



Cortical systems for local and global integration in discourse comprehension

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ABSTRACT

To understand language, we integrate what we hear or read with prior context. This research investigates the neural systems underlying this integration process, in particular the integration of incoming linguistic information with local, proximal context and with global, distal context. The experiments used stories whose endings were locally consistent or locally inconsistent. In addition, the stories' global context was either relevant or irrelevant for the integration of the endings. In Experiment 1, reading latencies showed that the perceived consistency of an ending depended on its fit with the local context, but the availability of a relevant global context attenuated this effect. Experiment 2 used BOLD fMRI to study whether different neural systems are sensitive to the local consistency of the endings and the relevance of the global context. A first analysis evaluated BOLD responses during the comprehension of story endings. It identified three networks: one sensitive to consistency with local context, one sensitive to the relevance of the global context, and one sensitive to both factors. These findings suggest that some regions respond to the holistic relation of local and global contexts while others track only the global or the local contexts. A second analysis examined correlations between BOLD activity during listening of the story endings and subsequent memory for those endings. It revealed two distinct networks: Positive correlations in areas usually involved in semantic processing and memory for language, and negative correlations in sensory, motor, and visual areas, indicating that weaker activity in the latter regions is conducive to better memory for linguistic content. More widespread memory correlates were found when global context was relevant for understanding a story ending. We conclude that integration at the discourse level involves the cooperation of different networks each sensitive to separate aspects of the task, and that integration is more successfully achieved when the processing of potentially distracting information is reduced.

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Introduction

Discourse comprehension is a process of progressive meaning construction that entails dynamic integration of incoming information with local, proximal context and with global, distal context (Kintsch, 1988, 1998). The local context is the most recently encountered information, and the global context is information introduced earlier. While reading or listening to a story, for example, people treat as local context for an incoming sentence information introduced in the prior one or two sentences, and treat as global context information introduced in earlier portions of the text (e.g., Albrecht and O'Brien, 1993; McKoon and Ratcliff, 1992).

Psychological theories of discourse comprehension, drawing on behavioral evidence and computational models, have often highlighted the importance of understanding how the balance between integrating local and global information is reached at the cognitive level. Theories differ in their view of the mechanisms and situations that bring global contexts to the integration process, but all agree that

incoming information is always integrated with local information and with some portions of the global context (for a review, see McNamara and Magliano, 2009). Thus, local integration is considered to be the default process in discourse comprehension, because local information is always available in working memory. The possibility for global integration, however, is determined by potential access to distal, less-recently encountered information in working memory at the time integration occurs. This access depends on the extent to which features of the incoming information function as memory cues for distal information, and on the extent to which certain types of information (e.g., time, space) are continually monitored and kept active (Gerrig and O'Brien, 2005; McNamara and Magliano, 2009; Zwaan and Radvansky, 1998). Our goal in this paper is to understand how distal, global context modifies the integration of incoming information with proximal, local context.

The current study presents the first examination of the neurobiological networks mediating local and global integration during comprehension. To date, neuroimaging studies of discourse comprehension have not examined these two types of integration separately. They have either only examined local integration, or they have not distinguished between contexts requiring local and global integration. These studies

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have identified general activity patterns associated with comprehending passages as compared to rest (e.g., [Kansaku et al., 2000](#); [Papathanassiou et al., 2000](#)), to reversed speech (e.g., [Crinion and Price, 2005](#); [Crinion et al., 2003](#); [Kansaku et al., 2000](#)), and to unconnected sentences (e.g., [Xu et al., 2005](#); [Yarkoni et al., 2008](#)). Other studies have examined coherence breaks in discourse, where the distance between the critical sentence and the text that created the coherence break was either small within the local context ([Hasson et al., 2007](#)) or was not controlled ([Deen and McCarthy, 2010](#); [Ferstl et al., 2005](#)). While all these methodologies certainly highlight central features of discourse integration, they were not designed to investigate the neural activity associated with local and global integration separately.

Those neuroimaging studies that have focused on distinguishing between local and global integration have used the term global integration in a different sense than we do here—not in terms of integration with prior linguistic content provided in the text, but as integration with general prior knowledge stored in long-term memory ([Maguire et al., 1999](#); [Martín-Loeches et al., 2008](#); [Menenti et al., 2009](#); [St George et al., 1999](#)). Most of these studies followed a classic paradigm in psycholinguistics ([Bransford and Johnson, 1972](#)): Participants read an ambiguous passage which was preceded or not by an explanatory context in the form of either a title or a picture ([Maguire et al., 1999](#); [Martín-Loeches et al., 2008](#); [St George et al., 1999](#)). The passages used in those studies were difficult to understand, to the point that even local consistency was disrupted when the explanatory context was not given (e.g., *Once you are settled, your thumbs should be pointing up. Sometimes there is no security but the animal's hair*; [Martín-Loeches et al., 2008](#); [St George et al., 1999](#)). These studies too, in most cases, did not examine local and global integration (as we intend it) separately. Both global and local coherence were either totally disrupted when no framing title or picture was given, or both could be achieved when the general topic was disclosed in advance. Thus, the processes of global and local integration were overlapping and the brain regions associated with the two processes could not be assessed separately.

Thus, prior work has left open the fundamental question of whether integration of incoming sentences with local and global contexts involves a network mediating integration with both kinds of contexts, or whether the integration with local and global contexts relies on partially different systems. To address this issue, we devised a paradigm that kept local and global contexts distinct so that it would be possible to differentiate their relation to incoming information and identify the brain regions associated with local and global integration separately. To this end, we created narratives that could have four versions (see [Fig. 1](#) for an example). The first few sentences of each story formed

the global, distal context, and the last few sentences the local, proximal context for a final sentence, which was the critical test sentence. This ending sentence was manipulated to always be either consistent or inconsistent with the local context. Independently, the global context was manipulated in a way that best allowed testing the impact of distal information on the integration process: It was either irrelevant or relevant for the integration of the ending. When the global context was irrelevant, its presence in the story had no impact on the integration of the endings, and local consistency was the only determining factor, because the integration of the ending depended solely on the local context. However, when the global context was relevant, there was always a possibility for consistency: The ending that was inconsistent with the local context was in this case consistent with the global context. Conversely, the ending that was consistent with the local context became inconsistent with the global context. The rationale for creating a situation of conflict between the demands of the local and global contexts was to dissociate their impact on the integration process. This opposition was crucial, as it allowed us to test how the global context can prevail on the requirements of the local context when it is informative during the integration of the endings.

The logic of our design shares commonalities with ERP studies on discourse comprehension that measure detection of inconsistencies as modulations of the N400 effect. These studies examine contextual factors that have direct bearing on meaning construction of a sentence and test whether global context can override integration constraints at the sentence level. For example, the word *slow* in the sentence *Jane told her brother that he was exceptionally slow* evokes a greater N400 than *quick* in *Jane told her brother that he was exceptionally quick* if the sentence is presented after a context in which the brother is described as being quick. This occurs even though at the sentence level both adjectives are equally coherent ([van Berkum et al., 1999, 2003](#)). Analogously, other studies have shown that different features of global discourse context can outweigh the detection of semantic violations within a sentence and elicit smaller N400 for words that match the global but not the sentence context (e.g., [Nieuwland and Van Berkum, 2006](#)). More generally, these ERP studies show that several aspects of the global context can modulate word-by-word incremental integration as indexed by the amplitude of the N400 (for a review, see [Hagoort and van Berkum, 2007](#)). Our own research has also shown that the N400 peak latency is delayed when understanding the implication of a story ending requires global (as opposed to sentence) integration ([Egidi and Nusbaum, 2012](#)).

The design of the current research, which strongly opposed local and global integration, allowed us to identify three functional networks:

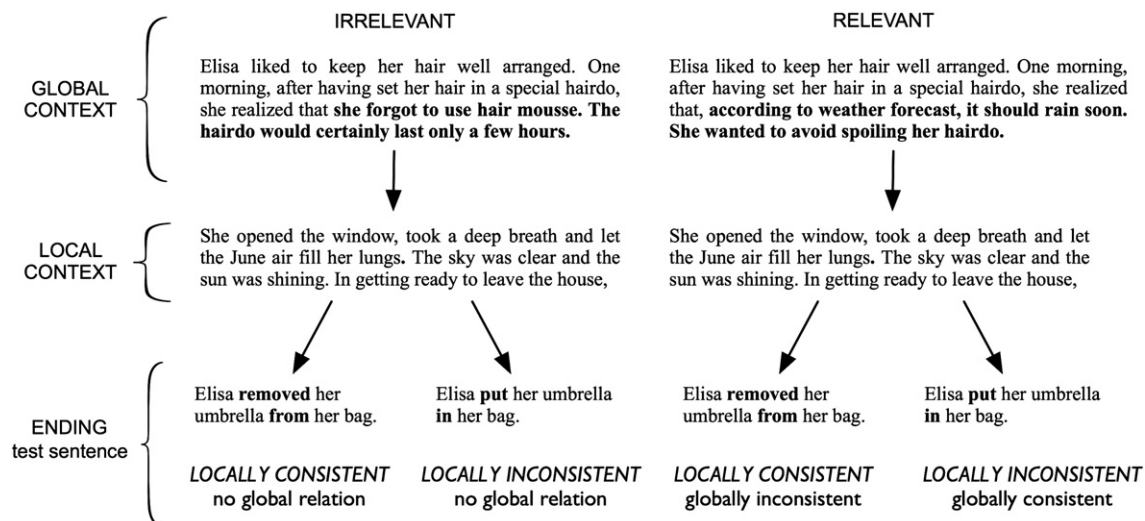


Fig. 1. Example of stimulus and design structure. Sample story used in the experiments and schematic of the experimental conditions.

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