



LIFG-based attentional control and the resolution of lexical ambiguities in sentence context

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ABSTRACT

The role of attentional control in lexical ambiguity resolution was examined in two patients with damage to the left inferior frontal gyrus (LIFG) and one control patient with non-LIFG damage. Experiment 1 confirmed that the LIFG patients had attentional control deficits compared to normal controls while the non-LIFG patient was relatively unimpaired. Experiment 2 showed that all three patients did as well as normal controls in using biasing sentence context to resolve lexical ambiguities involving balanced ambiguous words, but only the LIFG patients took an abnormally long time on lexical ambiguities that resolved toward a subordinate meaning of biased ambiguous words. Taken together, the results suggest that attentional control plays an important role in the resolution of certain lexical ambiguities – those that induce strong interference from context-inappropriate meanings (i.e., dominant meanings of biased ambiguous words).

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1. Introduction

Language understanding is a cognitive act that involves both automatic and controlled processes (e.g., see Meyer, Wheeldon, and Krott (2007) for discussions). Controlled processes are particularly important when interference arises during interpretation (see Novick, Trueswell, and Thompson-Schill (2005), for a recent review). In this paper, we focus on an internal source of interference – the automatic activation of word meanings – and examine the role of attentional control in the resolution of that interference during sentence comprehension. The issue will be addressed by examining the performance of brain-damaged patients with and without deficits in attentional control.

Certain words have multiple meanings that are unrelated to one another (e.g., *bank* refers to a financial institution or a river's edge). When two or more meanings have approximately equal association strengths to the ambiguous word form, the word is *balanced* among alternative meanings. When one meaning is much more strongly associated with the word form than are other meanings, the word is *biased* with the strongly associated meaning being its *dominant* meaning and other alternative meanings its *subordinate* meanings. Due to their association to the word form, unintended alternative meanings may be automatically activated into working memory (WM) as an ambiguous word is processed. This activation of irrelevant meanings is particularly likely when biased

ambiguous words are used to refer to a subordinate meaning (e.g., Duffy, Morris, & Rayner, 1988; Huettig & Altmann, 2005; Swaab, Brown, & Hagoort, 2003; Swinney, 1979; see Duffy, Kambe, and Rayner (2001) for review). Significant processing cost, manifested as an increase in reading time on a biased ambiguous word compared to that on an unambiguous control word, has been found for cases in which prior sentence context semantically disambiguates toward the word's subordinate meaning (e.g., Duffy et al., 1988). When prior sentence context disambiguates toward an alternative meaning of balanced ambiguous words, there is no significant processing cost for reading the ambiguous vs. unambiguous control words (e.g., Duffy et al., 1988).

The lack of processing cost for balanced ambiguous words and the significant processing cost for biased ambiguous words have typically been explained by assuming that context and the association strength between the ambiguous word form and an alternative meaning jointly influence the activation level of an alternative meaning (e.g., Duffy et al., 2001). In the case of balanced ambiguous words, each of the equally associated alternative meanings receives an equal amount of activation from the ambiguous word form and prior disambiguating context serves to boost the activation of the intended meaning above that of unintended ones, allowing the intended meaning to be selected immediately as a balanced ambiguous word is processed. In the case of biased ambiguous words, the dominant meaning receives a great amount of activation while subordinate meanings receive little activation from the ambiguous word form. Though prior context adds to the activation of the intended subordinate meaning, the summed activation for the intended subordinate meaning is not sufficient

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for it to be immediately selected as a biased ambiguous word is processed.

Several processes may underlie the processing cost observed for biased ambiguous words presented in prior subordinate biasing sentence context. One source of the cost may be a delay in the resolution toward the context-appropriate subordinate meaning due to competition from the context-inappropriate dominant meaning (e.g., Duffy et al., 2001). This hypothesis presupposes that both the meanings are simultaneously active in WM. Alternatively, the cost may be due to retrieval interference in which the context-inappropriate dominant meaning interferes with the retrieval of the target subordinate meaning (Shivde & Anderson, 2001). This hypothesis presupposes that the target subordinate meaning has not been sufficiently activated into WM. Perhaps which explanation is correct depends upon the degree of bias, such that competition occurs for biased ambiguous words with less pronounced bias ratios (e.g., word–meaning association strength = .70/.30 for dominant/subordinate meaning, respectively) while retrieval interference occurs for biased ambiguous words with more pronounced bias ratios (e.g., .90/.10). Critically, for our purposes, there is a demand for attentional control in both cases, such that comprehenders need to focus attention on contextual factors, which support the intended subordinate meaning, against distraction from the dominant meaning to successfully resolve the competition or retrieval interference from the dominant meaning during lexical ambiguity resolution (Balota, Cortese, & Wenke, 2001; Novick, Trueswell, & Thompson-Schill, 2005; Shivde & Anderson, 2001; Simpson & Adamopoulos, 2001; Simpson & Kang, 1994; Thompson-Schill, 2005).

Empirical evidence consistent with the attentional control hypothesis has been obtained in lexical ambiguity resolution studies that involve comprehenders with attentional control deficits (e.g., Balota & Duchek, 1991; Bedny, Hulbert, & Thompson-Schill, 2007). Balota and Duchek focused on lexical ambiguity resolution in comprehenders with Dementia of the Alzheimer's Type (DAT) (see Balota and Faust (2001) for a review on attentional control deficits in DAT individuals) and showed that DAT comprehenders had a deficit in lexical ambiguity resolution. The study involved naming of words presented in different contexts (concordant context: *music – organ – piano*, discordant context: *kidney – organ – piano*, control unrelated context: *kidney – ceiling – piano*). The target word (*piano*) was related to the context-appropriate meaning (musical instrument) of the ambiguous word (*organ*) in the concordant context condition (context word: *music*), and related to the context-inappropriate meaning (bodily part) of the same ambiguous word (*organ*) in the discordant context condition (context word: *kidney*). Similar to normal control comprehenders, DAT comprehenders were significantly faster at target word naming in the concordant vs. unrelated context condition, suggesting that they had no difficulty in activating context-appropriate meanings of ambiguous words. However, unlike normal control comprehenders (who showed no significant difference between the discordant and unrelated condition), DAT comprehenders were still faster at target word naming in the discordant compared to the unrelated context condition, suggesting that they had particular difficulty in resolving interference from context-inappropriate meanings of ambiguous words.

In a different study, Bedny et al. (2007) used a triplet lexical decision task to study lexical ambiguity resolution in a patient with LIFG damage (see Jonides and Nee (2006) for a review on attentional control deficits in LIFG patients). Similar to Balota and Duchek (1991), Bedny et al. (Experiment 2) showed that the LIFG patient had no trouble in activating context-appropriate word meanings; like normal controls, he was significantly faster to make target lexical decision (*baby*) in the consistent (*cow, calf, baby*) vs. neutral condition (*mirror, cut, baby*). However, unlike normal

controls, who showed evidence of suppression of context-inappropriate meanings (significantly slower to make target lexical decision in the inconsistent (*knee, calf, baby*) vs. consistent or neutral condition), the LIFG patient showed no difference between the inconsistent and consistent conditions, suggesting that he activated alternative meanings at a similar level whether they were appropriate or inappropriate to the context.

Together, the word-context studies (Balota & Duchek, 1991; Bedny et al., 2007) show that comprehenders with attentional control deficits are impaired in lexical ambiguity resolution. The impairment is specific to resolving interference from context-inappropriate meanings rather than to activating alternative meanings of ambiguous words. These findings suggest that attentional control is important for resolving interference from irrelevant word meanings during lexical ambiguity resolution. However, since the studies used only single words as context, it remains to be investigated whether similar evidence for a role of attentional control in lexical ambiguity resolution would obtain if sentence rather word context is used to provide basis for ambiguity resolution.

The goal of our study was to test the attentional control hypothesis of lexical ambiguity resolution using sentence context. Similar to the word-context studies, we tested the hypothesis by focusing on comprehenders with attentional control deficits. Experiment 1 examined attentional control in three patients and showed that two of the patients, who had damage to the LIFG area, had impaired attentional control while the other patient, who did not have LIFG damage, was relatively unimpaired in attentional control compared to normal controls. Experiment 2 examined ability to resolve lexical ambiguities in the patients. We constructed the materials so that prior sentence contexts always disambiguated toward a subordinate meaning of biased ambiguous words or a (slightly less frequent) alternative meaning of balanced ambiguous words. Given the contexts, the (slightly more frequent) alternative meaning of balanced ambiguous words should be minimally interfering while the dominant meaning of biased ambiguous words should likely interfere in lexical ambiguity resolution (e.g., Duffy et al., 1988). The attentional control hypothesis predicts a selective lexical ambiguity resolution deficit in the LIFG patients in the biased ambiguous word condition only.

2. Patient background

Two patients – ML and EV, who had lesions that included the LIFG area, and a control patient MB, who had a non-LIFG (parietal) lesion, were tested in both Experiment 1 and 2. Each patient's single word processing and active sentence comprehension were assessed to rule out the possibility that any patient difficulties in sentence processing could be attributed to difficulties with understanding single words or processing simple sentence structures. We used the Peabody Picture Vocabulary Test (choose one of four pictures that matches a spoken word) (PPVT; Dunn & Dunn, 1981) to assess single word comprehension, the Philadelphia Naming Test (name each single picture with a single word) (PNT; Roach, Schwartz, Martin, Grewal, & Brecher, 1996) to assess single word production, and a sentence–picture matching task (match each spoken sentence to an appropriate picture with distractor pictures showing a reversal of agent–patient roles or lexical substitutions) to assess comprehension of simple active reversible sentences.

2.1. LIFG patient ML

ML was a 68-year-old right-handed male, who suffered from a cerebrovascular accident in 1990 that resulted in a lesion comprising the LIFG, frontal areas more superior to the LIFG, and substantial areas of the left parietal lobe (see Fig. 1). His single word

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