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Short Paper I

Summary and Discussion of Fedorenko, Gibson & Rohde 2004

In *The Nature of Working Memory in Syntactic Processing and Beyond*, Fedorenko, Gibson & Rohde (2004; henceforth FG&R) add a new perspective to the debate over working memory, in particular the question of whether the WM resources associated with syntactic processing are distinct from those supporting other verbally-mediated tasks. Studies such as Caplan & Waters (1999) have reported evidence in support of the separate-pool hypothesis. However, the dual-task experiment conducted by Gordon, Hendrick & Levine (2002) returned evidence of interference between syntactic processing and the maintenance of a wordlist in memory, supporting the theory that these two tasks draw on the same WM resources. FG&R revisits the Gordon et al. study and expands on their results, returning a significant online effect where Gordon et al. reported only a trend (along with a significant effect on offline processing). In a second experiment, FG&R further investigate the relationship between mental load and sentence processing by replacing the memorized wordlists with a mental arithmetic task. A significant interaction between syntactic and arithmetic complexity was reported, again supporting the shared-resource hypothesis. Finally, FG&R provide evidence against a potential competing analysis, the attentional account, by demonstrating that a task with no verbal component, namely spatial rotation, failed to exhibit any interaction with the processing of syntactic complexity. FG&R complete their study by proposing a new architecture of WM resources, which I will discuss below.

The experiment conducted by Gordon et al. investigated the effect of holding a short list of words in memory while processing sentences of differing syntactic complexity (subject- versus object-extracted clefts). To manipulate memory load, they distinguished between a match condition, where the words in the list were of the same NP type as nouns in the sentence, and a nonmatch condition. It was predicted that retrieval of the trace of a linguistic antecedent in the match condition would be subject to interference due to the existence of a similar trace associated with the wordlist. Gordon et al. reported a significant interaction between match and cleft type in subjects' ability to answer comprehension questions about the sentences they read. However, in the case of on-line processing of sentences, indicated by reading times, the interaction fell short of significance in their data. In general, though, the results reported by Gordon et al. were consistent with the claim that syntactic processing and general verbal memory draw on a single shared pool of mental resources.

The first experiment reported by FG&R replicates the Gordon et al. study with a few modifications. Of these, the most significant was probably the addition of a new variable, memory load, which was controlled by manipulating the number of word items held in the memory list. It seems a good idea to control memory load directly instead of relying exclusively on the influence of matching as in Gordon et al., given that our understanding of the role of match conditions in linguistic processing is still somewhat unclear. Unlike Gordon et al., FG&R do not report a significant interaction between syntactic complexity and match in the subjects' ability to answer offline comprehension

questions about the sentences they read. It is pointed out that this difference might actually be attributable to the order in which tasks (such as list recall and comprehension questions) were presented to the subject, and it might be interesting to repeat FG&R's Experiment I with the opposite order for these tasks. However, the more important result reported by FG&R was a significant interaction between match and online sentence processing, revealed by reading time. This effect was manifested as a greater difference in processing time between subject- and object-extracted relative clauses when the NPs in the sentence were matched to the wordlist. The results reported by FG&R provide substantial evidence against the claim that separate pools of WM resources exist to support on-line sentence processing and general verbal memory.

In their second experiment, FG&R repeated the dual-task experiment but replaced the wordlist with an on-line task of simple arithmetic addition. The variable of NP match was eliminated, making it possible to manipulate and assess the effects of memory load more directly. Contrasting simple addition tasks with more difficult tasks involving larger values and addends, FG&R found that reading time was significantly influenced by both syntactic complexity and mathematical difficulty. More importantly, these two factors interacted such that the effect of syntactic complexity on reading time was greater in the context of the harder math task. This evidence again strongly supports the claim that sentence processing and other verbally-mediated cognitive tasks, including math problems, draw on the same WM resources.

In the third and final experiment, FG&R addressed a possible alternative to the shared-resources analysis that has been suggested in accounts such as Caplan & Waters 1999. In the proposed analysis, mental resources are used up relative to the need to shift attention back and forth between two tasks; under more complex conditions, it is possible that a switch in focus might tax the system more heavily. Thus, it is conceivable that the apparent interaction between syntactic complexity and other verbally-mediated processing could be explained without invoking a shared pool of WM resources. To assess this alternative, FG&R designed a situation in which linguistic processing is undertaken simultaneously with a task that lacks a verbal component—in this case, subjects performed a summation over segments of a circle, an exercise involving visuo-spatial rotation. If we assume that the processing cost of a task is determined by switches in attention, we would expect the spatial rotation task to pattern just like the arithmetic task in Experiment II. By contrast, if the use of WM resources is the determining factor, we predict that the verbally-mediated mathematical task should exhibit more interference than the nonverbal task of spatial rotation. In fact, FG&R's results were consistent with the latter prediction: there was not even a suggestion of interaction between the difficulty of the rotation task and the ability to process syntactic complexity. This result goes against the attention-switch analysis of resource use and instead supports the claim that all verbally mediated processes, unlike nonverbal processes such as spatial rotation, fall under a single pool of WM resources. The third experiment thus offers further support for the results and analysis of the first two experiments.

The results of the third experiment appear to be very clean and consistent with our expectation from the proposed theory. In spite of this, I did have a few questions about the procedure employed in the spatial rotation task. My primary concern is that not all subjects will take a purely nonverbal approach the spatial rotation task. In my own subjective experience, I am aware of relying on significant verbal mediation to perform

such a task (segments of the circle are given verbal labels such as “about 45 degrees,” “slightly more than half the circle,” etc.). Again, the fact that no interference with syntactic processing was detected does offer a strong indication that verbal mediation of this type was not a factor for the subjects tested; still, I thought it was worth noting as a hypothetical source of what could be significant problems for the present analysis.

As a general conclusion, the experiments conducted by FG&R demonstrated that verbal and mathematical tasks interact with on-line syntactic processing, while tasks of spatial manipulation do not. It can accordingly be concluded that the first two share one WM resource pool, while the last is processed separately. In the final segment of the paper, FG&R suggest possible implications of these findings for our understanding of the overall architecture of the WM system, specifically offering a unified account of interference phenomena in mathematical and linguistic processing. Previously, we saw a specific account of the interference created by a memorized wordlist during sentence processing, where a word in memory can interfere with the retrieval of a linguistic antecedent to a degree proportional to the similarity between the items. FG&R then offer a parallel analysis of interference in mathematical computation. If we assume that numbers are converted to a mental number line and represented via the distribution of activation patterns, a greater distance between two numbers entails a larger set of intervening numbers, which will create more significant interference. Thus, the unified analysis holds that the difficulty of integrating a new element is proportional to its distance away from the attachment site, with distance measured in terms of intervening elements of a similar type. Under this analysis, it is possible to move away from the traditional distinction between verbal and visuo-spatial processing; FG&R instead suggest that the crucial characteristic of the processing of sentences and math problems is the discrete and sequential nature of their input. Since visuo-spatial tasks tend to be non-sequential in nature, this new distinction largely overlaps with the more standard verbal versus visuo-spatial dichotomy. The role of discreteness in the proposed architecture is not as well-explicated and may merit further discussion.

On the whole, while I find the new WM architecture entirely plausible, I would be interested to see more explicit discussion of why it should necessarily replace the traditional scheme. In particular, I was curious as to how the properties of sequentiality and discreteness appear in populations with disordered verbal capacity. For me, the discussion of manipulation of numbers as discrete, sequential units called to mind the condition of certain aphasics whose impairment in number retrieval is such that they can only utter a particular target number by first counting out all the numbers leading up to the target. For such patients, an addition problem involving two distant numbers would most certainly take longer than a problem involving two closer ones. I do not know whether experiments along these lines have already been undertaken, or if they would be useful if conducted, but I would be interested to learn more about the performance of these aphasics on tasks involving different areas of the architecture suggested by FG&R. For instance, to what degree is their arithmetic ability impaired? Would they be better at problems involving estimation or spatial problems than those requiring pure computation? The new architecture suggested by FG&R thus raises a number of interesting questions for further investigation. In any case, their study provides clear evidence supporting the view that the WM resources for sentence processing and other tasks such as mental arithmetic are indeed held in common.