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The N400 in processing repeated name and pronoun anaphors in sentences and discourse

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ABSTRACT

We report two EEG/ERP experiments that examined processing of repeated name (e.g., *Bill*; Experiment 1) and pronoun (e.g., *he*; Experiment 2) subject anaphors to single antecedents (e.g., *Bill*) and to antecedents embedded in a conjunction (e.g., *Bill and Mary*) within sentences and discourses. Experiment 1 replicated previous reports of repeated references to single antecedents eliciting greater N400 negativity than repeated references to conjoined antecedents within sentences, and extended these results to cross-sentence (discourse) references. Experiment 2 found that pronouns also elicited greater N400 negativity following single than conjoined antecedents. In both experiments, references to conjoined antecedents elicited greater frontal negativity than references to single antecedents in both sentences and discourse. Our results indicate that, in processing subject anaphors, the N400 is an index of reference predictability rather than a marker of the fit between antecedent salience and reference form, and that frontal negativity marks referential ambiguity elicited by conjoined phrases.

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1. Introduction

Coherent discourse often consists of multiple sentences that are linked to one another by repeated reference to the same entities. Repeated reference involves the use of *anaphoric expressions*, i.e., expressions that refer to an *antecedent*, which is an earlier mention of the *referent*. Due to the prevalence and importance of anaphoric reference in discourse and text, considerable research has explored the psychological mechanisms that underlie the use and processing of these expressions (e.g., Almor, 1999; Ariel, 1990; Gernsbacher, 1989; Gordon, Grosz, & Gilliom, 1993). A general finding of this research is that the salience[1] of a given referent in memory affects the choice and comprehension of an anaphoric expression such that greater salience is associated with the preferential use of reduced anaphoric expressions such as pronouns (Ariel, 1990). The use of reduced anaphoric expressions is pervasive in discourse, and an individual's reading time will typically slow if, when referring to the most salient referent in the discourse, a repeated proper name anaphor is used in the subject position instead of a reduced anaphor. Gordon et al. (1993) first demonstrated that this effect, dubbed the Repeated Name Penalty (RNP), occurs with repeated proper names (e.g., *Daniel*), and subsequent research reported a similar effect with repeated definite descriptions *(e.g., the man;* Almor, 1999).

Although the earliest demonstrations of the RNP were restricted to behavioral studies in which the dependent measure was the reading speed of sentences and sentence fragments, subsequent studies employing ERP methodology demonstrated that the RNP is also reflected in a more negative N400 (Camblin, Ledoux, Boudewyn, Gordon, & Swaab, 2007; Ditman, Holcomb, & Kuperberg, 2008; Ditman, Nieuwland, & Kuperberg, 2009; Ledoux & Camblin, 2008; Ledoux, Camblin, Swaab, & Gordon, 2006; Ledoux, Gordon, Camblin, & Swaab, 2007; Swaab, Camblin, & Gordon, 2004). These studies contrasted the ERPs evoked by repeated proper name anaphors (e.g., *Daniel*) in different contexts. One group of studies (Camblin et al., 2007; Johns, Gordon, Long, & Swaab, 2014; Ledoux et al., 2007; Swaab et al., 2004) contrasted antecedents appearing as single noun phrases with antecedents that were embedded in conjoined noun phrases, as in the following example (the contexts and anaphors are underlined):

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[1] The term "salience" is used in different ways in the literature. Here we use this term to mark the accessibility of the referent in the discourse representation, and generally distinguish between the most salient referent, which in simple declarative sentences is typically the grammatical subject and topic, and less salient referents, which typically occupy other positions.

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Single noun phrase context: At the office Daniel moved the cabinet because Daniel needed room for the desk.
Conjoined noun phrase context: At the office Daniel and Jane moved the cabinet because Daniel needed room for the desk.

Over a series of studies, these researchers observed that when the antecedent was a single noun phrase, repeated name anaphors elicited a larger N400 than pronouns (Swaab et al., 2004) and that the N400 elicited by repeated name anaphors was comparable to the N400 elicited by mentioning a new name (Camblin et al., 2007). Following Gordon et al. (1993), they argued that the difference between the single and conjoined noun phrase conditions mostly affects the salience of the antecedent such that the antecedent is more salient in the single noun phrase condition than in the conjoined noun phrase condition. While these studies provide promising evidence for the existence of an ERP equivalent of the RNP, they have so far only examined anaphoric reference within sentences, whereas most behavioral studies of the RNP have used inter-sentence discourse anaphors (Almor, 1999; Gelormini-Lezama & Almor, 2011; Gordon et al., 1993; Yang, Gordon, Hendrick, & Wu, 1999). Indeed, there is reason for concern about the timing of integrative reference effects within sentences. For example, Greene, McKoon, and Ratcliff (1992) showed that readers often delay pronoun reference resolution until the end of sentences. These investigators argued that pronominal reference resolution can occur at different points in processing as a function of available resources and readers' goals. This suggests that some anaphors may not be fully interpreted as they are encountered within sentences and that reference processing within and across sentence boundaries may differ. One goal of the present research was therefore to extend the previous ERP studies to inter-sentence discourse reference. Throughout the rest of the paper we will refer to inter-sentence discourse anaphors as simply 'discourse anaphors' and to within-sentence anaphors as 'sentence anaphors'.

The identification of ERP components related to the RNP has several important theoretical implications. First, it will help complete our understanding of the electrophysiology of discourse reference processing, which has so far not examined subject anaphors in great detail, in particular with respect to the relation between anaphor form and the salience of the antecedent. The importance of distinguishing between these factors has been highlighted by the work of Kehler and colleagues in the framework of Bayesian modeling (Kehler, Kertz, Rohde, & Elman, 2008; Kehler & Rhode, 2013; Rohde & Kehler, 2014). Although there have been several reports of N400 associated with discourse anaphor processing, these studies only looked at anaphors that did not appear in the subject position (e.g., Burkhardt, 2006; Ditman et al., 2009) or at anaphors whose antecedents did not appear in the subject position of the previous sentence (e.g., Burkhardt, 2006; Ditman et al., 2009; Schumacher & Hung, 2012; Wang & Schumacher, 2013; Yang, Perfetti, & Schmalhofer, 2007). None of these cases is therefore likely to elicit the same kind of RNP reported in self-paced reading studies, which only occurs for anaphors in subject or fronted positions when their antecedent is in the subject position of the previous sentence (Gordon et al., 1993). Thus, while previous research suggests that the N400 marks the difficulty of identifying an antecedent in situations that do not give rise to the RNP (see Schumacher & Hung, 2012 for a review), the understanding of how processing is influenced by the relation between antecedent salience and reference form, necessary for a complete view of the electrophysiology of reference processing, requires that we examine whether, and if so how, the N400 responses are changed in contexts that elicit the RNP.

A second theoretical implication is that finding an ERP marker of the RNP in discourse would imply that the processes underlying the RNP occur rapidly and are not delayed. This has bearings for theories of reference processing that differ with respect to the order and timing of different aspects of reference processing. A third theoretical implication is that identifying ERP components such as the N400 and the LAN (left anterior negativity) that are associated with the RNP would suggest that the cognitive processes associated with these components play a role in the RNP. Finally, a fourth theoretical implication is that the similarities and differences between the ERP responses elicited by sentence and discourse anaphors can provide additional information about the underlying processes. For example, finding ERP responses for discourse anaphors similar to the ones reported for sentence anaphors (Swaab et al., 2004) would support the theoretical claims of Gordon and Hendrick's (1998) Discourse Prominence Theory (DPT), which considers the processing of anaphoric expressions to be similar within and across sentences. Finding different effects for discourse and sentence anaphors would be informative about the underlying reasons for the differences in processing the two kinds of anaphors, especially with respect to memory processes that are marked by distinct ERP components. Before we discuss these ERP components in detail, we address the neural basis as well as relevant aspects of the time course of processing an anaphoric reference.

1.1. The neural basis of reference processing

The fine level processing time information provided by ERP is crucial for placing recent evidence about the neural basis of the RNP in the broader context of reference processing. Another important type of evidence is provided by fMRI studies that can further help identify the brain regions that participate in these processes. Most relevant to the current study, Boiteau, Bowers, Nair, and Almor (2014) previously showed that, in multi-sentence texts, plural reference to a conjoined discourse entity leads to greater bilateral parietal activity relative to single reference to a single discourse entity. An earlier study from our lab (Almor & Nair, 2007), looking more specifically at the RNP (inter-sententially), also found greater involvement of parietal regions bilaterally in repeated vs. pronoun conditions. We have interpreted these findings as showing that parietal regions, especially in the superior part, are involved in the formation, maintenance, and manipulation of the multiple representations of referents during discourse comprehension.

Another fMRI study (Nieuwland, Petersson, & Van Berkum, 2007) found that ambiguous references evoked activity in fronto-parietal regions including the superior parietal lobes and the dorsolateral prefrontal cortex, which may reflect either introduction of new entities into the discourse model or the decision making processes involved in resolving ambiguous reference. Similarly, McMillan, Clark, Gunawardena, Ryant, and Grossman (2012) showed that processing ambiguous referents evoke more frontal activity (the dorsolateral prefrontal cortex in particular) than processing non-ambiguous ones. While our focus in this paper is on the time course and ERP components involved in reference processing, we consider the implications of these various findings for the neural bases of reference processing in the general discussion.

1.2. Time course and integrative processes

Several theories of anaphor resolution (e.g., Almor & Eimas, 2008; Almor & Nair, 2007; Duffy & Rayner, 1990) distinguish between multiple stages, with the lexical identification of the referent occurring in the initial stage, followed by the integration of

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