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Effects of grammatical categories on children's visual language processing: Evidence from event-related brain potentials

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Abstract

This study examined how school-aged children process different grammatical categories. Event-related brain potentials elicited by words in visually presented sentences were analyzed according to seven grammatical categories with naturally varying characteristics of linguistic functions, semantic features, and quantitative attributes of length and frequency. The categories included nouns, adjectives, verbs, pronouns, conjunctions, prepositions, and articles. The findings indicate that by the age of 9–10 years, children exhibit robust neural indicators differentiating grammatical categories; however, it is also evident that development of language processing is not yet adult-like at this age. The current findings are consistent with the hypothesis that for beginning readers a variety of cues and characteristics interact to affect processing of different grammatical categories and indicate the need to take into account linguistic functions, prosodic salience, and grammatical complexity as they relate to the development of language abilities.

Keywords: Reading; ERPs; Children; Development; Language processing; Grammatical categories; Word frequency; N400; Brain; Hemisphere; Grammatical complexity

1. Introduction

Our focus was to examine developmental aspects of neural functions mediating processing of naturally occurring grammatical categories. These grammatical categories represent a variety of word types that vary in linguistic functions, semantic features, and quantitative attributes including length and frequency (Brown, Hagoort, & Ter Keurs, 1999; Kellenbach, Wijers, Hovius, Mulder, & Mulder, 2002; King & Kutas, 1998; Munte et al., 2001; Neville, Mills, & Lawson, 1992; Osterhout, Allen, & McLaughlin, 2002; Osterhout, Bersick, & McKinnon, 1997). Several event-related brain potential (ERP) studies in adults indicate that frequency and length characteristics of words of various grammatical categories are systematically related and strong determiners of the peak latency of the second negative component occurring between 280 and 400 ms (King & Kutas, 1998; Munte et al., 2001; Osterhout et al., 2002, 1997). That is, higher frequency words which are also characteristically shorter in length elicit a second negativity with an earlier peak latency than lower frequency words that are also typically longer in length. This second negative ERP component that peaks within a temporal window of 280–400 ms is thought to reflect the first manifestation of the availability of word-category information from the mental lexicon (Brown et al., 1999; Ter Keurs, Brown, Hagoort, & Stegeman, 1999). At the temporal electrode sites, peak latencies across grammatical categories were found to range from 280 ms for the most frequent category, articles, to 320 ms for prepositions, 350 ms for pronouns, 360 ms for auxiliaries, and 400 ms for the lowest frequency categories of nouns and verbs (Osterhout et al., 1997). However, other researchers have reported latency differences related only to the broader word class distinctions (i.e., closed-class words peaking earlier than open-class words), finding no systematic

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relationship to within class lexical frequency/length characteristics (Brown et al., 1999; Neville et al., 1992). The peak latencies of the second negative component elicited by closed- and open-class words were also found to be differentially sensitive to language proficiency, both in native English speakers and in Chinese–English bilinguals (Weber-Fox, Davis, & Cuadrado, 2003; Weber-Fox & Neville, 2001). In both populations, the peak latency of the second negativity elicited by closed-class words, but not open-class words, varied as a function of linguistic proficiency.

Amplitude differences of this component across grammatical categories also vary with word frequency, with larger amplitudes associated with lower frequency words (Munte et al., 2001). Kellenbach and colleagues (2002) found that these amplitude differences may be due in part to naturally occurring differences in semantic features (e.g., concrete, abstract, and visual-motor). Furthermore, distinctions in scalp distributions for this component were found to be related to different grammatical categories (Neville et al., 1992; Osterhout et al., 1997). Specifically, for the closed-class grammatical categories, a left hemisphere asymmetry was observed over temporal sites. In contrast, for nouns and verbs, the negativity tended to be slightly larger and later over the right hemisphere (Osterhout et al., 1997).

In a later temporal window (~400–600 ms), words from closed-class grammatical categories (e.g., articles, prepositions), when presented in sentence contexts, elicited a broad negative shift (BNS) that was not present in the waveforms elicited by open class grammatical categories (e.g., verbs, nouns) (e.g., Brown et al., 1999; Kutas & Van Petten, 1994; Munte et al., 2001; Neville et al., 1992; Osterhout et al., 1997). These later differences between the word classes are thought to relate to post-lexical semantic and syntactic processing (Brown et al., 1999 ;Ter Keurs et al., 1999). Taken together, ERP findings for adults indicate that the neural functions for processing different grammatical categories reflect their linguistic function, semantic features, and their quantitative attributes of frequency and length.

Little is known about the development of neural functions mediating the processing of words from finely differentiated grammatical categories. However, ERPs elicited by words grouped according to the broader categories of closed- and open-class words have been examined in children between the ages of 8 and 11 years (Neville, Coffey, Holcomb, & Tallal, 1993). The ERPs elicited by visually presented closed-class words were averaged across grammatical categories and included articles, pronouns, prepositions, conjunctions, and auxiliaries. Open-class ERPs were averaged across nouns, verbs, and adjectives. A negative component peaking around 400 ms was elicited in the children's ERPs for closed- and open-class words. In typically developing children, the N400 was asymmetrical (larger over left anterior regions) for closed-class words but not for open-class words. This was consistent with previous findings in adults (Neville et al., 1992). The findings from this study indicate ERPs of children showed distinctions in processing open- and closed-class words; however, differences in the latencies of the second negative component were not adult-like. In adults, the peak latency of this component was earlier for closed-class words (280 ms) compared to open-class word (350 ms) (Neville et al., 1992). In summary, the development of neural functions mediating the processing of different word classes is not completely adult-like for ages up through 11 years of age, and unlike adults, children may not process highly frequent closed-class words more quickly than lower frequency open-class words.

Consistent with ERP evidence in children, behavioral findings indicate that word frequency is not the predominant cue in driving early word learning. Perhaps the most striking evidence is that in their earliest word learning, young children first produce nouns, which are least frequent, followed by verbs and adjectives which are also relatively infrequent (Bates et al., 1994). The most frequent categories, function words making up the closed-class category, are in fact the latest to emerge, typically when children have amassed a lexicon of over 400 words (Bates et al., 1994). Obviously, factors besides frequency contribute to early word learning and a general pattern of progression according to grammatical categories across early language development has been observed by a number of researchers (e.g., Bates et al., 1994; Bloom & Lahey, 1977; Brown, 1973).

Progressions in language development related to grammatical categories continue even beyond early language acquisition. The language abilities of school-age children for both auditory processing and reading also show distinctions according to word classes. Auditory word monitoring tasks in kindergarten children indicate that closed-class items are not segmented into words as readily as open-class words (Holden & MacGinitie, 1972), even when prosodic differences between the word classes are controlled (Ehri, 1975). In an auditory word-monitoring study of older children, Friederici (1983) found that children up through the age of 11 years were less sensitive to closed-class words (i.e., failed to respond as accurately) compared to open-class words. Parallel findings were reported for a study of the effects of word class on children's reading (Bruskin & Blank, 1984). Bruskin and Blank (1984) observed that children aged up to 11 years were less accurate and slower in reading closed-class (function) words compared to reading open-class (content) words that were matched for length and frequency. However, it should be noted that when children were asked to repeat the last word heard during a pause in a story, children as young as 5 years of age performed as accurately on closed- and open-class words (Karmiloff-Smith, Grant, Sims, Jones, & Cuckle, 1996). The 4-year-old children in that study, however, performed more accurately on open-class words compared to closed-class words. In summary, the production of closed-class or function words typically occurs later compared to