The Effects of Bilingualism on Attentional Processes in the First Year of Life

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Research Highlights

- We compared attentional control abilities in seven-month-old bilingual and monolingual infants.
- Auditory and visual conditions of an anticipatory looking measure of attentional control were tested in infants.
- Bilingual and monolingual infants' performance did not differ in attentional control.
- The proposed bilingual advantage in the development of attentional processes in the first year of life is not supported by the current data.

Abstract

Bilingualism is a powerful experiential factor, and its effects have been proposed to extend beyond the linguistic domain by boosting the development of executive functioning skills. Crucially, recent findings suggest that this effect can be detected in bilingual infants before their first birthday indicating that it emerges as a result of early bilingual exposure and the experience of negotiating two linguistic systems in infants' environment. However, these conclusions are based on only two research studies from the last decade (Comishen, Bialystok, & Adler, 2019; Kovács & Mehler, 2009), so to date, there is a lack of evidence regarding their replicability and generalisability. In addition, previous research does not shed light on the precise aspects of bilingual experience and the extent of bilingual exposure underlying the emergence of this early bilingual advantage. The present study addressed these two questions by assessing attentional control abilities in seven-month-old bilingual infants in comparison to same-age monolinguals and in relation to their individual bilingual exposure patterns. Findings did not reveal significant differences between monolingual and bilingual infants in the measure of attentional control and no relation between individual performance and degree of bilingual exposure. Bilinguals showed different patterns of allocating attention to the visual rewards in this task compared to monolinguals. Thus, this study indicates that bilingualism modulates attentional processes early on, possibly as a result of bilinguals' experience of encoding dual-language information from a complex linguistic input, but it does not lead to significant advantages in attentional control in the first year of life.

Keywords: Attentional control; Attentional flexibility; Bilingualism; Bilingual effect; Infancy; Anticipatory looking

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The majority of infants in the world are born into multilingual families and/or communities and face the challenging task of simultaneously acquiring more than one language (Grosjean, 2010). This early bilingual experience has significant and long lasting effects on language processing and language acquisition mechanisms (Sebastián-Gallés, 2011), and these effects are observed in behavioural patterns and neural signatures underlying linguistic processing from childhood to old age (see Costa & Sebastián-Gallés, 2014 for a comprehensive review). Importantly, the effects of bilingualism have been proposed to extend beyond the linguistic domain leading to advantages in more general cognitive abilities (e.g., Adesope, Lavin, Thompson, Ungerleider, 2010; Bialystok, 2017; Kroll & Bialystok, 2013), specifically executive functioning, which encompasses processes such as inhibition, monitoring, and working memory (Miyake et al., 2000). However, recent studies have raised doubts about the extent of these bilingual advantages, sparking an extensive and lively debate (see Antoniou, 2019; De Bruin, Treccani, & Della Sala, 2015; Paap, Johnson, & Sawi, 2015; Valian, 2015 for reviews). Aside from scrutinising the replicability of the effects of bilingualism reported in the literature, this debate has also been concerned with identifying the aspects of bilingual experience that could lead to the potential cognitive advantages, the specific cognitive domains to which they would extend, and whether their manifestations at behavioural and neurophysiological levels can be generalisable across bilingual populations and experimental techniques. This study focuses on these questions by investigating the emergence, extent, and generalisability of the bilingual effect on the development of early attentional skills in pre-verbal infants.

Early accounts of the bilingual advantage have proposed that it is manifested primarily in tasks that incur response inhibition. This effect was attributed to bilinguals' constant experience of inhibiting one of their languages while the other is in use (Green, 1998; Kroll, Gollan, Goldrick, Ferreira, & Miozzo, 2014). This implies that the bilingual cognitive advantage would emerge as a result of actively using two languages and switching between them during the processes of speech comprehension and production, whereby bilinguals constantly put their inhibition skills into practice to suppress one of their languages. Recent evidence, however, has not supported this explanation as bilinguals do not consistently outperform monolinguals in tasks that assess solely response inhibition skills (Antón et al., 2014; Antón, Carreiras, & Duñabeitia, 2019; Antón, García, Carreiras, & Duñabeitia, 2016; Barac, Moreno, & Bialystok, 2016; Carlson & Meltzoff, 2008; Duñabeitia et al., 2014; Esposito, Baker-Wand, & Mueller, 2013; Martin-Rhee & Bialystok, 2008; Paap, Johnson, & Sawi, 2015). Instead, more recent accounts have emphasised the role of attentional flexibility rather than inhibition (Bialystok, 2017), specifically bilinguals' ability to selectively allocate their attentional resources in cognitively demanding or effortful tasks such as tasks that involve conflicting cues or require participants to switch attention from one cue to another (Costa, Hernández, Costa-Feidella, & Sebastián-Gallés, 2009). Crucially, this explanation focuses on the bilinguals' experience of differentiating their two languages and contrasting the linguistic information relevant to each language system. Supporting this view, there is evidence that bilingual advantages can emerge even in bilingual populations who have had brief experience in actively using their two languages such as young simultaneous bilingual toddlers (Crivello et al., 2016; Poulin-Dubois, Blaye, Coutya, & Bialystok, 2015) and young sequential bilinguals who are still in the process of learning their second language (Carlson & Meltzoff, 2008; Kalashnikova & Mattock, 2014).

In addition to this research with preschool- and school-aged children and adults, recent efforts have been directed to the study of the effects of bilingualism in infancy. Bilingual infants are able to discriminate their two languages already in their first months of life (Byers-Heinlein, Burns, & Werker, 2010; Molnar, Gervain, & Carreiras, 2014; Bosch & Sebastián-Gallés, 1997), several months before they face the need to inhibit one of their languages during speech production. Therefore, the study of the effects of bilingualism in infants provides a unique opportunity for pinpointing the aspects of bilingual experience that give rise to the effects of bilingualism reported in the literature, and to assess the extent of these early effects beyond the domain of linguistic processing, specifically, the development of general executive functioning skills.

Two studies published to date have proposed that the effects of bilingualism on attentional processes can be observed already during infants' first year of life. In the first study in this area, Kovács and Mehler (2009a) compared seven-month-old monolingual (*N* = 20 per experiment) and bilingual (*N* = 20 per experiment) infants' performance on a behavioural measure of cognitive control. This study reported three experiments that assessed infants' ability to learn to anticipate the appearance of a visual reward following a specific cue. In an anticipatory looking paradigm where eye-tracking was used to record infants' gaze patterns, infants were first exposed to a learning phase (pre-switch phase) in which an auditory- or visually-presented cue (a sequence of three syllables or three shapes) was followed by the appearance of a puppet on one side of the screen. After nine trials, the test phase (post-switch phase) began in which the location of the puppet was switched to the opposite side (e.g., if the puppet appeared on the left during the pre-switch phase, now it would appear on the right). All infants were predicted to successfully learn that the visual reward appears consistently on one side of the screen after the cue in the pre-switch phase. However, the post-switch phase was predicted to impose greater demands on infants' cognitive control skills as they would be required to abandon the previously learned response pattern in order to successfully learn the new location for the reward. If infants were not able to engage cognitive control in this task, they should show fewer anticipatory looks to the new location or even persevere in expecting the reward to appear in the incorrect location. Experiments 1 and 2 presented infants with auditory cues that had no consistent internal structure (i.e., random three-syllable words, Experiment 1) and auditory cues involving a structure change in pre- and post-switch (i.e., three syllable words with AAB vs. ABB structure, Experiment 2). Regardless of the cue, monolinguals and bilinguals performed similarly in the pre-switch phase, but only bilinguals were successful in the post-switch phase. Experiment 3 employed an identical paradigm, but visual sequences that involved a structure change (i.e., geometric shapes appearing in AAB vs. ABB sequences) were used instead. The aim of using visual as well as auditory stimuli consisted in assessing whether bilinguals only manifest advantages in the domain in which they encounter conflicting information in their daily environment (i.e., linguistic domain in which they are exposed to auditory input), or if it extends across domains to tasks that do not require any auditory processing. Supporting the second possibility, the pattern of results in Experiment 3 was identical to Experiments 1 and 2. These findings led the authors to conclude that the early experience of monitoring incoming linguistic information in two languages and simultaneously constructing two linguistic systems fosters the development of cognitive control abilities manifested beyond the domain of linguistic processing in bilinguals at this young age, well before they start to produce their two languages.

While Kovács and Mehler (2009a) claimed that their task assessed early cognitive control, the exact nature of the processing mechanisms underlying infants’ performance and the component(s) of executive functioning involved in their task were not defined. A recently published study by Comishen and colleagues (Comishen, Bialystok, & Adler, 2019) postulated that this type of tasks engages selective attentional mechanisms, which are precursors of later executive functioning skills (Bialystok, 2017). They used a similar anticipatory looking paradigm to Kovács and Mehler's Experiment 3, but with one modification that was proposed to specifically target infants' attentional flexibility. That is, rather than having to inhibit a previously learned response in favour of a new response, infants were required to switch their attention from the previous cue-response rule to a new rule. In this task, six-month-old monolingual ($N = 20$) and bilingual infants ($N = 20$) were presented with two simple visual cues (a colourful checkerboard and a bulls eye), and each cue predicted the appearance of a visual reward (e.g., the reward appeared on the left after the checkerboard and on the right after the bulls eye). After 30 pre-switch trials, the location of the rewards was switched, and infants completed 30 post-switch trials. Even though Analyses of Variance yielded no significant effects of phase, language group, and no significant interaction, post hoc analyses showed that while both groups anticipated the location of the reward above chance levels in the pre-switch phase, only the bilinguals did so in the post-switch phase. Furthermore, monolinguals were slower at directing their gaze to the reward after its appearance in the post-switch compared to the pre-switch phase (reactive rather than anticipatory looking), but this was not the case for the bilinguals. It should be noted, however, that this study collapsed infants' gaze data across all trials in the pre- and post-switch phases (infants completed 30 trials in each phase, but only 20 were used for analyses by excluding the first and last 10 trials of the task), so the analyses did not account for changes in infants' performance as the task progressed. As seen in Kovács & Mehler's data, infants' performance is expected to improve as they get more exposure to the critical rule across trials. This type of analyses could have revealed whether the monolingual infants in Comishen et al. were slower than bilinguals in learning the new rule, or whether they failed entirely. Nevertheless, it was concluded that bilingual infants' early experience of contrasting their two languages fosters the development of general attentional skills, and which in turn, may boost the development of executive functions observed in bilingual children (e.g., Bialystok & Martin-Rhee, 2008; Crivello et al., 2016; Poulin-Dubois et al., 2015).

These early effects of bilingualism on cognitive development can be attributed to the differential nature of monolingual and bilingual infants' early language experiences that result in adaptations in mechanisms of selective attention and learning strategies. Supporting this claim, differences in the allocation of attentional resources by bilingual and monolingual infants have been shown in tasks of audio-visual speech perception. Sebastián-Gallés and colleagues (Sebastián-Gallés, Albareda-Castellot, Weikum, & Werker, 2012) investigated infants' ability to discriminate languages based solely on the information present in a silent speaking face, and bilinguals outperformed monolinguals even when the face produced a language that they have not heard before. Furthermore, bilinguals have shown the tendency to attend to the mouth regions of a speaking face to a greater degree than monolinguals in audio-visual speech perception tasks indicating increased attention to additional cues that can assist language discrimination and speech perception (Pons, Bosch, & Lewkowicz, 2015, but see Tsang, Atagi, & Johnson, 2019 for a different results pattern). These findings provide examples for a bilingualism effect on infants' attentional skills in language-processing tasks, and it opens the question about its extent beyond the linguistic domain.

In addition to the studies by Kovács and Mehler (2009; see also Kovács & Mehler, 2009b for a similar finding with 12-month-old bilingual infants) and Comishen et al. (2019) mentioned above, there is some evidence suggesting that bilinguals can engage their attentional skills to a greater degree than monolinguals in non-linguistic tasks that assess processes of novel information-encoding and retention. Singh et al. (2015) showed that bilinguals required fewer habituation trials than monolinguals in a visual habituation task, which is a reflection of greater information encoding efficiency. A set of studies by Brito and colleagues is of particular relevance to the present research, as they provide evidence for an early bilingual advantage in another precursor of executive functions, namely memory flexibility. Their studies assessed infants' ability to form new memories and generalise them to novel situations and showed that bilingual infants at six- and 18-months of age were successful at repeating a learned action when presented with novel contexts while same age monolinguals only repeated but did not generalise the learned actions to novel contexts (Brito & Barr, 2012, 2014; Brito, Sebastián-Gallés, & Barr, 2015).

Despite these converging findings, the conclusion that bilingual experience already boosts general attentional development in the first months of life is not uncontroversial. First, the available evidence continues to be scarce. Second, bilingual advantage effects in children, young adults, and the elderly have been recently contested (e.g., De Bruin, Treccani, & Della Sala, 2015; Anton et al., 2014, 2016, 2019; Duñabeitia et al., 2014; Gathercole et al., 2014; Lehtonen et al., 2018; Paap et al., 2015; Costa & Sebastián-Gallés, 2014). Such inconsistencies in findings and replication failures across bilingual populations, experimental techniques, and laboratories raise the need for direct tests of the replication validity of the earliest manifestations of the bilingual advantage. This is not restricted to this area of research. Recent years have seen a rise in replication efforts in psychological research (Adolph et al., 2012; Frankenhuis & Nettle, 2018; Klein et al., 2014; Open Science Collaboration, 2015) and more specifically, infancy research (Frank et al., 2017; Kucker et al., 2018), which do not only aim to scrutinise previously reported effects in light of field-specific challenges such as highly specialised experimental techniques and small sample sizes, but to deepen our understanding of early cognitive development by accumulating evidence from a variety of infant populations and experimental approaches. Following this motivation, this study aims to replicate and extend the findings by Kovács and Mehler (2009). In addition to assessing the replicability and generalisability of their findings in a new sample of monolingual and bilingual infants, our aim is to further our understanding of the domain-specificity of the early effects of bilingualism and the specific aspects of early bilingual experience that relate to the manifestation of bilingual advantages in the development of early attentional processes.

This replication effort is driven further by specific concerns regarding the generalisability of the findings reported in the two previous studies that have assessed executive control in monolingual and bilingual infants. First, Kovács and Mehler (2009) only provided indirect evidence for the argument that early bilingual exposure fosters the development of attentional control, and crucially, that this effect can be observed across the linguistic and the non-linguistic domains. That is, in their study, infants' performance was tested using auditory and visual stimuli but in a between-subjects design, so it was not possible to discern whether monolingual and bilingual performance in the two tasks reflected a single underlying construct. Second, while Kovács and Mehler report converging evidence from three experiments using different stimuli, the analyses for each experiment involved 20 infants per language group, and no information about the size of the reported effects was provided. A similar concern relates to the more recent study by Comishen et al. (2019) who reported a single experiment including 20 monolingual and 20 bilingual infants. This could have resulted in low statistical power, which would explain the lack of significant effects in their initial planned Analyses of Variance.

The two studies also provided limited information about their bilingual samples. Kovács and Mehler reported that all bilinguals in their sample were ‘crib-bilinguals’ who acquired the two languages from birth. However, no information about infants’ degree of exposure to their languages was provided, but it was reported that infants were recruited in a monolingual community, and they were acquiring the community language and one additional language. Comishen et al. reported that the 20 bilingual infants in their study were recruited from a metropolitan area, and that they were acquiring English, the community’s official language, and one additional language. This study reports that bilinguals were exposed to the language other than English for 60% of the time on average, but the range of exposure within the sample also was not reported and was not included in the analyses. There is no clear evidence to suggest that heterogeneity in bilinguals’ language background per se can impact the manifestation of the hypothesised effects of bilingualism. Nevertheless, the use of bilingualism as an umbrella term for describing infants exposed to more than one language in their environment can be misleading as individual bilingual experience is modulated by the properties of the bilingual’s two languages, degree of bilingualism, and infants’ patterns of language exposure and language use (Byers-Heinlein, 2015). For instance, significant individual variability in language-processing (Garcia-Sierra et al., 2011; Garcia, Guerrero-Mosquera, Colomer, & Sebastián-Gallés, 2018; Ramon-Casas, Swingley, Sebastián-Gallés, & Bosch, 2009) and memory tasks (Brito et al., 2015) has been found within bilingual samples as a function of infants’ degree of exposure to their two languages. Furthermore, emerging evidence suggests that the executive functioning advantages found in bilingual children may be also modulated by their degree of bilingualism (Bosma, Hoekstra, Versloot, & Blom, 2017; Sorge, Toplak, & Bialystok, 2017; but see

Nicoladis, Hui, & Wiebe, 2018), so it can be expected that this relation will be observed also in infancy.

In light of these concerns, the objective of this study was to test the bilingual effect reported by Kovács and Mehler (2009a) in a new population of bilingual infants. While Kovács & Mehler's work has received extensive attention in the literature, no direct replications are available to date. As mentioned above, the study by Comishen et al. (2019) investigated a related research question using a similar anticipatory looking paradigm, but this study was not designed as a replication of Kovács and Mehler, so a direct comparison between the two studies is difficult. The present study also aims to expand the previous finding in two ways. First, this study incorporates a within-subjects design to assess individual performance across the auditory and visual modalities. This will allow us to test the extension of the effects of bilingualism across domains and to assess the test-retest reliability of the experimental procedure used by Kovács and Mehler. If the previous findings reflect the effects of bilingualism on general executive control skills, then they are not only expected to be detectable across modalities, but individual performance is expected to correlate across the two tasks confirming that they reflect a single underlying mechanism. Second, this study incorporates a direct measure of infants' individual bilingual exposure and a measure of its relation to their performance in the attentional control task. All bilingual infants in this study were exposed to a single pair of two typologically distinct languages from birth, Spanish and Basque. Each infant's individual exposure patterns were assessed in this study in order to obtain an objective measure of exposure to the two languages for bilinguals, and for monolinguals, exposure to their single language and any incidental second language exposure in the community.

Following Kovács & Mehler, we predicted an experiment phase by language group interaction. Specifically, in both the auditory and the visual tasks, monolingual and bilingual infants were expected to perform similarly in the pre-switch phase, which would be manifested in a similar proportion of anticipatory looks to the location of the reward after hearing the auditory cue. However, only bilinguals were expected to succeed in the post-switch phase by producing a greater proportion of anticipatory looks to the reward's location compared to monolinguals. Second, we predicted a significant correlation between infants' post-switch proportion of anticipatory looks in the auditory and visual tasks denoting that infants' attentional control abilities underlie their performance across task domains and testing sessions. Finally, we predicted that the bilingual infants' individual degree of exposure to their languages would be a significant predictor of their anticipatory looking behaviour in the post-switch but not the pre-switch phase in both the auditory and visual tasks.

Method

Participants

Seventy seven-month-old infants participated in this study: 40 infants were monolingual acquiring Spanish or Basque (*M* age = 224.4 days, *SD* = 6.15; 13 female; 16 Spanish monolinguals, 24 Basque monolinguals) and 34 infants were bilingual acquiring Spanish and Basque (*M* age = 223.97 days, *SD* = 6.23; 23 female). Infants were recruited between the ages of 7 months 0 days and 7 months 30 days, and the mean age did not differ between the two groups, $t(72) = 298$, $p = .767$, $d = 0.07$. According to parental reports, all infants were born full term (premature birth was defined as 36 or fewer weeks of gestation), have not experienced significant health issues, and were not at family risk for neurodevelopmental disorders. Exclusions based on these criteria and the language selection criteria listed below were made prior to recruitment. Families were recruited at a local hospital and all came from the Basque

Country in Spain. Monolingual and bilingual families did not differ according to their level of annual income, Kolmogorov-Smirnov $Z = .158$, $p = 1.00$, and level of maternal education, $Z = .927$, $p = 357$. Six additional infants (4 monolingual, 2 bilingual) participated but were excluded due to gaze loss (failure to contribute a minimum of 40% gaze data for the entire task) (4 infants) and failure to comply with the language exposure criteria for monolingualism or bilingualism, which became known to the experimenters after completing the experimental session (2 infants). Participants received a small gift as a token of appreciation for their time. This study was approved by the Basque Center for Cognition, Brain and Language ethics committee [approval number: 291118D], and all caregivers provided informed consent prior to participating in the study. Data collection was carried out between 09 January 2019 and 10 March 2020[1].

Language background questionnaire. Information about infants' language exposure was collected using a language exposure questionnaire (based on Bosch & Sebastián-Gallés, 2001; Molnar, Gervain, & Carreiras, 2014). This questionnaire is administered to all monolingual and bilingual participants across our lab's studies. It is completed by the experimenter during an interview with the infant's caregivers, and it includes questions about the infant's primary interlocutors (who interact with the infant on a day-to-day basis), the languages that they use, the number of hours that they spend using these languages around the infant every day, and the changes in these patterns of exposure across the infant's lifetime (the template of the questionnaire is available at osf.io/k3e9z/). This information is then used to calculate the percentage of time that the infant receives exposure to each one of their languages.

[1] We planned to include 35 monolingual and 35 bilingual infants who contributed analysable data for both the auditory and visual conditions of the anticipatory looking task. However, data collection was stopped before reaching this objective due to the closure of our lab on 14 March 2020 caused by the COVID-19 emergency confinement period imposed nationwide.

Monolingual infants. Infants were considered to be monolingual if they received at least 90% of weekly exposure to their native language. These infants received exposure to an additional language for no more than 10% of a child's weekly awake time (*M* = 4.43%, *SD* = 3.14, range 0.3 to 9.8%).

Bilingual infants. Infants were considered to be bilingual if they received a maximum of 75% and a minimum of 25% exposure to each of their languages (Pearson, Fernandez, Lewedeg, & Oller, 1997). All bilingual infants received exposure to their two languages from their parents at home and from regular interactions with close relatives or other members of the community. For 13 infants exposure to both languages was provided by the same parent, for 13 infants both parents were bilingual and used both languages with the child, for 5 infants parents used the one-parent one-language approach, and 3 infants were exposed to their non-dominant language via regular interactions with grandparents. Infants' exposure to their dominant language ranged from 50.4 to 74.7% (*M* = 60.25%, *SD* = 3.31), and to their non-dominant language ranged from 25.3 to 49.6% (*M* = 39.75%, *SD* = 7.66). Twenty infants were Spanish-dominant and 14 were Basque-dominant. Infants were not reported to receive exposure to a third language.

Criteria for exclusion. According to the pre-registered protocols for this study, which were specified prior to data collection, infants' data were planned to be excluded from the final analyses due to (1) failure to complete the task if the task was terminated before the completion of all trials due to extreme fussiness, infant becoming upset, or if requested by the caregiver; (2) caregiver interference if the caregiver clearly pointed at the screen during the trials of the task and/or spoke to the baby; (3) experimenter error such as running an incorrect condition and recruiting an incorrect age, etc.; (4) equipment failure if there were any software or hardware issues with the eye-tracker; and (5) gaze loss if infants failed to contribute a minimum of 40%

gaze data for the entire task. There were no exclusions based on (1-4); 4 infants did not contribute data for both experimental sessions (see Participants) and 6 infants did not contribute data for one experimental session (see Procedure) based on (5).

Stimuli and Apparatus

Infants sat on their caregiver's lap inside a sound-attenuated booth in an infant laboratory. The infant sat approximately 50cm away from an arm-mounted EyeLink 1000 Plus eye-tracker connected to an LCD screen (SR Research Ltd). The position of the monitor and the eye-tracker was adjusted for each infant. A small sticker was placed on the infant's forehead as the reference point for the eye-tracker. Audio stimuli were played over loudspeakers hidden behind the screen with the volume level set to 65dB for all infants. An experimenter sat in an adjoining room and controlled the experiment. A second experimenter was present inside the testing room to adjust the screen position and to assist with calibration. After calibration was complete, this experimenter hid behind a curtain and remained silent and out of the infant's sight throughout the task.

All auditory and visual stimuli are available for download at osf.io/k3e9z/. Sample stimuli are displayed in Figure 1. The stimuli were designed based on Kovács and Mehler (2009a; Experiments 2 and 3). A female native bilingual speaker of Spanish and Basque was recorded producing the isolated syllables /le/, /to/, /ni/, /mo/, /ri/, /be/. These syllables have identical phonetic realisations in Spanish and in Basque. The speaker was instructed to produce the syllables monotonously and with the same intensity. The recording was conducted within a sound-attenuated booth using a Marantz PMD1671 recorder and a Sennheiser noise-reducing microphone. Next, Praat software (Boersma & Weenink, 2010) was used to concatenate the syllables into 18 three-syllable words (9 AAB and 9 ABB words) with the syllables /le/, /ni/, /to/

assigned to the A group and /mo/, /ri/, /be/ to the B group. The visual stimuli consisted of colourful geometrical shapes: arrow, circle, pentagon, star, triangle, and moon. The shapes were concatenated into 9 AAB and 9 ABB sequences with the arrow, circle, and pentagon assigned to the A group and star, triangle, and moon to the B group.

The visual display consisted of a black background, with two white 7 x 7cm boxes located in the right and left upper quadrants. The visual rewards consisted of animations of 4 colourful puppets that loomed from 4 to 7 cm, and that appeared inside one of the white boxes. In addition, an animation of colourful twinkling stars was used as an attention getter.

Procedure. At the start of the task, a three-point (left, center, right) calibration routine was administered. Next, infants proceeded to the experiment. The task consisted of 12 pre-switch and 12 post-switch trials. The trials were identical except for the side in which the visual reward appeared (right in pre-switch and left in post-switch for half of the infants, and vice versa). Trials began by presenting infants with two white boxes located in the right and left quadrants of the screen with a colourful fixation cross presented in the center for 500 msec. Then, the cross disappeared, and the cue was presented. Following Kovács and Mehler, each auditory cue lasted for 400msec, and they were presented with an ISI of 250msec, and each visual cue was displayed for 800msec with an ISI of 300msec. Thus, the presentation of the cues was complete at 1600msec, after which a 1000msec anticipation period took place. After the anticipation period, the reward appeared in one of the boxes (2000 msec; looming puppet accompanied by a tinkling sound). After every 6 trials, infants were presented with the attention getter display that remained on the screen for 1 second to prevent them from losing attention and diverting their gaze away from the screen. The cue structure assigned to the pre-switch phase (AAB vs. ABB) and the side of reward presentation in the pre-switch phase (left vs. rights) were counterbalanced across participants. The structure of the cue and the side of reward presentation in the post-switch phase were always opposite to the pre-switch phase.

Each child completed the auditory and visual tasks in two experimental sessions administered approximately one week apart (*M* = 6.71 days, *SD* = 2.47 days), and the order of the sessions was counterbalanced across participants (21 monolingual and 19 bilingual completed the auditory session first and 19 monolingual and 15 bilingual completed the visual session first). Two monolinguals and 7 bilingual infants only contributed data to one of the conditions (auditory condition: missing data for 2 monolinguals and 3 bilinguals; visual condition: missing data for 4 bilinguals) due to inability to come back to the lab for a second visit (3 infants) and due to gaze loss (6 infants). During the first session, caregivers completed the informed consent and the language background questionnaire while the infants had an opportunity to familiarise themselves to the lab space. Both experimenters were proficient bilingual speakers of Spanish and Basque. They only used the monolingual participant's language during the entire visit to the lab, and for bilingual participants, they used the caregiver's preferred language.

Data processing. Three areas of interest (AoI) of identical size were used: left, centre, and right (Figure 1, C). A 1000 msec anticipation window was defined, starting at 150 msec before the offset of the auditory cue and finishing at 150 msec after the appearance of the reward and thus allowing infants to initiate an anticipatory gaze shift (McMurray & Aslin, 2004). Two measures were computed for this time window: correct anticipatory responses and proportion of anticipatory looking time to target. The *correct anticipatory response* measure was based on the analyses reported in Kovács and Mehler (2009a). A trial was considered correct (scored 1) if the infant fixated the correct location of the reward during the anticipation time window. If the infant did not fixate the correct location, the trial was considered incorrect (scored 0). If the infant fixated both the correct and the incorrect location, the trial was scored according to the location of the longest fixation. The *proportion of looking time to target* measure was computed as the proportion of fixation time to the correct location out of the total time that the infant spent fixating the correct and the incorrect locations during the anticipation window. Additionally, in order to ensure that infants were paying attention and complying with the task requirements, infants' proportion of looking time to target during the reward period was calculated for both phases of the task. Gaze data were analysed in blocks of 4 trials (3 blocks per phase) in order to capture infant's progression across the task.

Pilot Data

As can be seen, our experimental paradigm and planned analyses differ from Kovács and Mehler (2009a). The exact design differences are summarised in Table 1. Specifically, our paradigm included a total of 24 trials instead of 18, and we included three attention getter trials interspersed among the pre-switch and post-switch trials. These decisions were based on results of pilot testing that used a task identical to Kovács and Mehler (18 trials and no attention getters). Twenty infants were included in the pilot sample, 5 monolinguals and 5 bilinguals completed the auditory task and 5 monolinguals and 5 bilinguals completed the visual task. As the pilot consisted of an exact replication of Kovács and Mehler, the two tasks were administered in a between-subjects design. The results for the two dependent variables described above are displayed in Figure 2. As can be seen, in the auditory task, we were able to partially replicate the findings of the pre-switch phase as reported by Kovács and Mehler whereby infants' anticipatory looks to the target's location increased as the task progressed. In the post-switch phase, however, monolingual and bilingual infants' proportion of anticipatory looks remained at around 50%

even in the last block of trials. Furthermore, there was an unexpected decrease in the proportion of bilinguals who produced anticipatory looks (Figure 2, top right panel). In the visual task, the performance pattern was less clear. The proportion of anticipatory looks to the target's location was low in the pre- and post-switch phases for monolingual and bilingual infants. However, the proportion of looking time to the target appeared to increase as the task progressed in both groups in the pre-switch phase and only for bilinguals in the post-switch phase. The fact that the two measures did not provide exactly converging results supports our objective of reporting both measures in our final analyses for completeness and transparency purposes.

A close inspection of infants' behaviours revealed that overall it was difficult to maintain and regain infants' attention during the task. That is, while infants were overall interested in the task, they often looked away from the screen, which is not unusual for young infants. However, in these cases, the trial sequence would continue uninterrupted, and infants would not hear any attention-getting sounds to recapture their attention to the screen. For that reason, we decided to include the attention getter displays and to increase the number of trials to give infants the opportunity to re-engage with the task if they look away thus providing them with greater exposure to the cues and the rewards in the pre- and post-switch phases.

These pilot data were also used to calculate the statistical power for the planned analyses (see Results section below for the specification of the model structure). A simulation-based power analysis was conducted using the simr package (Green & Macleod, 2016) in R (R Core Team, 2013). The pilot sample was extended to 70 infants (35 monolingual and 35 bilingual) for the simulation. The result based on 1000 simulations yielded a desirable high power of 100% (CI 99.63, 100%) when using proportion of correct anticipation as the dependent variable and

97.70% (CI 96.57, 98.54) when using proportion of target fixation as the dependent variable in the model, which confirms the suitability of the sample size for this experimental design.

Data Analyses

Raw fixation data were extracted using the EyeLink DataViewer software. The raw data file was processed using the EyetrackingR package (Dink & Ferguson, 2015) in R (R Core Team, 2013). The steps followed during the analysis were:

(1) Fixation durations during the attention getters were excluded;

(2) Data were re-zeroed to the start of each trial;

(3) Percentages of gaze loss were calculated for each infant;

(4) Infants with less than 40% gaze during the task were excluded;

(5) Two critical windows were selected for analyses, the anticipation window for the main analyses of infants' fixations before the appearance of the reward (2250msec to 3250msec) and the reward window for the preliminary analyses to examine whether infants fixated the correct location when the reward appeared (3250msec to 5000msec);

(6) For each window, the proportion of gaze to the correct location out of the two possible reward locations (left and right) was computed for each trial, and these proportion data were extracted for use as the dependent variable in the LME models described below. In addition, only for the anticipation window, the correct anticipation score was calculated by assigning a value of 1 to the trials in which the infant fixated the correct location of the reward.

All anonymised raw and processed data files and analyses scripts are available on osf.io/k3e9z/. Linear Mixed Effects (LME) models were used for all analyses included in this study. Analyses were conducted using the lme4 package (Bates, 2005) in R (R Core Team, 2013) and the lmerTest package (Kuznetsova, Brockhoff, & Christensen, 2015) was used to compute *p*-values and conduct pairwise comparisons to inform significant interactions.

The independent variables (IV) defined for the models are: language group (monolingual, bilingual), condition (auditory, visual), experiment phase (pre-switch, post-switch), and trial block (first, second, third). The dependent variables (DV) were number of correct trials (Model 1) and proportion of looking time to the target (Model 2). The initial LME models were constructed with a maximal random effects structure (Barr, Lev, Scheepers, & Tily, 2013), specified as DV ~ IV1 + IV2 + IV3 + (…|subject) + (…|task order). If the models failed to converge, we proceeded to first remove random slopes nested within subjects, and task order, and then removing random intercepts for task order if necessary. Following these analyses, additional two models were constructed separately for the monolingual and bilingual sub-samples with an identical structure, but with the addition of percentage of exposure to the non-dominant language as an IV.

Results

Reward Window Performance

First, we assessed infants' tendency to look at the visual reward when it appeared after the anticipation period (time window from 3250 to 5000 msec in a trial). The proportions of looking time directed to the correct location by the monolingual and bilingual infants in the two experimental conditions are presented in Table 2. As can be seen, infants were overall likely to fixate the reward when it appeared on the screen, which indicates that they were engaged and complied with the task. In the visual condition, however, monolinguals did not direct their gaze to the reward above chance levels (chance = .5) in the first and second post-switch blocks, and this was also the case for the first post-switch block for bilinguals. This suggests that infants may have continued to anticipate the reward to appear in its pre-switch location at the beginning of the post-switch phase even when it appeared on the opposite location on the screen.

To compare reward looking patterns across groups and experimental conditions, an LME model was constructed with proportion of looking time to the reward as the dependent variable, and Language Group (monolingual, bilingual), Condition (auditory, visual), Experiment Phase (pre-switch, post-switch), and Trial Block (first, second, third) as the independent variables and random intercepts for participant. The IV Block was entered as a main effect and the rest of the IVs were entered as an interaction term. The model summary is presented in the Appendix, and the model results are presented in Table 3. Results yielded significant main effects of Condition, Phase, and Block, as well as significant Group by Phase and Condition by Phase interactions. As seen in Table 2, infants' tendency to fixate the reward increased as the task progressed, and infants fixated the reward to a greater extent in the auditory than the visual condition, $\beta = .221$, $SE = .015$, $CI[.19, .25]$, $t = 14.392$, $p < .001$, and in the pre-switch than the post-switch phase across the two conditions, $\beta = .091$, $SE = .015$, $CI[.12, .06]$, $t = 6.022$, $p < .001$. Overall, infants fixated the reward more in the pre-switch than the post-switch phase in the monolingual, $\beta = .130$, $SE = .020$, $CI[.17, .09]$, $t = 6.511$, $p < .001$, and bilingual groups, $\beta = .053$, $SE = .023$, $CI[.09, .01]$, $t = 2.310$, $p = .021$, but bilinguals were more likely to fixate the reward in the post-switch phase of the two conditions than monolinguals, $\beta = .057$, $SE = .023$, $CI[.10, .01]$, $t = 2.416$, $p = .017$.

Anticipation Window Performance

Next, infants' anticipatory gaze behaviours were analysed by assessing the proportion of looking duration to the correct location of the reward during the anticipation time window (from

2250 to 3250 msec in a trial). See Figure 3 for the anticipatory looking performance in the pre- and post-switch phases of the auditory and visual conditions of the task. As stipulated in our analysis plan, all analyses were conducted using the correct anticipation scores (Model 1 in the pre-registered analysis plan) and the proportion of gaze duration to the correct location as the dependent variables (Model 2 in the pre-registered analysis plan). All results were identical across these models. Therefore, for brevity, we only report the analyses using the proportion of looking times to the correct location as the dependent variable. The results for the models using correct anticipatory scores can be found in the Online Supplementary Materials.

First, infants' performance was compared across the two language groups, experimental conditions, and task phases. For this purpose, following our analysis plan, an LME model was specified with the proportion of looking time to the correct location as the Dependent Variable, and Language Group (monolingual, bilingual), Condition (auditory, visual), Experiment Phase, (pre-switch, post-switch), and Trial Block (first, second, third) as the independent variables and random intercepts for participant. The initial model also included random slopes for task order, but these were removed as the model failed to converge. The model results are presented in Table 4 and detailed output can be found in the Appendix. As can be seen, the model did not yield significant effects of Task or Group, but there were main effects of Phase and Block. Infants' performance therefore increased as the trials progressed, and infants fixated the correct location to a greater extent in the pre-switch than the post-switch phase, $\beta = .087$, $SE = .028$, $CI[.14, .03]$, $t = 3.062$, $p = .002$.

Given that we had predicted a Group by Phase interaction and we were interested in assessing infants' performance across the auditory and visual domains, a follow up model was constructed that included a Group by Condition by Phase interaction term. As in the original model, Block was specified as a main effect with random intercepts for participant. In order to confirm the suitability of our sample size for testing this three-way interaction a post-hoc simulation-based power analysis was conducted for the interaction term of this model. The simr package in R was used (see the Pilot Data section above). Based on 1000 simulations, the power for detecting this interaction was 99.7% (CI 99.13, 99.94).

The model summary is presented in the Appendix, and the model results are presented in Table 5. A main effect of Block showed that infants' performance increased as the task progressed. The model also yielded a main effect of Phase; across the two conditions, infants were more likely to fixate the correct location in the pre-switch than the post-switch trials of the task, $\beta = .092$, $SE = .029$, *CI*[.15, .04], $t = 3.175$, $p = .002$. There was also a three-way Language Group by Condition by Phase interaction. To understand the source of this interaction, separate exploratory models were constructed for the auditory and the visual conditions with an identical structure except that Condition was no longer included as a factor.

Auditory condition. The results of the separate Auditory and Visual models are presented in Table 6, and the detailed model output can be found in the Appendix. In this condition, infants' performance also increased as the task progressed (main effect of Block), and infants fixated the correct location in anticipation of the reward to a greater extent in the pre-switch than the post-switch phase (main effect of Phase), $\beta = .114$, $SE = .035$, *CI*[.19, .05], $t = 3.257$, $p = .001$. This main effect was qualified by a Group by Phase interaction. Planned pairwise comparisons revealed that monolingual infants were more likely to fixate the correct location in the post-switch phase than bilingual infants, $\beta = .160$, $SE = .050$, *CI*[.06, 26], $t = 3.196$, $p = .002$, but there was no significant group difference in the pre-switch phase, $\beta = .086$, $SE = .050$, *CI*[.18, .01], $t = 1.738$, $p = .083$. In fact, monolingual infants' performance did not differ significantly between the pre- and post-switch phases of the task, $ß = .008$, $SE = .046$, CI[-.08, .10], $t = .179$, $p = .858$, while bilinguals fixated the correct location to a significantly greater extent before than after the switch, $ß = .237$, $SE = .053$, CI[.34, .13], $t = 4.489$, $p < .001$.

Following the findings by Kovács and Mehler (2009), the Group by Phase interaction was expected to emerge in the opposite direction with bilinguals demonstrating better anticipatory performance post-switch compared to monolinguals. Hence, the greater anticipatory looking proportions post-switch in the monolingual group observed here were unexpected. However, inspection of Figure 3 suggests that it was not the case that monolinguals anticipated the appearance of the reward correctly post-switch and bilinguals did not. This was confirmed by follow up *t*-test analyses comparing monolingual and bilingual performance for each block of the Auditory task (see Table 7 for descriptive statistics). In the pre-switch phase, monolinguals and bilinguals did not differ in Blocks 1 ($t(64) = .268$, $p = .789$, $d = .067$), 2 ($t(64) = 1.093$, $p = .278$, $d = .273$), and 3 ($t(63) = 1.954$, $p = .055$). In the post-switch phase, monolinguals fixated the correct location more than bilinguals in Block 1, $t(64) = 2.291$, $p = .005$, $d = .489$, but monolinguals' performance was around chance levels, whereby bilinguals were below chance (chance = .5, monolingual $M = .55$, bilingual $M = .31$). This group difference became non-significant in Blocks 2 ($t(64) = 1.282$, $p = .205$, $d = .321$) and 3 ($t(60) = 1.255$, $p = .215$, $d = .324$). Taken together, these results suggest that bilinguals failed to disengage their attention from the pre-switch location of the reward for the first three trials after the switch. Monolinguals, on the other hand, did not persevere in their anticipatory behaviours post-switch, but rather showed chance performance at the start of that phase. This led to overall higher post-switch proportions of looking to the correct location when they were averaged across blocks for monolinguals even though there were no language group differences in anticipatory performance in the second and third blocks of the post-switch phase.

Visual condition. Contrary to the auditory condition, this model yielded only marginal effects of Block and Phase suggesting that monolingual and bilingual infants were not successful in anticipating the location of the reward when presented with visual cues (see Tables 6 and Appendix for model output and Table 7 for average proportions of looking to the correct location in each block).

Relation between Performance in the Auditory and Visual Conditions

Next, we were interested in assessing the stability of infants' performance across the two conditions of the anticipatory looking task. For this purpose, a Pearson correlation analysis was conducted including the proportions of looking to the correct location in the pre- and post-switch blocks in the auditory and visual conditions. As can be seen in Table 8, infants' anticipatory gaze patterns were significantly correlated within each condition of the task. Importantly, correlational coefficients were positive within each phase indicating that infants produced correct anticipatory looks across blocks, but correlations were negative between phases suggesting that infants who showed greater rates of learning the pre-switch location of the reward were less likely to anticipate it in its new location post-switch. However, there were no consistent significant correlations across the two conditions of the task, which does not support the expected stability in individual infants' performance across the two experimental sessions.

Effects of Bilingual Language Exposure

Finally, two separate models were constructed for the monolingual and bilingual samples in this study with the inclusion of infants' percent of exposure to their non-dominant language as a predictor variable. Exposure to the non-dominant language was used in these models given that this single measure captured both bilinguals' exposure to one of their languages (i.e., greater exposure to the non-dominant language denoted more balanced bilingualism), and also monolinguals' incidental exposure to the second language used in their community (i.e., greater exposure to the second language denoted more bilingual-like language background). Following the pre-registered analysis plan, these initial models specified main effect terms for Condition, Phase, Language Exposure, and Block, and random intercepts for participant. As can be seen in the model results in Table 9 (see Appendix for detailed model output), there was no effect of Language Exposure on monolingual and bilingual performance.

Given that language exposure was expected to impact infants' post-switch performance, we constructed two additional models to explore the possible interaction between language exposure and experimental phase on monolingual and bilingual infants' performance. Therefore, the models were specified with Block and Condition as the main effects and a Phase by Language Exposure interaction and random intercepts for participant. As seen in the results presented in Table 10 (see Appendix for the model summary), infants' degree of bilingual exposure did not have a significant impact on their anticipatory looking performance in the auditory and visual conditions, and crucially, it did not interact with the main effect of phase for either language group.

Discussion

This study compared monolingual and bilingual seven-month-old infants' performance in two versions of an anticipatory looking measure of attentional control. Our findings demonstrate that infants successfully anticipated the location where a reward would appear after an auditory or a visual cue, but their performance was significantly less consistent after the location of the reward was switched in the second half of the task. Following the findings by Kovács and

Mehler (2009), bilingual infants were expected to be more successful at anticipating the correct location of the reward after the switch, but this was not supported by our results. Furthermore, direct analyses accounting for monolingual and bilingual infants' degree of exposure to their non-dominant language did not identify significant effects of bilingual experience on young infants' performance in this task. Therefore, our results add to the growing literature demonstrating comparable monolingual and bilingual performance in multiple measures of executive functioning abilities in children and adults (e.g., De Bruin et al., 2015; Anton et al., 2014, 2016, 2019; Duñabeitia et al., 2014; Gathercole et al., 2014; Lehtonen et al., 2018; Paap et al., 2015; Costa & Sebastián-Gallés, 2014).

Our study was not the only effort to replicate Kovács and Mehler's findings, which further attests to the field's interest in testing the reliability and generalisability of the proposed bilingualism effects. We provide a summary of the methodological details and results of all the studies available to date in Table 11, which includes direct or conceptual replications of Kovács and Mehler. In addition to the study by Comishen et al. (2019) reviewed in the introduction, two additional studies were published while this study was in progress, and they have also failed to replicate the original results. Tsui and Fennell (2019) employed the visual condition of the paradigm with nine-month-old monolingual English (N = 24) and bilingual French-English (N = 23) infants and showed no significant performance differences between the language groups. Furthermore, they reported that infants overall were unsuccessful at anticipating the location of the reward in the post-switch phase, which is similar to the present findings for the visual condition. D'Souza and colleagues (D'Souza, Brady, Haensel, & D'Souza, 2020) also employed the visual condition of the task with eight-month-old monolingual English- (N = 51) and bilingual infants acquiring a variety of language pairs (N = 51). In their study, infants were able to correctly anticipate the reward's location post-switch, but there were no significant effects of bilingualism on pre- or post-switch performance. Finally, recall that despite providing some evidence for a bilingual effect on attentional processes, the earlier conceptual replication by Comishen et al. also failed to identify significant language group differences in six-month-old infants' anticipatory gaze patterns in their adaptation of the visual task. Together these multiple failures to replicate Kovács and Mehler's findings indicate that bilingual experience does not lead to advantages in the development of attentional control in the first year of life.

Even though the present findings did not yield significant language group effects in anticipatory looking, it is noteworthy that bilinguals' performance differed significantly from monolinguals' in other aspects of this task. Specifically, in the first post-switch block of the auditory condition, bilinguals persevered to a greater extent in their anticipatory looking behaviour than monolinguals. This perseverance was manifested in longer anticipatory looks to the incorrect location at the start of the post-switch phase (i.e., the location that was correct before the switch). Furthermore, in the post-switch phase of both the auditory and visual conditions, bilingual infants fixated the reward more than monolinguals. That is, despite their initial perseverance in anticipating the reward to appear in its pre-switch location, bilinguals were still more likely to fixate their gaze on the visual reward than monolinguals, even when it appeared in an unexpected location.

This performance pattern has not been detected in previous studies using this experimental paradigm (Kovács & Mehler, 2009; Tsui & Fennell, 2019; D'Souza et al., 2020), but it dovetails with several recent reports of bilingual effects on patterns of allocating attention to novel auditory and visual information. For instance, bilinguals allocate greater attention to novel than familiar linguistic stimuli (Bosch & Sebastian-Gallés, 2001), and they are faster than monolinguals at disengaging their gaze from a central visual stimulus to another stimulus presented in the periphery (D'Souza et al., 2020). Similarly, in our task, bilinguals did not show greater attentional control, but they were more likely to find and fixate the reward regardless of whether it did or did not appear in the location that they anticipated. These results suggest that bilinguals display different attentional patterns in experimental paradigms; specifically, bilingual infants are faster at detecting and directing their attention to new auditory or visual information than monolingual infants. The source of these differences in attentional allocation and potential benefits that they could yield to language processing are still poorly understood, but it is possible that they emerge as a result of bilingual infants' need to attend to cues that assist language discrimination in their linguistic environment (Garcia et al., 2018; Sebastian- Gallés et al., 2012). That is, bilingual infants' experience of encountering language switches in their day-to-day communicative interactions requires them to selectively attend to and track details that are relevant for encoding meaningful linguistic information in each language. This view has received further support from neurophysiological studies showing that unlike monolinguals, bilinguals engage attentional neural networks in a variety of language processing tasks (Arredondo, Hu, Stterfield, & Kovelman, 2017; Ferjan Ramírez, Ramírez, Clarke, Taulu, & Kuhl, 2017; Petitto et al., 2012). This experience of selectively allocating their attention to changing or novel cues in their linguistic environment can be manifested in more sustained attention and faster re-direction of attention to novel stimuli in the context of an experimental task like the task employed in our study. However, this does not necessarily imply that bilinguals develop more advanced executive functioning abilities that extend across the linguistic and non-linguistic domains. Rather, these findings demonstrate that bilingual infants' attentional processes adapt to their linguistic experience and their need to successfully navigate the two linguistic systems in their environment.

Our study was the first to also assess the extent to which infants' attentional control skills generalise across domains by administering the auditory and visual conditions of the anticipatory looking task in a within-subjects design. Overall, infants were more likely to anticipate the location of the reward pre- than post-switch when it followed auditory and visual cues. Therefore, at seven months, infants showed the capacity to learn the location of the reward and anticipated its appearance as the pre-switch trials progressed, but they were not successful at learning its second location following the switch. Infants demonstrated selective attention skills that allowed them to encode the initial location of the reward, but they did not show the ability to employ attentional control to disengage from the previously learned response and direct their attention to a new response pattern. This indicates that selective attention skills are still developing at this age, setting a precursor for the consolidation of more mature attentional control and attentional flexibility abilities proposed to develop around nine months of age (see Hendry, Jones, & Charman, 2016 for a review). Moreover, the present study demonstrates that there was no significant relation in individual infants' performance in the auditory and visual conditions of this task when they were administered approximately one week apart. Therefore, our findings indicate low stability in these measures of early attentional control, which provides a plausible explanation for the difficulty of replicating the same performance pattern across different infant populations and laboratories. This issue is not specific to this experimental paradigm. There are several reports that measures of early attentional processes, including attentional control and flexibility tasks, are characterised by low test-retest stability and predictive validity, particularly when administered to infants before nine months of age (e.g., Kannas, Oakes & Shaddy, 2006; Holmboe, Bonneville-Roussy, Csibra, & Johnson, 2018). Therefore, caution must be applied when employing these paradigms to evaluate individual differences and to predict later cognitive outcomes in longitudinal designs.

This study also assessed the possibility that infants' performance may be shaped by individual patterns of language exposure and degree of bilingualism (Bosma et al., 2017; Sorge et al., 2017; Tran, Arredondo, & Yoshida, 2018; Verhagen, Bree, & Unsworth, 2020). Our results showed that monolinguals' and bilinguals' degree of bilingual language exposure had no significant effects on anticipatory looking performance in this task. Therefore, it was not the case that bilinguals outperformed monolinguals as a group, or that within each sub-sample, infants who receive greater bilingual exposure showed more advanced attentional control skills. As outlined in the introduction, our study allowed us to strictly control for infants' bilingual exposure by not only including bilinguals from identical language and cultural backgrounds, but also by assessing our monolinguals' incidental bilingual exposure by virtue of growing up in a bilingual community. While optimal for our language exposure analyses, these characteristics significantly differentiated our sample from the bilingual sample in Kovács and Mehler, so it could be argued that this is why we failed to replicate their results. Specifically, one of the main differences across samples is that the bilinguals in this study came from a bilingual community where most adults are proficient in their two languages and the two languages are used almost interchangeably in most communicative contexts. On the contrary, infants in Kovács and Mehler were acquiring two languages in a monolingual community, so they were exposed to the non-community language primarily at home and from specific individuals (presumably one or both their parents). However, exact predictions about the effects that these different types of bilingual contexts would have on the development of infants' attentional control remain unspecified. For instance, it has been proposed that executive functioning advantages are most likely to be detected in dual-language contexts in which most speakers are bilingual compared to primarily monolingual contexts where language use is restricted to specific situations (Green & Abutalebi, 2013; Verhagen, Mulder, & Leseman, 2017). On the other hand, not all dual-language contexts would be equally conducive to the bilingual advantage. This would be only the case for contexts in which bilingual speakers switch languages between conversations, and not the contexts in which dense switching occurs between and within utterances in a single conversation since the latter impose lesser demands on individuals' language monitoring and suppression (Gathercole et al., 2010). Most importantly, we note that failures to replicate Kovács and Mehler are not restricted to studies with infants from bilingual communities (this study and Tsui & Fennell, 2019) since the infants in De Souza et al. (2020) came from a monolingual community similar to Kovács and Mehler. Therefore, considering this evidence from bilingual infants growing up in different geographical locations, cultural backgrounds, and acquiring very different language pairs, we conclude that even if bilingual advantages can be sometimes detected in some measures of early attentional control and under restricted language exposure conditions, they do not generalise across bilingual populations.

Bilingualism is a powerful experiential factor that influences infants' linguistic processing and their abilities to encode language-specific information from a complex linguistic input. Our findings confirm that this experience is manifested in bilinguals' attentional responses to novel stimuli in experimental settings, which possibly reflects their experience of navigating two linguistic systems in their environment. However, this study provides no evidence for a bilingualism advantage in the development of early attentional control. This evidence contributes to the on-going debate about the effects of bilingualism on general cognitive capacities, and we join the call for rigorous replications of previous findings in diverse populations of bilinguals in order to continue challenging the extent and generalisability of the proposed bilingualism effects in young infants, children, and adults.

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Table 1. *Differences in design, procedure, apparatus, and analysis strategies between Kovács and Mehler (2009) and the present study.*

Kovács & Mehler, 2009	The present study
1. Auditory and visual tasks administered in a between-subjects design	1. Auditory and visual tasks administered in a within-subjects design
2. Heterogeneous bilingual sample	2. Homogeneous bilingual sample
3. 20 participants per language group × task	3. 35 participants per language group[1] (and task is a within-subjects factor)
4. Synthesised auditory stimuli	4. Naturally produced auditory stimuli
5. 9 pre-test and 9 post-test trials	5. 12 pre-test and 12 post-test trials
6. No attention-getter displays	6. 3 attention-getter trials interspersed throughout the 24 experimental trials
7. Tobii-1750 Eye tracker	7. EyeLink 1000 Plus eye-tracker
8. Only correct anticipation scores used as the DV	8. Correct anticipation scores and proportion of looking time to the correct vs. the incorrect reward location used as DV

Table 2. *Mean (SD) proportion of looking time directed to the visual reward during the reward time-window of the auditory and visual conditions of the anticipatory looking tasks (results of one-sample t-tests comparing performance to .5 chance levels, **p < .001, *p < .025).*

	Auditory		*Visual*	
	Monolingual	Bilingual	Monolingual	Bilingual
Pre-switch Block 1	0.86 (0.15)**	0.89 (0.1)**	0.65 (0.26)**	0.62 (0.27)*
Pre-switch Block 2	0.9 (0.13)**	0.85 (0.22)**	0.71 (0.25)**	0.7 (0.27)**
Pre-switch Block 3	0.88 (0.15)**	0.92 (0.11)**	0.8 (0.24)**	0.69 (0.22)**
Post-switch Block 1	0.77 (0.2)**	0.8 (0.19)**	0.42 (0.25)	0.5 (0.32)
Post-switch Block 2	0.81 (0.15)**	0.84 (0.16)**	0.56 (0.25)	0.62 (0.24)*
Post-switch Block 3	0.83 (0.19)**	0.89 (0.12)**	0.62 (0.27)*	0.7 (0.28)**

Table 3. *Output of LME model assessing monolingual and bilingual infants' performance in the reward phase of the auditory and visual conditions of the anticipatory looking task.*

	F	*df (res)*	*p*
Group	1.003	71.090	.320
Condition	209.515	785.010	.001
Phase	42.186	735.230	.001
Block	31.937	736.130	.001
Group × Condition	0.183	792.620	.669
Group × Phase	6.652	735.250	.010
Condition × Phase	5.383	735.730	.021
Group × Condition × Phase	1.942	735.640	.164

Table 4. *Output of the LME model assessing monolingual and bilingual infants' anticipatory looking performance in the auditory and visual conditions of the anticipatory looking task.*

	χ^2	p
Group	0.176	.675
Task	0.160	.689
Phase	9.373	.002
Block	17.882	.001

Table 5. *Output of the LME interaction model assessing monolingual and bilingual infants' anticipatory looking performance in the auditory and visual conditions of the anticipatory looking task.*

	F	*df (res)*	*p*
Group	0.179	70.170	.674
Condition	0.163	692.980	.687
Phase	9.520	642.360	.002
Block	17.448	644.450	.001
Group × Condition	0.661	696.730	.416
Group × Phase	2.169	641.710	.141
Condition × Phase	0.206	646.200	.650
Group × Condition × Phase	10.124	645.420	.002

Table 6. *Output of the models assessing monolingual and bilingual infants' performance separately in the auditory and visual conditions of the anticipatory looking task.*

Auditory condition			
	F	*df (res)*	*p*
Group	1.032	64.520	.314
Phase	7.978	323.320	.005
Block	17.594	324.240	.001
Group × Phase	12.202	323.450	.001
Visual condition			
	F	*df (res)*	*p*
Group	0.056	65.316	.814
Phase	2.928	265.926	.088
Block	3.218	267.794	.074
Group × Phase	2.015	265.002	.157

Table 7. *Mean (SD) proportion of looking time to the correct location in the pre- and post-switch blocks of the auditory and visual conditions by monolingual and bilingual infants.*

	Auditory Condition		*Visual Condition*	
	Monolingual	Bilingual	Monolingual	Bilingual
Pre-switch Block1	0.51 (0.37)	0.53 (0.34)	0.6 (0.45)	0.52 (0.44)
Pre-switch Block2	0.6 (0.38)	0.7 (0.36)	0.65 (0.45)	0.7 (0.39)
Pre-switch Block3	0.66 (0.3)	0.8 (0.23)	0.64 (0.39)	0.54 (0.37)
Post-switch Block1	0.55 (0.34)	0.31 (0.32)	0.46 (0.44)	0.45 (0.41)
Post-switch Block2	0.6 (0.36)	0.48 (0.4)	0.54 (0.43)	0.52 (0.45)
Post-switch Block3	0.65 (0.35)	0.53 (0.38)	0.52 (0.4)	0.75 (0.4)

Table 8. *Results of Pearson correlational analyses of monolingual and bilingual infants' performance in the auditory and visual conditions of the anticipatory looking task (*p<.05).*

	Aud Pre 2	Aud Pre 3	Aud Post 1	Aud Post 2	Aud Post 3	Vis Pre 1	Vis Pre 2	Vis Pre 3	Vis Post 1	Vis Post 2	Vis Post 3
Aud Pre 1	.42*	.37*	-.16	-.38*	-.16	-.05	.18	-.12	-.26	.14	-.08
Aud Pre 2		.34*	-.40*	-.40*	-.15	.12	-.01	-.24	.04	.41*	-.02
Aud Pre 3			-.41*	-.36*	-.23	-.22	-.15	-.16	-.20	.06	.06
Aud Post 1				.46*	.30*	-.16	.19	.13	-.09	-.18	-.02
Aud Post 2					.32*	.11	.11	.26	.13	-.19	.17
Aud Post 3						-.13	.11	.26	.20	-.02	.06
Vis Pre 1							.34*	.57*	-.09	-.03	.22
Vis Pre 2								.61*	-.02	-.13	.05
Vis Pre 3									.02	-.25	-.01
Vis Post 1										.21	-.04
Vis Post 2											.37*

Table 9. *Output of the LME models assessing the effects of the degree of bilingual exposure on infants' performance in the auditory and visual conditions of the anticipatory looking task.*

Monolingual			
	F	*df (res)*	*p*
Condition	1.626	235.615	.204
Phase	0.127	231.526	.722
Lg Exposure	0.038	21.408	.848
Block	1.850	231.118	.175
Bilingual			
	F	*df (res)*	*p*
Condition	0.089	305.980	.766
Phase	10.014	278.380	.002
Lg Exposure	0.138	27.280	.713
Block	16.447	282.070	.001

Table 10. *Output of the LME interaction models assessing the effects of the degree of bilingual exposure on infants' performance in the auditory and visual conditions of the anticipatory looking task.*

Monolingual			
	F	*df (res)*	*p*
Condition	1.725	234.570	.190
Phase	0.127	230.480	.722
Lg Exposure	0.038	21.407	.848
Block	1.908	230.081	.169
Phase × Lg Exposure	1.816	228.882	.179
Bilingual			
	F	*df (res)*	*p*
Condition	0.090	304.979	.764
Phase	9.980	277.382	.002
Lg Exposure	0.137	27.266	.714
Block	16.388	281.060	.001
Phase × Lg Exposure	0.058	276.198	.810

Table 11. *Summary of the methodological details and main findings by Kovács and Mehler (2009) and the four replication studies available to date.*

	Infants' age	**Infants' language background**	**Sample size**	**Version of the anticipatory looking task**	**Number of trials**	**Bilingual advantage** (anticipatory looking in the post-switch phase)	**Group differences** (other aspects of the anticipatory looking task)
Kovács & Mehler (2009)	7 mos	Italian monolingual; Italian-other bilingual	40 (in each of 3 experiments)	Auditory and visual (between-subjects)	18	Yes	No
Comishen et al. (2019)	6 mos	English monolingual; English-other bilingual	40	Visual	60	Yes* (based on post-hoc within-group comparisons; no group differences in main analyses of variance)	Faster latencies in re-directing gaze post-switch in bilinguals than monolinguals
Tsui & Fennell (2019)	9 mos	English monolingual; English-French bilingual	47	Visual	12	No	No
D'Souza et al. (2020)	8 mos	English monolingual; English-other bilingual	51	Visual	18	No	No
Kalashnikova et al. (this study)	7 mos	Spanish/Basque monolingual; Spanish-Basque bilingual	77	Auditory and visual (within-subjects)	24	No	Longer fixation to reward post-switch in bilinguals than monolinguals

Appendix

Table A1. *Detailed output of LME model assessing monolingual and bilingual infants' performance in the reward phase of the auditory and visual conditions of the anticipatory looking task.*

	ß	*SE*	*df*	*t*	*p*
Intercept	0.698	0.028	710.657	24.871	.001
Group [Bilingual]	0.042	0.032	465.887	1.310	.191
Task [Visual]	-0.267	0.028	744.017	-9.443	.001
Phase [Pre-switch]	0.077	0.029	734.131	2.679	.008
Block	0.052	0.009	734.617	5.651	.001
Group [Bilingual] × Task [Visual]	0.029	0.043	768.124	0.675	.500
Group [Bilingual] × Phase [Pre-switch]	-0.035	0.044	734.238	-0.801	.423
Task [Visual] × Phase [Pre-switch]	0.106	0.040	734.544	2.664	.008
Group [Bilingual] × Task [Visual] × Phase [Pre-switch]	-0.085	0.061	734.120	-1.394	.164

Table A2. *Detailed output of the LME model assessing monolingual and bilingual infants' anticipatory looking performance in the auditory and visual conditions of the anticipatory looking task.*

	ß	*SE*	*df*	*t*	*p*
Intercept	0.398	0.045	559.828	8.883	.001
Group [Bilingual]	-0.014	0.033	67.545	-0.420	.676
Task [Visual]	-0.011	0.029	696.857	-0.401	.689
Phase [Pre-switch]	0.087	0.028	644.023	3.061	.002
Block	0.074	0.017	645.881	4.229	.001

Table A3. *Detailed output of the LME interaction model assessing monolingual and bilingual infants' anticipatory looking performance in the auditory and visual conditions of the anticipatory looking task.*

	ß	*SE*	*df*	*t*	*p*
Intercept	0.458	0.051	636.665	9.043	.001
Group [Bilingual]	-0.159	0.057	411.219	-2.807	.005
Task [Visual]	-0.099	0.054	662.710	-1.844	.066
Phase [Pre-switch]	-0.009	0.050	631.471	-0.181	.857
Block	0.072	0.017	642.569	4.178	.001
Group [Bilingual] × Task [Visual]	0.229	0.081	679.603	2.823	.005
Group [Bilingual] × Phase [Pre-switch]	0.246	0.076	632.031	3.226	.001
Task [Visual] × Phase [Pre-switch]	0.133	0.075	648.199	1.769	.077
Group [Bilingual] ×Task [Visual] × Phase [Pre-switch]	-0.363	0.114	643.563	-3.183	.002

Table A4. *Detailed output of the models assessing monolingual and bilingual infants' performance separately in the auditory and visual conditions of the anticipatory looking task.*

Auditory Condition					
	ß	*SE*	*df*	*t*	*p*
Intercept	0.420	0.054	386.000	7.830	.001
Group [Bilingual]	-0.160	0.050	386.000	-3.196	.002
Phase [Pre-switch]	-0.008	0.046	386.000	-0.179	.858
Block	0.090	0.021	386.000	4.195	.001
Group [Bilingual] × Phase [Pre-switch]	0.246	0.070	386.000	3.493	.001
Visual Condition					
	ß	*SE*	*df*	*t*	*p*
Intercept	0.401	0.073	295.487	5.525	.001
Group [Bilingual]	0.077	0.074	137.373	1.048	.297
Phase [Pre-switch]	0.132	0.059	268.931	2.225	.027
Block	0.049	0.027	264.051	1.796	.074
Group [Bilingual] × Phase [Pre-switch]	-0.126	0.089	261.083	-1.421	.157

Table A5. *Detailed output of the LME models assessing the effects of the degree of bilingual exposure on infants' performance in the auditory and visual conditions of the anticipatory looking task.*

Monolingual					
	ß	*SE*	*df*	*t*	*p*
Intercept	0.523	0.079	139.102	6.586	.001
Task [Visual]	-0.060	0.047	235.595	-1.277	.203
Phase [Pre-switch]	0.017	0.047	231.501	0.357	.721
Lg exposure	0.002	0.009	21.379	0.194	.848
Block	0.040	0.029	231.093	1.361	.175
Bilingual					
	ß	*SE*	*df*	*t*	*p*
Intercept	0.331	0.139	37.582	2.385	.022
Task [Visual]	0.013	0.043	305.973	0.300	.765
Phase [Pre-switch]	0.134	0.042	276.892	3.166	.002
Lg exposure	-0.001	0.003	25.875	-0.372	.713
Block	0.105	0.026	280.756	4.059	.001

Table A6. *Detailed output of the LME interaction models assessing the effects of the degree of bilingual exposure on infants' performance in the auditory and visual conditions of the anticipatory looking task.*

Monolingual					
	ß	*SE*	*df*	*t*	*p*
Intercept	0.479	0.086	162.996	5.592	.001
Task [Visual]	-0.062	0.047	234.526	-1.316	.190
Phase [Pre-switch]	0.105	0.080	230.070	1.304	.194
Lg exposure	0.011	0.011	59.054	1.015	.314
Block	0.040	0.029	230.024	1.382	.168
Phase [Pre-switch] × Lg exposure	-0.020	0.015	228.823	-1.348	.179
Bilingual					
	ß	*SE*	*df*	*t*	*p*
(Intercept)	0.306	0.174	88.450	1.752	.083
Task [Visual]	0.013	0.043	305.000	0.302	.763
Phase [Pre-switch]	0.185	0.216	274.400	0.857	.392
Lg exposure	-0.001	0.004	76.180	-0.124	.902
Block	0.105	0.026	279.800	4.052	.001
Phase [Pre-switch] × Lg exposure	-0.001	0.005	274.700	-0.241	.810

Online Supplementary Materials

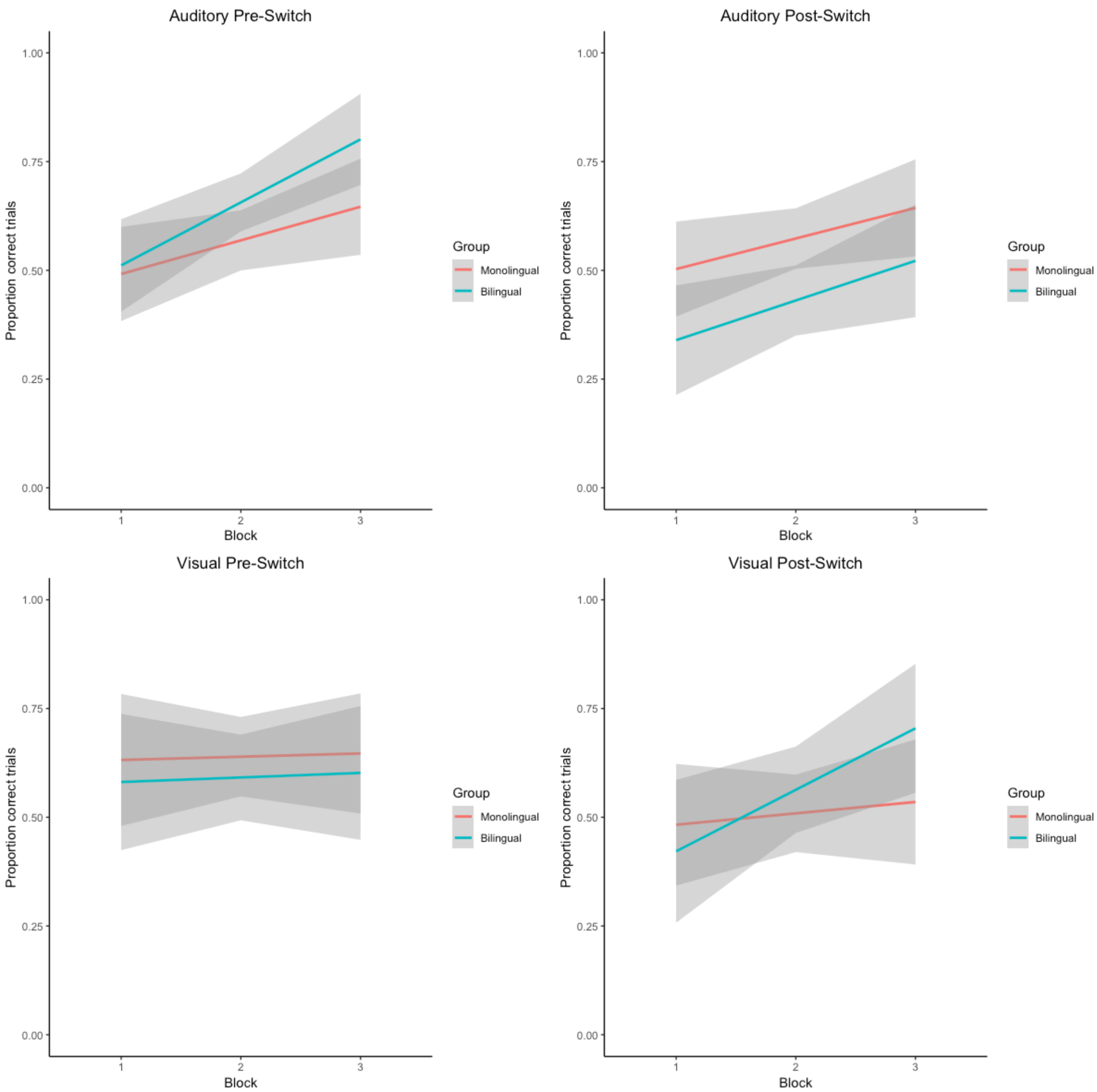

Figure S1. Proportion of trials with correctly anticipated reward location by monolingual and bilingual infants in the pre- and post-switch phases of the auditory (top panel) and visual (bottom panel) conditions (shaded areas represent the Standard Error of the Mean).

Table S1. *Results of the LME model assessing monolingual and bilingual infants' anticipatory looking performance in the auditory and visual conditions of the anticipatory looking task.*

	χ^2	p
Group	0.127	.721
Condition	0.167	.683
Phase	9.400	.002
Block	16.635	.001

Table S1a. *Detailed output of the LME model assessing monolingual and bilingual infants' anticipatory looking performance in the auditory and visual conditions of the anticipatory looking task.*

	ß	*SE*	*df*	*t*	*p*
Intercept	0.378	0.046	571.916	8.301	.001
Task [Visual]	-0.012	0.033	68.107	-0.357	.722
Phase [Pre-switch]	0.012	0.029	697.458	0.408	.683
Block	0.089	0.029	645.174	3.066	.002
Group [Bilingual]	0.072	0.018	647.084	4.079	.001

Table S2. *Results of the LME interaction model assessing monolingual and bilingual infants' anticipatory looking performance in the auditory and visual conditions of the anticipatory looking task.*

	F	*df (res)*	*p*
Group	0.129	70.030	.721
Condition	0.169	693.490	.682
Phase	9.503	642.870	.002
Block	16.221	645.050	.001
Group × Condition	0.285	697.090	.594
Group × Phase	1.964	642.200	.162
Condition × Phase	0.075	646.810	.784
Group × Condition × Phase	8.228	646.000	.004

Table S2a. *Detailed output of the LME interaction model assessing monolingual and bilingual infants' anticipatory looking performance in the auditory and visual conditions of the anticipatory looking task.*

	ß	*SE*	*df*	*t*	*p*
Intercept	0.433	0.052	644.620	8.402	.001
Group [Bilingual]	-0.142	0.058	424.574	-2.476	.014
Task [Visual]	-0.067	0.055	663.834	-1.230	.219
Phase [Pre-switch]	-0.005	0.051	632.206	-0.100	.921
Block	0.071	0.018	643.635	4.029	.001
Group [Bilingual] × Task [Visual]	0.199	0.083	680.341	2.405	.016
Group [Bilingual] × Phase [Pre-switch]	0.231	0.078	632.783	2.963	.003
Task [Visual] × Phase [Pre-switch]	0.131	0.077	649.364	1.696	.090
Group [Bilingual] ×Task [Visual] × Phase [Pre-switch]	-0.334	0.117	644.603	-2.869	.004

Table S3. *Results of the models assessing monolingual and bilingual infants' performance separately in the auditory and visual conditions of the anticipatory looking task.*

Auditory condition			
	F	*df (res)*	*p*
Group	0.538	64.520	.466
Phase	7.074	323.320	.008
Block	17.771	324.240	.001
Group × Phase	10.069	323.450	.002
Visual condition			
	F	*df (res)*	*p*
Group	0.012	65.351	.913
Phase	3.574	265.778	.060
Block	2.353	267.622	.126
Group × Phase	1.624	264.858	.204

Table S3a. *Detailed output of the models assessing monolingual and bilingual infants' performance separately in the auditory and visual conditions of the anticipatory looking task.*

Auditory condition					
	ß	*SE*	*df*	*t*	*p*
Intercept	0.387	0.055	386.000	6.982	.001
Group [Bilingual]	-0.143	0.052	386.000	-2.770	.006
Phase [Pre-switch]	-0.004	0.048	386.000	-0.092	.927
Block	0.093	0.022	386.000	4.216	.001
Group [Bilingual] × Phase [Pre-switch]	0.230	0.073	386.000	3.173	.002
Visual condition					
	ß	*SE*	*df*	*t*	*p*
Intercept	0.419	0.073	294.792	5.727	.001
Group [Bilingual]	0.064	0.074	136.652	0.856	.393
Phase [Pre-switch]	0.135	0.060	268.778	2.261	.025
Block	0.042	0.027	263.902	1.536	.126
Group [Bilingual] × Phase [Pre-switch]	-0.114	0.089	260.965	-1.276	.203

Table S4. *Results of the LME models assessing the effects of the degree of bilingual exposure on infants' performance in the auditory and visual conditions of the anticipatory looking task.*

Monolingual			
	F	*df (res)*	*p*
Condition	0.598	235.753	.440
Phase	0.105	231.613	.746
Lg Exposure	0.046	21.378	.832
Block	2.388	231.203	.124
Bilingual			
	F	*df (res)*	*p*
Condition	0.406	305.950	.524
Phase	9.947	278.566	.002
Lg Exposure	0.049	27.125	.827
Block	14.865	282.374	.001

Table S4a. *Detailed output of the LME models assessing the effects of the degree of bilingual exposure on infants' performance in the auditory and visual conditions of the anticipatory looking task.*

Monolingual					
	ß	*SE*	*df*	*t*	*p*
Intercept	0.487	0.081	142.018	5.995	.001
Task [Visual]	-0.038	0.049	235.863	-0.775	.439
Phase [Pre-switch]	0.016	0.048	231.753	0.325	.746
Lg exposure	0.002	0.009	21.540	0.215	.832
Block	0.046	0.030	231.347	1.546	.123
Bilingual					
	ß	*SE*	*df*	*t*	*p*
Intercept	0.305	0.137	37.880	2.220	.032
Task [Visual]	0.028	0.043	305.900	0.640	.522
Phase [Pre-switch]	0.135	0.043	277.100	3.155	.002
Lg exposure	-0.001	0.003	25.700	-0.221	.827
Block	0.101	0.026	281.100	3.859	.001

Table S5. *Results of the LME interaction models assessing the effects of the degree of bilingual exposure on infants' performance in the auditory and visual conditions of the anticipatory looking task.*

Monolingual			
	F	*df (res)*	*p*
Condition	0.637	234.741	.426
Phase	0.105	230.588	.746
Lg Exposure	0.046	21.369	.832
Block	2.427	230.186	.121
Phase × Lg Exposure	0.951	228.960	.331
Bilingual			
Condition	*F*	*df (res)*	*p*
Phase	0.409	304.956	.523
Lg Exposure	9.912	277.570	.002
Block	0.048	27.107	.828
Phase × Lg Exposure	14.812	281.375	.001
Condition	0.023	276.352	.879

Table S5a. *Detailed output of the LME interaction models assessing the effects of the degree of bilingual exposure on infants' performance in the auditory and visual conditions of the anticipatory looking task.*

Monolingual					
	ß	*SE*	*df*	*t*	*p*
(Intercept)	0.454	0.088	166.523	5.174	.001
TaskVisual	-0.039	0.049	234.836	-0.800	.425
PhasePre-switch	0.081	0.083	230.351	0.982	.327
Lg Exposure	0.009	0.011	60.662	0.796	.429
Block	0.047	0.030	230.308	1.559	.120
PhasePre-switch × Lg Exposure	-0.015	0.015	229.090	-0.976	.330
Bilingual					
	ß	*SE*	*df*	*t*	*p*
(Intercept)	0.289	0.174	91.150	1.662	.100
TaskVisual	0.028	0.043	305.000	0.642	.521
PhasePre-switch	0.167	0.218	274.600	0.769	.443
Lg Exposure	0.000	0.004	78.340	-0.064	.949
Block	0.101	0.026	280.100	3.852	.001
PhasePre-switch × Lg Exposure	-0.001	0.005	274.800	-0.153	.879