



Word-to-text integration: Message level and lexical level influences in ERPs

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ABSTRACT

Although the reading of connected text proceeds in a largely incremental fashion, the relative degree to which message level and lexical level factors contribute to integration processes across sentences remains an open question. We examined the influence of both factors on single words using event-related potentials (ERPs). Word pairs with either strong or weak forward association strength were critical items: embedded as coreferential words within two-sentence passages in a text comprehension task, and as isolated word pairs in a word meaning judgment task. While the N400 ERP component reflected an effect of forward association strength on lexico-semantic processing in the word task (i.e., reduced N400 amplitudes were seen for strongly associated pairs relative to weakly associated pairs), in the comprehension task, passages embedded with any associated word pairs elicited reduced N400 amplitudes relative to coherent baseline passages lacking one of the critical words. These comprehension effects reflect responses from the highest skilled comprehenders. The results demonstrate the effects of message level factors, and reading abilities, on the processing of single words.

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1. Introduction

Text comprehension processes operate on a single word to connect its meaning with the reader's understanding of the text. These word-to-text integration processes are essential to building and updating, within and across sentence boundaries, a situation model of the text (Kintsch, 1988). These integrative processes are observable in word reading times (Tyler & Marslen-Wilson, 1977), eye-movements (Rayner, Sereno, Morris, Schmauder, & Clifton, 1989), and evoked brain potentials that reflect lexico-semantics (Kutas & Hillyard, 1980). Thus, a tight coupling of the message level (the meaning of the text) and the lexical level (the meaning of the word) produces fluid word-to-text integration.

An important question is how this tight coupling comes about. In particular, how do the lexical level and the message level interact during text comprehension? To what extent do word-to-word connections in associative or semantic memory drive certain integrative processes? To what extent is the message level, which selects the text-relevant meaning, in control of the process? The current experiment examines a specific form of this general

question: does associative strength between coreferential words function *across sentence boundaries* to influence on-line word-to-text integration? If so, how does this influence compare to the effects of associative strength on word-to-word processing? Finally, does reading ability modulate effects of associative strength in word-to-text and word-to-word processing in similar ways?

The analysis of Event-Related Potentials (ERPs) measured on specific words provides a powerful method for investigating questions in text processing. The fine temporal correlation between the EEG signal and mass neuronal activity affords a millisecond by millisecond record of processing that is unavailable to other non-invasive measures. Much of ERP research has focused on the influence of context on the processing of words in isolated sentences, and to a lesser extent, in connected text. The combination of ERP measures and careful experimentation has been used to build theoretical models of language processing (e.g., Federmeier, 2007).

One particularly well-documented ERP measure in the study of language is the N400 component (Kutas & Hillyard, 1980), a negative-going deflection of the ERP waveform, peaking at around 400 ms after the onset of any potentially meaningful stimulus (Kutas & Federmeier, 2011). The initial discovery of the N400 revealed that it is larger (i.e., of greater amplitude) in response to words that are incongruent within their context relative to those that are congruent within their context (Kutas & Hillyard, 1980). Subsequently, the sensitivity of the N400 component to a large

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range of linguistic manipulations has been tested, including the cloze probability of words (Kutas & Hillyard, 1984) and their position in sentences (Kutas, Van Petten, & Besson, 1988; Van Petten & Kutas, 1990). At the lexical level, decreased N400 responses were found to words following lexical associates in sentences (Van Petten, 1993) as well as to words in the same conceptual category as expected words (Federmeier & Kutas, 1999).

ERP studies of word-by-word processing also have been carried out with connected texts. For example, Van Berkum, Hagoort, and Brown (1999) observed ERPs while participants read either single sentences or short texts in which the 3rd sentence was either congruent or incongruent. The critical words in the texts were congruent with the local sentence context, but incongruent with the message level context set up by the first two sentences. In both single sentences and three-sentence texts, the N400 on incongruent words was larger than on congruent words. The N400 effects (i.e., incongruent–congruent) and topographies were largely consistent across sentence and text reading conditions. These results demonstrate that discourse-level meaning can influence the semantic processing of individual words in a manner similar to sentence-level meaning.

Other studies suggest discourse context allows the prediction of individual lexical items (Van Berkum, Brown, Zwisterlood, Kooijman & Hagoort, 2005; Wicha, Moreira, & Kutas, 2004). Van Berkum et al. (2005) studied native Dutch speakers who either listened to (Experiment 1) or read (Experiment 3) two-sentence passages, in which the first sentence was highly constraining for a specific noun in the second sentence. The experimental manipulations were the inclusion of the expected (congruent) noun or an unexpected (incongruent) noun in its place, as well as the inclusion of a consistently or inconsistently gender-marked preceding adjective. For example, the Dutch noun for “painting” (*schilderij*) has a neuter gender and could be preceded either by a consistent neuter gender “zero” suffix adjective (“big”=*groot*), or an inconsistent common gender -e suffix adjective (*grote*). As expected, the congruent, expected nouns elicited reduced N400 amplitudes relative to unexpected, incongruent nouns. More interesting, there was an effect on the preceding adjective. If the gender marking of the adjective was not consistent with the gender of the expected noun, an effect was observed on an early positive deflection between 50 and 250 ms after adjective inflection onset. This, along with other evidence (Lau, Almeida, Hines, & Poeppel, 2009; Wicha et al., 2004), seems to indicate that the message level context can lead to the anticipation of specific words, and not simply abstract meaning features (e.g., Federmeier & Kutas, 1999).

To this point, most research on context effects has used at least moderately constraining texts, and has examined differences between processing contextually congruent and contextually incongruent words. To extend our understanding of the way multiple levels of representation interact, it is critical to examine message level and lexical level factors in the processing of specific discourse devices that connect words and texts in the construction of situation models. Anderson and Holcomb (2005) provide an example in a study (Experiment 2) in which participants read two-sentence texts: the first sentence contained a noun in the object position that was repeated or synonymous with the word in the subject position in the second sentence. This second sentence subject was made either coreferential by the definite article (“the”) or new to the discourse by the indefinite article (“a”). The ERP measures on the critical words revealed that repetitions and synonyms elicited reduced N400 responses relative to filler words, with synonyms eliciting a N400 response between that of repetitions and fillers. However, the authors did not find a reliable N400 effect of coreference (“a” vs “the”) on the critical noun, which they took to suggest that the repetition and synonym effects were lexical in nature.

In an ERP study on word-to-text integration processes, Yang, Perfetti, and Schmalhofer (2007) demonstrated an effect on word processing driven by the referential availability of a critical word across a sentence boundary. For example, in their *explicit* condition the critical word was a repetition of a word in the first sentence (with occasional morphological variation; e.g., *exploded-explosion*), and in the *paraphrase* condition the critical word was conceptually related to an event expressed by a different word or phrase in the first sentence (e.g., *blew up-explosion*). Importantly, in contrast to Anderson and Holcomb (2005), the coreferential paraphrase words were not chosen to be synonyms of the antecedent words. During reading of the critical words, ERP measures revealed reduced N400 responses for both repetition and paraphrase conditions relative to a baseline condition. A condition that did not contain a readily available antecedent in the first sentence, but required additional inferencing, did not elicit the same N400 reduction.

We can specify the processes involved in connecting the two sentences word-by-word by referring to the reading of the key word *explosion* from the Yang et al. (2007) study. In the *explicit* condition, the reader has constructed a situation model (Johnson-Laird, 1980; Kintsch, 1988) that includes a bomb explosion event from the final clause of the first sentence (“...the bomb hit the ground and exploded”). Integration of the word *explosion* is well supported both by the explosion event and the word *exploded* in the previous sentence. In the *paraphrase* condition, however, only the event structure (the event described by “blew up” in the first sentence) is available for integration—there is no word form overlap. As the reader encounters the “explosion” in the paraphrase condition, integration depends on making a coreferential link to the event described by “blew up” in the first sentence. It is this coreferential process that is captured by the phrase “word-to-text integration” and is responsible for a reduced N400 in the paraphrase condition. In the *baseline* condition, there is no “explosion” event in the first sentence and thus no coreferential integrative process in the second sentence at the word “explosion”. Instead, the reader may establish a new referent (the explosion). However, even here, the word “bomb” appeared in the first sentence, which allows a word-level connection to be made when “explosion” is read in the second sentence. Thus, the advantage of the paraphrase condition (its N400 reduction) over the baseline condition is not dependent on the word “bomb” but seems to require a message level explanation in the form of referential binding.

While existing research using brief discourse contexts has provided evidence of message level factors on word processing, it has examined the lexical-level factors that might be involved in word-to-text integration to a lesser extent. One lexical level factor concerns the connections among words stored in memory, a factor that can be indexed by traditional associative norms that provide estimates of strength of association between two words or by directionless metrics that capture multi-dimensional semantic distances between pairs of words measured from large corpora, e.g. LSA (Landauer & Dumais, 1997; Landauer, Foltz, & Laham, 1998). Words preceded by semantically or associatively related words are processed more quickly and accurately than words preceded by unrelated words (Balota & Lorch, 1986; Meyer & Schvaneveldt, 1971). Such effects are thought to result from automatic spreading activation at short stimulus-onset asynchronies (SOAs) and the development of semantic expectancy sets at longer SOAs (Neely & Keefe, 1989; Neely, 1991). In certain contexts, associative priming is graded; Coney (2002) found a linear decrease in lexical decision reaction times with increasing associative strength between primes and targets. Priming effects have been found in ERP studies, where words preceded by related words elicit reduced N400s compared to words preceded by unrelated words (Bentin, McCarthy, & Wood, 1985; Holcomb, 1988).

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