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# Bilingualism and increased attention to speech: Evidence from event-related potentials

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ABSTRACT

A number of studies have shown that from an early age, bilinguals outperform their monolingual peers on executive control tasks. We previously found that bilingual children and adults also display greater attention to unexpected language switches within speech. Here, we investigated the effect of a bilingual upbringing on speech perception in one language. We recorded monolingual and bilingual toddlers' event-related potentials (ERPs) to spoken words preceded by pictures. Words matching the picture prime elicited an early frontal positivity in bilingual participants only, whereas later ERP amplitudes associated with semantic processing did not differ between groups. These results add to the growing body of evidence that bilingualism increases overall attention during speech perception whilst semantic integration is unaffected.


## 1. Introduction

Bilingualism is thought to have implications for cognition beyond the linguistic domain. For example, bilingual toddlers and adults have repeatedly been shown to outperform their peers on tasks that require suppressing interference from stimuli unrelated to the task at hand, i.e., they display better executive control (Bialystok, 2009). This effect, often referred to as the bilingual advantage, has been observed in infants as young as seven months who are able to switch between tasks when monolingual infants fail to do so (Kovacs & Mehler, 2009) and has even been hypothesised to provide better resilience against dementia (Bialystok, Craik, & Freedman, 2007). Recently however, large-scale studies have cast doubt on the existence of this phenomenon failing to replicate the bilingual advantage in executive control tasks (Dunabeitia et al., 2014; Gathercole et al., 2014). The question of a bilingual advantage is thus hotly debated with some authors proposing that correlates of interference may fail to appear in bilinguals (e.g., indexed by the Stroop effect) because they have globally reduced reaction times (Hilchey & Klein, 2011), whilst others have proposed a limitation of the executive control advantage in the domain of inhibitory control, based on interference measures in a flanker task (Wu & Thierry, 2013).

A bilingual upbringing in the first years of life will predominantly differ from a monolingual one in the range and variety of speech sounds encountered. Previous research has sought correlates of differences in auditory processing between bilingual and monolingual children that stem from such differential exposure and use of language. Indeed, bilingual children appear to have enhanced phonological awareness in offline tasks (e.g., pen-and-paper tasks on phonological awareness; Bialystok, Majumder, & Martin, 2003; Campbell & Sais, 1995) and a greater ability to learn new phonemic rules (Kuo & Anderson, 2012) than their monolingual peers. However, when bilingual language input is non-systematic due to self-reported frequent language switching by caregivers, language learning may be negatively affected (Byers-Heinlein, 2013). However, results of such offline and self-report studies are difficult to replicate (Paap & Sawi, 2014), and tend to differ from studies using online language measures. For example, Bail, Morini, and Newman (2014) found no effect of parental code switching measured in actual conversations on bilingual toddlers' language proficiency measures. Few studies have used online measures of bilingual speech perception or production to establish neural correlates of differences in mono- and bilingual language processing.

In one such brain imaging study on auditory perception of speech sounds, Krizman, Marian, Shook, Skoe, and Kraus (2012) showed that, compared to their monolingual peers, bilingual adolescents display enhanced encoding of a speech syllable (/da/) as reflected in an increased brain stem response. This increase was

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correlated with higher performance under high auditory processing load only in the bilinguals. Thus, bilinguals seemed to pay greater attention to the speech resulting in better neural encoding of speech sounds. However, MRI data such as those collected by Krizman et al. (2012) provide no insight into the time-course of attention allocation. Here we studied online speech perception in bilingual and monolingual toddlers using event-related potentials (ERPs). ERPs are electric potentials recorded from the scalp time-locked to the presentation of a particular stimulus (e.g., a word). They provide the opportunity to study the cognitive processes involved in online speech processing with a high temporal resolution. ERP components can be roughly divided into early components reflecting perceptual processes modulated by attention (up to ~300 ms after stimulus onset), and later components reflecting more conscious stimulus processing influenced by voluntary allocation of attention and cognitive strategies (~300–600 ms after stimulus onset). Importantly, studies of early ERPs in response to (speech) sounds have shown that maturation of the auditory cortex is directly liked to language learning and that the rate of maturation differs in monolingual and bilingual children (Kuhl et al., 2008; Shafer, Yu, & Datta, 2011).

Previous ERP and behavioural studies have shown that, in the first year of life, phonological discrimination ability is progressively reduced to the phonological repertoire of the native language (Cheour et al., 1998; Kuhl et al., 2006). This process seems to develop similarly for monolingually and bilingually raised children (Burns, Yoshida, Hill, & Werker, 2007), although bilingual children sometimes show inconsistent patterns of phoneme discrimination (Bosch & Sebastian-Galles, 2003) with these skills being proportional to their exposure to each of their languages (Garcia-Sierra et al., 2011). Surprisingly, this differential development of the bilingual auditory cortex has been associated with increased language processing ability rather than an impoverished one (Petitto et al., 2012).

In previous studies, we found that bilingual adults and toddlers display a larger P2 ERP response than their monolingual peers in response to an unexpected language change (Kuipers & Thierry, 2012). The P2 is a positive peak occurring approximately 200 ms after stimulus onset. Although the functional significance of the P2 can vary substantially between experimental contexts, in both the auditory and visual perception literature it is often associated with target detection and classification, and it is modulated by attention (Crowley & Colrain, 2004; Luck & Hillyard, 1994). We interpreted the larger P2 response to a language-switch in bilinguals than monolinguals as an index of increased attention to speech in bilinguals, consistent with findings in six month-old bilinguals (Shafer, Yu, & Garrido-Nag, 2012).

With ERPs one can also study the process of meaning integration, which is reflected in the amplitude of the N400 ERP response, a negative deflection peaking between 300–500 ms after stimulus onset (Federmeier & Kutas, 2002). The more a stimulus is semantically unrelated to its context, the more negative the amplitude of the N400 response. This effect is hypothesised to index the additional neural activation prompted by the semantic analysis of a stimulus when it is unrelated to its context. The N400 has sometimes –albeit rarely– been observed to be delayed in adult late bilinguals compared to their monolingual peers (Ardal, Donald, Meuter, Muldrew, & Luce, 1990; Hahne & Friederici, 2001; Weber-Fox & Neville, 1996) suggesting that late bilinguals (but not early bilinguals; Kuipers & Thierry, 2012, 2013; Weber-Fox & Neville, 1996) show signs of slower semantic stimulus integration. Although the N400 has been observed in infants as young as 14 months (Friedrich & Friederici, 2005) and 11 months (Asano et al., 2015), little data on semantic processing are available from children raised bilingually.

Here, we aimed to determine whether attention to online speech is generally greater in bilingual as compared to monolingual toddlers and whether this tends to affect semantic integration efficiency. Some studies have shown that children of this age range outperform monolingual children on tasks that specifically tap into executive control whilst performance in other cognitive tasks seems unaffected (Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011). We presented 2–3 year old monolingual and bilingual toddlers with picture–spoken word pairs either semantically matched or unrelated whilst recording their ERPs. These experimental conditions were embedded in a study on language switch detection (Kuipers & Thierry, 2012). Using the same stimuli and a similar procedure in adult participants, we found that the semantic match condition elicited a relative increase of P2 amplitude in the bilingual participants, whereas semantic processing did not differ between groups, as shown by unaffected N400 amplitudes (Kuipers & Thierry, 2010).

## 2. Methods

### 2.1. Participants

From each of the two groups of 18 participants tested by (Kuipers & Thierry, 2012), 14 children had the minimum number of trials (>20) and displayed sufficiently stable ERP waveforms for analysis in the matching and unrelated conditions separately. Language ability was assessed with a shortened British version of the McArthur-Bates Communicative Development Inventory (CDI; Hamilton, Plunkett, & Schafer, 2000) and an un-normed Welsh translation, both of which were posted to the caregivers before the experiment with the request to fill in the relevant sections to the best of their knowledge. Children were grouped on the basis of language exposure and proficiency. Monolingual children were reported not to know any Welsh words apart from some basic commonly used words (e.g., "dioch"; "thank you"), nor to have (or having had) significant exposure to Welsh (e.g., no Welsh only day care). The bilingual group consisted of children that had balanced estimated knowledge of Welsh and English and were exposed to both Welsh and English on a day-to-day basis (e.g., Welsh nursery, English or mixed language home, or *vice versa*). The monolingual English children (8 female; mean age 32 ± 3 months) had a mean CDI score (with a 95% confidence interval) of 268 ± 58 words (i.e., 87% the words in the list). The Welsh-English bilingually raised children (9 female, mean age 29 ± 3 months) had an English CDI score 220 ± 48 words (78%) and a Welsh score of 195 ± 65 words (73%). The caregivers of 1 monolingual and 2 bilingual children failed to return the CDI. Mean age did not differ significantly between groups ($p > .1$), but the difference in scores on the English CDI approached significance ($p < .06$), which given the low number of returned CDIs, suggests that the monolingual children may have had a higher English CDI score than the bilingual group. However, the total vocabulary score of the bilingual children (the Welsh and English CDI's combined, corrected for cognates) was 360 ± 112, which did not significantly differ from the number of English words for the English children ($p > .4$; cf. Pearson, Fernandez, & Oller, 1993). The experimental procedures were approved by the ethics committee of Bangor University and a caregiver gave written informed consent before the experiment.

### 2.2. Materials

Participants were presented with picture–spoken words pairs that were semantically matched in half of the trials. In addition, the language spoken was manipulated in an oddball-like paradigm