The role of working memory in inference generation during reading comprehension: Retention, (re)activation, or suppression of verbal information?

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ABSTRACT

The present study explored the role of working memory (WM) in online activation of bridging and predictive inferences during reading comprehension. Using short narratives and a probe-naming procedure, five hypotheses were examined: Text retention, text reactivation, inference retention, inference activation, and text and inference suppression. In addition, three types of WM span tests—listening-, operation- and symmetry-span tests—were used to examine whether the role of WM in inference generation is domain-specific for discourse items, domain-specific for verbal items, or domain-general, respectively. Different patterns of results were observed for high- and low-span groups only when participants were divided based on the listening-span test. High-span participants generated predictive inferences faster than low-span participants, and then quickly inhibited them when they became less relevant in the following sentence. Moreover, high-span participants generated more bridging inferences than low-span participants, possibly due to enhanced retention and reactivation of inference-evoking textual information. These findings support the inference activation, inference inhibition, text retention, text reactivation, and discourse-domain-specific hypotheses of WM’s role in inference generation. The unique contribution of this study to the field is discussed in relation to existing findings and theories of WM.

1. Introduction

A large body of evidence has indicated that readers with high working memory capacity (i.e., high-span readers) generate more inferences from background knowledge than readers with low working memory capacity (i.e., low-span readers) during reading comprehension (e.g., Linderholm, 2002; Singer, Andruslak, Reisdorf & Black, 1992; St. George, Mannes, & Hoffman, 1997). However, there is no agreement about the manner in which working memory (WM) functionally supports the generation of inferences, and it is less clear which type of inference benefits from a higher capacity (see McNamara, de Vega, & O’Reilly, 2007, and McNamara & O’Reilly, 2009, for a review). Moreover, it has remained unknown whether the role of WM in inference generation is domain-general or domain-specific.

Different hypotheses have been suggested to explain the role of WM in the activation of two types of knowledge-based inferences—bridging and elaborative inferences. Bridging inferences refer to mediating information that clarifies the conceptual links between textual ideas (e.g., causality), and consequently enhances coherence and supports text comprehension (Graesser, Singer, & Trabasso, 1994). Elaborative inferences refer to information that expands upon (e.g., predictions) or further defines textual ideas (e.g., objects’ properties). These inferences may enhance text memory, but are not crucial for comprehension during reading (Gerrig & O’Brien, 2005). Several studies found that high-span readers generate more bridging inferences than low-span readers (Singer, Andruslak, Reisdorf, & Black, 1992; Virtue, van den Broek and Linderholm, 2006; Virtue, Parrish & Jung-Beeman, 2008; but cf. St. George et al., 1997). Other studies found that high-span readers generate more elaborative inferences than low-span readers (Linderholm, 2002; Linderholm & van den Broek, 2002; But cf. Estevez & Calvo, 2000).

The present study was designed to examine the activation of bridging and predictive inferences of high- and low-span readers under a single experimental setting, and to explore the various hypotheses suggested to explain the differences observed between the two span groups in inference generation. The following sections expand on the various WM hypotheses, which converge on the three main functions of working memory—storage, processing (or operation) and control (Baddeley, 2001; Engle, 2002; Just & Carpenter, 1992), and on the degree of specificity these hypotheses attribute to WM functions in

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inference generation.

1.1. Storage-oriented hypotheses: differences in information retention

Perhaps the most common theory regarding the role of WM in reading comprehension in general and inference generation in particular refers to the short-term retention of textual information during reading (Graesser, Millis, & Zwaan, 1997; Kintsch, 1998; van den Broek, 2010). According to this theory, WM enables the retention of prior textual ideas during the processing of current ideas. This concurrent maintenance of prior and current textual ideas is crucial for the identification of conceptual connections between them and the construction of a coherent text representation. In line with this theory, high-span readers, who have a greater capacity to maintain more textual ideas active in WM, generate more bridging inferences than low-span readers in order to establish connections between the ideas they retain in WM (Budd, Whitney, & Turley, 1995; Just & Carpenter, 1992; McNamara & O'Reilly, 2009; Schmalhofer, McDaniel, & Keefe, 2002; Whitney, Ritchie, & Clark, 1991; Yuill, Oakhill, & Parkin, 1989).

Consistent with this hypothesis, Whitney et al. (1991), using the think-aloud procedure, found that high-span readers generated coherence-based inferences later in the text than low-span readers. Low-span readers generated inferences earlier in the text, which were more speculative and elaborative in nature. They concluded that high-span readers could retain larger segments of text, and thus draw more reliable inferences than low-span readers. Yuill, Oakhill and Parkin (Oakhill & Yuill, 1986; Yuill & Oakhill, 1991; Yuill et al., 1989) showed that skilled comprehenders with higher working memory capacity identified (e.g., inconsistencies detection) and resolved (e.g., reference resolution) coherence gaps between non-adjacent textual ideas more efficiently than less skilled comprehenders with low working memory capacity.

The retention hypothesis was also suggested to explain the individual differences observed in the generation of elaborative inferences (Estevez & Calvo, 2000). According to this hypothesis, high-span readers allow themselves to generate more elaborate inferences than low-span readers, although these inferences are not crucial for text comprehension, because they have sufficient capacity to retain necessitated text information during reading with a lower risk of impairing comprehension. Some indirect support for this theory comes from studies that examined other aspects of reading comprehension. Just and Carpenter (1992), for example, found that high-span readers were better able to maintain a (temporary) irrelevant interpretation of sentences with syntactic ambiguity. Lee-Sammons and Whitney (1991), when examining the effect of reading perspective (i.e., reading a text on houses from a perspective of a home buyer or a burglar) on text memory, found that high-span readers recalled more perspective-irrelevant information than low-span readers.

1.2. Processing-oriented hypotheses: differences in information (re)activation

Studies have shown that high-span readers generate more coherence-based inferences than low-span readers, particularly when the yet-to-be-connected textual ideas were further apart in the text (Oakhill, Hartt, & Samols, 2005; Oakhill & Yuill, 1986; Singer et al., 1992). For example, Singer et al. (1992) examined the role of WM capacity in the generation of bridging inferences by using short narratives that included adjacent and non-adjacent pairs of sentences which required bridging information to clarify their connection (see Table 1). Using regression analysis, Singer et al. found that reading span predicted the answer accuracy observed for inference questions on the non-adjacent sentences, but not on the adjacent sentences. They concluded that high-span readers have more processing resources than low-span readers for the reactivation of prior textual ideas back into working memory, and thus generate more bridging inferences to connect these reactivated ideas with current ideas in focus.

Others have suggested that the amount of WM processing resources readers possess can explain the individual differences found in the generation of predictive inferences (Miyake, Carpenter & Just, 1994; Estevez & Calvo, 2000; Just & Carpenter, 1992; Linderholm, 2002; St. George et al., 1997). Linderholm (2002), for example, examined the generation of predictive inferences by high- and low-span readers, using two-sentence sequences which suggested a possible outcome in high, moderate or low probabilities, and a probe word which encapsulated the predicted outcome (see Table 2). Linderholm found that high-span readers were faster in naming the probes in the high-probability condition compared to both moderate- and low-probability conditions, while low-span readers did not show any differences in naming times across probability conditions. She concluded that the activation of predictive inference depends on the amount of activation spread from textual ideas (i.e., text probability constraints) and the amount of activation (WM) resources available for the reader. High-span readers can activate optional information such as predictive inferences, which are less constrained by textual ideas (Yeari & van den Broek, 2015) and are consequently less accessed by readers during reading (Estevez & Calvo, 2000; St. George et al., 1997), because they have more processing resources than low-span readers for the activation of this unnecessary information.

Several researchers adopted the hypothesis that high- and low-span readers differ in their ability to (re)activate information from prior text or background knowledge, but explained this difference from a different perspective. According to their view, high- and low-span readers do not differ in the amount of WM resources they possess, but rather in the efficiency with which they utilize their WM resources to (re)activate information back to WM (e.g., Case, Kurland, & Goldberg, 1982; Cowan, 1988; Daneman & Carpenter, 1980; Engle & Marshall, 1983; Ericsson & Kintsch, 1995; McNamara & O'Reilly, 2009). In particular, McNamara and colleagues (McNamara & Kintsch, 1996; McNamara & O'Reilly, 2009; McNamara & Scott, 2001; McNamara et al., 2007) suggested that high-span readers have an enhanced access to long-term memory and more efficient retrieval processes than low-span readers, because they possess more elaborated knowledge (i.e.,

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<tr>
<th>Table 1</th>
<th>A text-questions example from Singer et al.'s (1992) study.</th>
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<tbody>
<tr>
<td>Text</td>
<td>Carol was getting very irritated. She forgot about the meat she was broiling. (Non-adjacent first sentence) Carol heard the dog barking upstairs. Somewhere a bird had gotten trapped in the bathroom. She released the creature and trudged back down. Smoke was pouring from the oven. (Non-adjacent second sentence) Carol wondered what could happen next. Then she found that the milk was three weeks old. (Adjacent first sentence) The smell turned her stomach. (Adjacent second sentence) She threw everything out and went to McDonald's.</td>
</tr>
<tr>
<td>Inference questions</td>
<td>Did the meat burn? (Non-adjacent bridging inference) Was the milk sour? (Adjacent bridging inference)</td>
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<tr>
<th>Table 2</th>
<th>A text-probe example from Linderholm (2002).</th>
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<tr>
<td>Text</td>
<td>Patty bit into the apple, then stared at it. High prediction probability It had half a worm in it. Moderate prediction probability It had an unpleasant taste. Low prediction probability It had little flavor.</td>
</tr>
<tr>
<td>Probe word</td>
<td>SPIT</td>
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