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Cognitive and neural mechanisms underlying semantic priming during language acquisition

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Both automatic and controlled mechanisms have been shown to contribute to the magnitude of the N400 priming effect in adults. It has been proposed that at short stimulus onset asynchronies (SOAs), automatic processes are engaged, while at long SOAs, controlled processes are activated. Here, we explored whether the magnitude of event-related potentials (ERPs) in 18-month-old children are SOA-dependent to further understand the developmental mechanisms underlying semantic priming during early language acquisition. Children were exposed to an auditory semantic priming task in two invariant SOA conditions (1000 ms and 1600 ms). The results showed that the amplitudes of N2, N400 and late posterior negativity (LPN) components were modulated by semantic relatedness, but only those of N2 and LPN were modulated by the SOA length. The amplitudes of the frontally distributed N2 were larger at long than at short SOAs, while the posteriorly distributed LPN was larger over the right hemisphere at the short SOA and more pronounced over the left hemisphere at the long SOA. These findings suggest that both automatic and controlled processes contribute to priming effects in the developing brain, but neural resources underlying these processes might differ.

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1. Introduction

1.1. Semantic priming and N400 effect in adults

For several decades semantic priming paradigms have commonly been used as a tool to better understand the organization of the mental lexicon and word retrieval from long-term memory (e.g., Kutas & Hillyrad, 1989; Lucas, 2000; Meyer & Schvaneveldt, 1971). In lexical decision contexts, results generally show faster reaction times and more accurate responses to target words preceded by a semantically related word than to target words preceded by a semantically unrelated word (for a review, see Neely, 1991). Both automatic and controlled processes have been shown to influence the semantic priming effect (Neely & Keefe, 1989; Neely, Keefe, & Ross, 1989). According to the automatic spreading activation model, a prime word activates related representations in a semantic network, reflecting links previously established between words. It is fast-acting and does not require attentional resources (Collins & Loftus, 1975; Quillian, 1962). Automatic processes contribute to semantic priming effects when the temporal window between the onsets of the prime and the target words is short (around 400 ms). In contrast, controlled mechanisms, including expectancy and post-lexical matching, are the result of attentional processes and reflect post-lexical semantic integration, being therefore slow and highly demanding of attentional capacity (Becker, 1976; Brown & Hagoort, 1993; Neely, 1977, 1991; Posner & Snyder, 1975; Shiffrin & Schneider, 1977). Longer time intervals between prime and target words (>400 ms) allow controlled processes to be activated.

Lexical-semantic organization has been also studied by measuring the N400, a negative ERP component, evoked in response to unrelated *versus* related word pairs, or to incongruent *versus* congruent terminal words in sentences. N400 amplitudes are shown to be more negative to target words (e.g., nurse) preceded by unrelated (e.g., bread) than by related (e.g., doctor) prime words (e.g., Federmeier & Kutas, 1999; Kutas & Hillyard, 1980; for a review, see Kutas & Federmeier, 2000). This is called the N400 semantic priming effect, and is suggested to reflect semantic integration both in linguistic and non-linguistic domains (for review, Kutas & Federmeier, 2011). Typically, it appears over the central-parietal recording sites (Bentin, McCarthy, & Wood, 1985), but its latency and distribution varies according to the modality of the stimulus presentation (e.g., Bentin et al., 1985; Holcomb & Neville, 1990; Kutas, van Petten, & Besson, 1988; Van Petten & Luka, 2006).

Several studies investigated the contribution of automatic and controlled mechanisms to the N400 effect by using masked priming paradigms, by manipulating the proportion of related target words or the stimulus onset asynchrony (SOA) between the prime and the target words, or the direction of priming (forward *versus* backward) between words (e.g., Anderson & Holcomb, 1995; Balota, Black, & Cheney, 1992; Brown, Hagoort, & Chwilla, 2000; Chwilla, Brown, & Hagoort, 1995; Deacon, Hewitt, Yang, & Nagata, 2000; Deacon, Uhm, Ritter, Hewitt, & Dynowska, 1999; Franklin, Dien, Neely, Huber, & Waterson, 2007; Hill, Strube, Roesch-Ely, & Weisbrod, 2002; Holcomb, 1988; Kiefer, 2002; Silva-Pereyra et al., 1999). Overall, it has been suggested that both automatic activation and controlled processes underlie the N400 priming effect (e.g., Chwilla, Hagoort, & Brown, 1998; Deacon et al., 2000; Kiefer, 2002; Silva-Pereyra et al., 1999). Evidence for the support of automatic spreading activation has been shown in masked priming paradigms, where the N400 priming effects were obtained regardless of whether the words were masked or not, suggesting that the N400 reflects automatic spreading activation in the semantic network (Deacon et al., 2000; Kiefer, 2002). On the other hand, increasing the proportion of related word pairs within an experimental block increases the use of controlled processes related to expectancy: Indeed, the N400 effect was more pronounced in the high than in the low relatedness proportion lists (e.g., Brown et al., 2000; Chwilla et al., 1995; Holcomb, 1988). This suggests that even if automatic processes are involved in the N400 effect, controlled processes modulate its amplitude. In a complementary set of studies, different SOAs were used to manipulate automatic *versus* controlled processes (e.g., Anderson & Holcomb, 1995; Hill, Ott, & Weisbrod, 2005; Hill et al., 2002). Automatic processes are engaged at short (<400 ms) SOAs (De Groot, 1984; Neely, 1977), but decay over an extended time interval, which is when controlled processes are activated. Increasing the SOA length has been shown to augment the magnitude of the N400 component (Anderson & Holcomb, 1995; Hill et al., 2005), to modulate its distribution and timing (Anderson & Holcomb, 1995), or to have different effects depending on the ERP component (Franklin et al., 2007;