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The nature of working memory capacity in sentence comprehension: Evidence against domain-specific working memory resources ☆

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Abstract

This paper reports the results of a dual-task experiment which investigates the nature of working memory resources used in sentence comprehension. Participants read sentences of varying syntactic complexity (containing subject- and object-extracted relative clauses) while remembering one or three nouns (similar to or dissimilar from the sentence-nouns). A significant on-line interaction was found between syntactic complexity and similarity between the memory-nouns and the sentence-nouns in the three memory-nouns conditions, such that the similarity between the memory-nouns and the sentence-nouns affected the more complex object-extracted relative clauses to a greater extent than the less complex subject-extracted relative clauses. These results extend Gordon, Hendrick, and Levine's (2002) report of a trend of such an interaction. The results argue against the domain-specific view of working memory resources in sentence comprehension (Caplan & Waters, 1999).

Keywords: Working memory; Sentence comprehension; Domain specificity

Introduction

A major question in cognitive science concerns the nature and the functional organization of the working memory system. In psycholinguistic research, this question has focused on investigating the nature of the working memory resources underlying language processing. More generally, the question of the functional organization of the working memory system is relevant to the modularity debate (Fodor, 1983), which is aimed at understanding whether there exist cognitive modules—subserved by highly specialized neural structures—dedicated to specific cognitive functions [e.g., linguistic knowledge representation (e.g., Chomsky, 1986), face perception (e.g., Kanwisher, McDermott, & Chun, 1997), musical processing (e.g., Peretz & Hyde, 2003; McDermott & Hauser, in press)], or whether our cognitive system is more domain-general in nature, such that the same neural/cognitive resources are used for multiple cognitive functions.

Earlier research has suggested that different pools of working memory resources are used for processing visuo-spatial information and verbal information (e.g., Baddeley & Hitch, 1974; Baddeley, 1986; Hanley,

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Young, & Pearson, 1991; Jonides et al., 1993; Shah & Miyake, 1996; Vallar & Shallice, 1990. Caplan & Waters (1999) have hypothesized that the verbal working memory pool can be further divided into two sub-pools: (1) verbal working memory for linguistic processing; and (2) verbal working memory for non-linguistic verbally-mediated cognitive tasks. In contrast, other researchers (e.g., Just & Carpenter, 1992; King & Just, 1991) have argued that linguistic processing and non-linguistic verbally-mediated cognitive tasks rely on the same pool of verbal working memory resources. This paper attempts to empirically evaluate these alternatives.

Two approaches have been traditionally used to address the question of working memory resources used in on-line linguistic processing: (1) an individual-differences approach, and (2) a dual-task approach. In the individual-differences approach, participants are divided into two or more groups on the basis of their performance on some form of a verbal working memory task and tested on linguistic structures of varying syntactic complexity. In the dual-task approach, on the other hand, participants perform two tasks simultaneously: (1) on-line sentence processing, and (2) a non-linguistic verbally-mediated task. The underlying assumption of the two approaches is that syntactic complexity should interact with group-type or with the difficulty of the secondary task, respectively, only if the non-linguistic verbally-mediated task and on-line linguistic processing rely on the same pool/overlapping pools of verbal working memory resources.

King and Just (1991) and Just and Carpenter (1992) provided suggestive evidence in support of the same resource pool/overlapping resource pools hypothesis.[1] This evidence consisted of differential behavior of low- and high-span readers, classified using Daneman and Carpenter's (1980) reading span task, in the processing of syntactic structures of low and high complexity (subject- vs. object-extracted relative clauses). However, Caplan and Waters (1999) noted that the required statistical analyses—interactions between group-type, syntactic complexity, and sentence region—were not reported, and the qualitative pattern of the reported data did not support the overlapping resource pools hypothesis. Furthermore, Caplan and Waters attempted to replicate King and Just's and Just and Carpenter's results using a variety of methods and large subject pools, and were not able to demonstrate the required interactions, nor were there any suggestions of such effects.

Waters and colleagues (Waters, Caplan, & Hildebrandt, 1987, 1995) also tested the overlapping resource pools hypothesis by conducting a series of experiments using a dual-task approach where subjects were asked to perform self-paced reading/listening while maintaining a memory load (usually, a string of digits). No on-line interactions or suggestive trends between syntactic complexity and memory load were found in any of the experiments. Waters et al. interpreted their results as supporting the hypothesis whereby there is an independent pool of verbal working memory resources dedicated to on-line sentence processing (for a more complete review of the studies outlined above, see Caplan & Waters, 1999). In addition to the individual-differences studies and the dual-task experiments, Caplan and Waters (1999) reported some data from neuropsychological studies conduced with various patient populations. These data are interpreted as providing further support for the idea of an independent pool of verbal working memory resources for on-line linguistic processing (see Caplan & Waters, 1999, pp. 87–92).

It is worth noting that there have been several reports of off-line interactions between syntactic complexity and memory load in the literature. For example, Waters et al. (1987) and Waters and Caplan (1996) found that syntactic complexity had an effect on the number of sentence-final words recalled in a sentence-acceptability-judgment task. Similarly, Wanner and Maratsos (1978) used a task where sentence presentation was interrupted by a list of words, which had to be recalled at the end of the sentence. They reported poorer word recall performance in more complex object-extracted relative clauses, compared to less complex subject-extracted relative clauses. Caplan and Waters (1999) used two different lines of argumentation to show that the off-line interactions observed in some of the previous experiments are still consistent with the idea of an independent pool of verbal working memory resources dedicated to on-line sentence comprehension. First, they made a distinction between interpretive (on-line) and post-interpretive (off-line) processes, which are involved in sentence comprehension. Interpretive processing, according to Caplan and Waters, involves the "extraction of meaning from a linguistic signal" (p. 79), whereas post-interpretive processing involves using this extracted meaning to accomplish tasks, like reasoning, planning actions, and storing information in long-term semantic memory. Caplan and Waters then argued that the off-line interactions observed between linguistic processing and non-linguistic verbally-mediated tasks do not directly address the question of an overlap in verbal working memory resources, because post-interpretive processing (used in off-line tasks) involves a variety of cognitive processes beyond linguistic processing. Second, Caplan and

[1] In fact, Just and Carpenter (1992) argued for a capacity-constrained comprehension model, where on-line language processing and non-linguistic verbally-mediated tasks rely on the *same* pool of resources. However, using the individual-differences approach and the dual-task approach, it is logically impossible to determine from the observed interactions the extent of the overlap—partial vs. complete—between the verbal working memory pools used for linguistic processing and other non-linguistic verbally-mediated tasks.