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Event-related potentials associated with cognitive mechanisms underlying lexical-semantic processing in monolingual and bilingual 18-month-old children

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ABSTRACT

Prior to their second birthday, children are sensitive to the semantic relatedness between spoken words. Yet, it remains unclear whether simultaneous second language acquisition affects this sensitivity. Here, we investigated the influence of early acquisition of two languages on the event-related potentials (ERPs) associated with lexical-semantic processing of spoken words in 18-month-old monolingual and bilingual children. Children were exposed to an auditory semantic priming task in French, while their ERPs were recorded. Word pairs were either semantically related (e.g., train-bike) or unrelated (e.g., chicken-bike), and they were presented at two stimulus onset asynchronies (SOA). The results revealed that only monolingual children exhibited a semantic priming effect at the short SOA while at the long SOA condition, both monolingual and bilingual children exhibited more pronounced ERPs in response to unrelated compared with related target words. This finding suggests that both language groups are sensitive to taxonomic relations between words but activation of sematic network might be less automatized or slower in bilingual children.

1. Introduction

Hearing or reading a word activates semantically related words in the lexical-semantic network, thus facilitating the processing of subsequent words. This effect is known as 'semantic priming'. Priming effects are typically studied in lexical-decision tasks, during which participants are presented with prime-target word pairs and their task is to decide whether the target is a word or a non-word. The reaction times are faster and more accurate when the target word is preceded by a related word than by an unrelated word (e.g., Meyer & Schvaneveldt, 1971). Two distinct processes or strategies—automatic and controlled—have been suggested to contribute to the semantic priming effect. While the former is fast acting and occurs when the temporal window between the onsets of the two words (prime and target) is short (around 400 ms; Quillian, 1962; Collins & Loftus, 1975), the latter involves expectancy and post-lexical matching, demands attention allocation, and occurs when the temporal window between the onsets of the two words (prime and target) is long (> 400 ms; Posner & Snyder, 1975; Becker, 1976; Neely, 1977, 1991; Shiffrin & Schneider, 1977; Brown & Hagoort, 1993). In addition to behavioural tasks, the lexical-semantic organization has been extensively investigated by measuring event-related potentials (ERPs) in response to target words in semantic priming tasks. It has been shown that the amplitudes of the N400 component are more negative in response to target words (e.g., table) preceded by unrelated (e.g., dog) than by related (e.g.,

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chair) prime words (e.g., Kutas & Hillyard, 1980; Federmeier & Kutas, 1999; for a review, see; Kutas & Federmeier, 2000), suggesting that the occurrence of the N400 is associated with processing of semantics in a context. Both automatic and controlled processes have been suggested to underlie also the N400 priming effect (e.g., Chwilla, Hagoort, & Brown, 1998; Deacon, Hewitt, Yang, & Nagata, 2000; Kiefer, 2002; Silva-Pereyra et al., 1999) but its magnitude is augmented at longer SOAs when controlled processes are engaged (e.g., Anderson & Holcomb, 1995; Hill, Ott, & Weisbrod, 2005).

There is accumulating evidence that towards their second birthday, children start to develop a lexical-semantic system based on different semantic relationships. Taxonomic (e.g., chicken – dog) or associative (e.g., cat – dog) relationships between words were previously shown to emerge by the age of 24-months (e.g., Arias-Trejo & Plunkett, 2009; Arias-Trejo & Plunkett, 2013; Rämä, Sirri, & Serres, 2013; Styles & Plunkett, 2009; Torkildsen, Syversen, Simonsen, Moen, & Lindgren, 2007; Willits, Wojcik, Seidenberg, & Saffran, 2013) but further studies have shown that these relationships between word meanings emerge even earlier, at 18-months of age (Delle Luche, Durrant, Floccia, & Plunkett, 2014; Rämä et al., 2013; Sirri & Rämä, 2015). In ERP studies, a semantic N400 priming effect for spoken words has been found in 18- and 24-month-olds (Rämä et al., 2013; Sirri & Rämä, 2015) while a larger N400 amplitude for inconsistent than for consistent object-word pairs has been found already from 12 months of age (Friederici, 2006; Friedrich and Friederici, 2006; Friedrich & Friederici, 2004, 2005a, 2005b, 2010). All these studies suggest that the neural generator mechanisms of N400 are mature early in development but some of the findings suggest that vocabulary skills contribute to the development of a taxonomically organized lexical-semantic system (e.g., Rämä et al., 2013; Torkildsen et al., 2006). There are also other ERP components that have been associated with lexical processing, such as the N2 (Friedrich & Friederici, 2004; Mills, Coffey-Corina, & Neville, 1997, 1993; Thierry, Vihman, & Roberts, 2003; Torkildsen et al., 2007) and late negativity (Friedrich & Friederici, 2004; Torkildsen et al., 2007). The N2 component has been associated with word familiarity (Mills, Coffey-Corina, & Neville, 1993, 1997), attention to lexical information (Thierry et al., 2003), and lexical expectancy or facilitation (Friedrich & Friederici, 2004; Torkildsen et al., 2007) while the late negativity, continuing beyond the N400 window, has been suggested to indicate slower semantic processing in younger children (Friedrich & Friederici, 2004; Torkildsen et al., 2007).

The aim of the current study was twofold: First, to investigate the occurrence and the distribution of ERPs in response to semantic relatedness in bilingual children to ascertain whether simultaneous dual language experience affects lexical-semantic processing, and second, to explore whether the magnitude or/and the distribution of ERPs are modulated by the SOA length to further investigate the cognitive mechanisms underlying semantic priming. In bilingual children, linguistic experience is divided between their two languages, which results in less experience with words in each language compared with monolingual children, which might in turn affects the development of their lexical-semantic system. Despite the fact that bilingual children need to construct in parallel two different phonological-lexical systems and learn two words for each object or concept, they achieve their language milestones in each of their languages at the same age (e.g., Oller, Eilers, Urbano, & Cobo-Lewis, 1997; Pearson, Fernandez, & Oller, 1993; Petitto et al., 2001). There is, however, evidence that bilinguals tend to have a smaller vocabulary in each of their languages even if the total vocabulary has been reported to be comparable to that of monolinguals (e.g., Bialystok, 2009; Hoff, Core, Place, Rumiche, Senor, & Parra, 2012; Poulin-Dubois, Bialystok, Blaye, Polonia, & Yott, 2013). Additionally, it has been shown that the speed of familiar word processing in two and half years old bilingual children was linked to the vocabulary knowledge in a given language but unrelated to the processing efficiency of the other language (Marchman, Fernald, & Hurtado, 2010). A few ERP studies investigated the neural correlates of word processing in bilingual children. Conboy and Mills (2006) explored the ERP components in response to known and unknown words in each of the 19- to 22-month-old bilinguals' languages. The results showed that the word familiarity effect (as reflected by more pronounced N200 and N400 amplitudes to known than to unknown words) was larger and occurred earlier for the dominant (the language to which children were mostly exposed in total time; hereafter: DL) than for the non-dominant (the language to which children were less exposed; hereafter: NDL) language. In addition, the distribution of language-related ERPs was shown to vary across the DL and the NDL in two-to four-year-old toddlers: The posteriorly distributed N400 component was observed for the DL only whereas processing of the NDL activated frontally distributed resources over the left scalp positions (Sirri & Rämä, 2017). Two other studies investigating lexical-semantic processing of the DL in 30-month-old bilingual toddlers showed that in a word-picture priming task, bilingual toddlers exhibited a similar N400 effect in their DL as their monolingual peers (Kuipers & Thierry, 2013, 2015). Altogether, these earlier ERP findings suggest that while lexical-semantic processing differs across the two languages of bilinguals, lexical-semantic processing in a picture-word context in the DL remains similar to that of their monolingual peers, at least at the ages of 2–4 years.

Our aim was to investigate whether bilingual children process lexical-semantic information similarly to their monolingual peers in a spoken word context already at earlier age and whether the SOA length modulates the ERPs to further understand the cognitive mechanisms underlying semantic priming in bilingual children. For 18-month-old monolingual children, our earlier results showed that the amplitudes of the N2 and LPN were modulated by both semantic relatedness and SOA length, whereas the N400 component was modulated only by semantic relatedness (Sirri & Rämä, 2015). The amplitudes of the frontally distributed N2 were larger for unrelated than for related words at the long SOA, while the semantic priming effect for posteriorly distributed LPN was larger over the right hemisphere at the short SOA and more pronounced over the left hemisphere at the long SOA. Even though there is no developmental evidence on the relation between the SOA length and associated cognitive processes, our findings suggested that both automatic and controlled processes might contribute to priming effects already in the developing brain. In the present work, the experimental design and its procedure respected that of Sirri and Rämä (2015): Children of 18-months were presented with word pairs (with two variable SOA lengths) that we were either taxonomically related or unrelated. We chose relatively long SOAs in both experimental conditions since in the auditory modality, simultaneous or overlapping word presentation (with SOAs of 0 ms or 200 ms) has been shown to attenuate the N400 priming effect (Anderson & Holcomb, 1995). Additionally, 18-month old children are slower at identifying familiar spoken words than older children (Fernald, Pinto, Swingley, Weinbergy, & McRoberts, 1998). Based on