $p = .951$. Hence, bilingual but not monolingual infants discriminated the contrast (Figure 4).

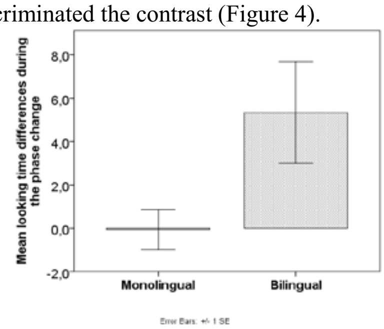

Figure 4: *Mean looking time differences in the phase change*

3. Discussion

The current study tested three contrasts between monolingual and bilingual infants in the first year after birth. Results showed differences between monolingual and bilingual infants and similarities across experiments. In Exp.1, monolingual infants did not discriminate the native vowel contrast. This finding differs from major language-specific perceptual attunement findings showing that sensitivity to native contrasts is maintained and improved in infancy [19], but conforms to some other studies illustrating the perceptual difficulty in some native contrasts [20]. Perception of native and non-native speech contrasts may be elastic [21], influenced by multiple factors including but not limited to frequency and age of exposure, as well as acoustic salience [22]. Contrasts with high acoustic salience can be discriminated across ages regardless of whether they are presented in the native sound inventories [23]; whereas contrasts with low acoustic salience (e.g., Exp.1) may initially be hard to discriminate, and infants' perception improves with their native linguistic experience. Crucially, bilingual but not monolingual infants discriminated the native vowel contrast, contrasting previous studies in which either delay or equal pace was found for bilingual infants in comparison to their monolingual peers. We hypothesize that the difference may surface with contrasts of low acoustic salience.

Considering that one's native linguistic experience may constrain her speech perception, and bilinguals have more referents to hinge on when perceiving a native contrast, a non-native contrast was examined in Exp.2. Differences between monolingual and bilingual infants were once again observed. Since language-specific perceptual attunement would predict a loss of sensitivity to non-native contrasts, the current differences may be interpreted as a successful perceptual attunement in monolingual infants, but a delayed process in bilinguals triggered by a more complex language environment. Alternatively, infants may have undergone the perceptual attunement of linguistic pitch [24], but bilingual's rich, more varied linguistic experience facilitates their perception of the non-native contrast. In addition, musicianship and learning tone language has been shown to facilitate non-native tone perception in adulthood [25]. The current finding suggests that exposure to two languages may lead to similar outcomes.

In Exp.3, a music contrast was tested with the results showing the similar pattern as in previous two experiments. The null result in monolingual infants suggests that similar to language contrasts, music perception is subject to acoustic salience. It is harder to perceive the inconspicuous violin pitch contrasts. The difference between monolingual and bilingual infants indicates that the bilingual advantage may extend to the musical domain. Furthermore, language and music processing may share common perceptual and neural mechanisms, which may further be affected by the bilingual experience. The detailed separation and overlap between speech and music processing proposed in some previous studies [26,27] need to be explored in future research under a bilingual setting.

From the outcomes of the three experiments, we propose a heightened acoustic sensitivity hypothesis: Bilingual infants may pay more attention to acoustic details in the input than their monolingual peers. This hypothesis may originate from, or be intertwined with: 1) daily experience of a complex language environment; 2) a tightened phonetic space from two languages, forcing bilingual infants to be sharp in detecting native sound patterns; 3) better neural plasticity and less neural commitment, avoiding the formation of false sound categories; etc. Crucially, bilingual infants' heightened acoustic sensitivity is not restricted to the linguistic domain but extends to music perception. The advantage may surface with less salient contrasts as shown in Exps 1 and 2.

The proposed hypothesis may be one of the explanations not only for studies showing bilingual infants' enhanced sensitivity to non-native contrasts compared to monolingual infants [28,29] but also for mixed findings. For initially discriminable contrasts that require realignment or strengthening, too much attention to acoustic details may not help in category formation / boundary stabilization, resulting in (temporary) delay [7,8], and a later sound category formation than monolinguals [30]. Paying more attention to the acoustic cues from the input may be another learning strategy bilingual infants use to keep pace with monolinguals along the developmental trajectory [31].

An alternative hypothesis is that bilingual infants may benefit from their enhanced cognitive abilities, such as executive function and/or attention in the discrimination tasks. Follow-up studies are needed to disentangle these possibilities.

4. Conclusion

Before the first year of life, bilingual infants outperform their monolingual peers in the perception of a native vowel, a non-native pitch, and a musical pitch contrast. The cross-domain perceptual differences between monolingual and bilingual infants are explained by a heightened acoustic sensitivity hypothesis stating that infants growing up in a bilingual environment may pay more attention to acoustic details in the input compared to monolinguals. Previous studies have shown cognitive advantages [11,12] among bilingual infants. The current study extends the advantages to linguistic and musical perception, indicating a cross-domain effect brought by bilingualism in infancy.

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