standing, one may wonder to what extent Ruchkin and colleagues are targeting something of a straw man here. For example, in recent years there has been a trend for working-memory researchers themselves to conceptualise this capacity more as a process than a set of distinct task-specific stores. These researchers have raised important questions regarding the role of rehearsal in transferring mnemonic information from short-term memory (STM) to long-term memory (LTM), and to observed temporally-mediated differences in the recency effect of serial recall. Furthermore, the distinction between phonological (STM) and semantic (LTM) processing has been challenged by consideration of the processes underlying capacities such as sentence comprehension.

From a different perspective, Ruchkin et al.'s neurologically informed analysis is timely; that is to say, it agrees with some contemporary evaluations of the functional properties of working memory offered by cognitive researchers such as Gordon Brown (cf. Brown 2002; Brown et al. 2000; Neath et al. 1999), as well as by neuropsychological researchers, including Morris Moscovitch and Gordon Winocur (the latter articulating concepts such as "working with memory" in the 1990s; cf. Moscovitch & Winocur 2001). It has been suggested by some recent cognitive researchers, for example, that the demonstration of a working-memory recency effect occurring across different time spans relates to the use of working-memory "scanning," which depends (at least in part) on the exact relationship between items of target information and the background from which they must be discriminated.

Ruchkin et al. raise an important point regarding the claim by Baddeley (2001a) that construing short-term memory as activated long-term memory is inconsistent with neuropsychological data. Furthermore, patients may also show dissociations within the domain of STM; that is, there are demonstrated selective cases of impaired verbal versus visuospatial STM (Basso et al. 1982; Hanley et al. 1991).

There is also some evidence that visual (as distinct from visuospatial) STM can also be selectively impaired (e.g., Davidoff & Ostergaard 1984; Warrington & Rabin 1971), and that phonological and lexical STM deficits may be separable (Martin et al. 1994).

Long-term memory is sometimes preserved in these individuals with STM deficits (e.g., in Warrington & Shallice's (1969) patient, KF, with selective auditory verbal STM loss). Indeed, this is the kind of evidence that has been adduced by researchers such as Baddeley (2001a). However, consistent with the views articulated by Ruchkin et al., the widely held view regarding selective STM loss in some neuropsychological patients has been called into question in situations in which the STM and LTM tests tap into the same type of information (e.g., Baddeley et al. 1988; Hanley et al. 1991), with suggestions that there is, in fact, evidence of serial processing from STM to LTM. Mayes (2000) argues that LTM probably is only selectively preserved when it taps different information from that affected by a STM disorder.

The views articulated by Ruchkin et al. offer significant heuristic value. Indeed, as indicated in the previous paragraph, what may now be emerging in the memory literature is the breakdown of the old primary-STM-WM/secondary-LTM distinction, with an emphasis instead on *function* and *process* (see, e.g., Toth & Hunt 1999; "Not one versus many, but zero versus any"). On a related theme, Roediger et al. (1999) have articulated a component-processing framework of memory, whereas Gordon Brown (personal communication) has provided considerable food for thought in recent years by modelling the diversity of memory phenomena in terms of potentially common processes across previous structural divisions. In conjunction with Gordon Brown, my colleagues and I working in Western Australia have demonstrated that working-memory capacity may also be affected in a selective hippocampal patient with profound long-term memory deficits. More specifically, this patient's poor performance on the primacy portion of serial recall appears to be a result of the fact that (in contrast to controls) he does not rehearse items in working memory when he is encouraged to do so. This may be an informative observation with respect to the framework articulated by Ruchkin et al.

There are some elements of the framework proposed by Ruchkin et al. in which further information would have been useful in order to evaluate the model's explanatory value. For example, when stating that "long-term memory systems in posterior cortex are initially activated for the processing of incoming information" (target article, sect. 5, para. 1), it would be useful to know explicitly whether these LTM systems are deemed to be semantic systems, episodic systems, or both. Or, indeed, whether a systems framework is embraced at all by the authors, and, if so, which one? (See Foster & Jelicic 1999, for a discussion of this complex question.) On the related theme of memory systems, to what extent are implicit, as distinct from explicit, memory representations drawn upon in mediating working-memory processes, according to this framework? Ruchkin and colleagues further state that "as stimuli are perceived and processed in posterior cortex, long-term memory codes are activated" (sect. 5, para. 2). Yet, there is considerable ongoing debate in the literature regarding the representational nature of these LTM codes.

More specifically, there is currently substantial debate regarding the significance of context in the neural representation of established memories. It would have been useful to know whether this is a relevant consideration for the kinds of posterior memory systems that are specified by Ruchkin and colleagues. On a related note, to what extent is the medial temporal lobe memory system deemed relevant in this model? The authors state,

> the neural systems that ultimately become the repositories of the consolidated long-term episodic memory for the novel information are initially active, with the hippocampus providing coordinate control. In this view, short-term episodic memory consists of well-consolidated and partially consolidated long-term episodic memories in an active state.

Yet, according to the conventional consolidation hypothesis, memories are "downloaded" from the hippocampus to the neocortex over time. If the hippocampus is considered relevant for the Ruchkin et al. framework, as appears to be the case, to what extent would it be possible to identify the involvement of this circumscribed brain region using an ERP methodology, given some of the localization issues that the authors themselves identify in the Appendix? To what extent, in this framework, is attention considered to be related to or distinct from memory rehearsal processes, specifically regarding the proposed role of the prefrontal cortex in subserving "attentional control." Are prefrontally-mediated mechanisms the only factors of consideration when evaluating the basis of short-term memory *capacity*, or may posterior cortical constraints be relevant as well (i.e., aside from those matters relating to working-memory decay specified by Ruchkin et al.). The authors state, "Recall and maintenance of episodic information involves activation of the binding circuitry; retention of novel episodic information involves the operation of binding formation and the initial consolidation process" (sect. 1.3). However, the significance of these statements is unclear as written, and further elaboration is required.

Missing the syntactic piece

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Abstract: The notion that the working-memory system is not to be located in the prefrontal cortex, but rather constituted by the interplay between temporal and frontal areas, is of some attraction. However, at least for the domain of sentence comprehension, this perspective is promoted on the basis of sparse data. For this domain, the authors not only missed out on the chance to systematically integrate event-related brain potential (ERP) and neuroimaging data when interpreting their own findings on semantic aspects of working memory, but also neglected syntactic aspects of working memory and computation altogether.

Ruchkin et al. argue that the so-called working-memory system is not a separate system located in the prefrontal cortex, but that the prefrontal cortex only provides the attentional pointer system for maintaining activation in posterior long-term memory systems. Although the idea that particular memory representations are not moved from posterior to frontal areas during active maintenance is compelling, the data presented in its support is unnecessarily sparse – at least for the domain of sentence processing.

The present commentary argues that a less speculative claim with respect to the functional specificity of posterior and frontal areas during sentence processing and retention could have been made if imaging data had been incorporated more systematically. When discussing the issue of sentence processing and working memory, Ruchkin and colleagues first choose to focus only on semantic aspects of sentence processing, rather than also taking into account syntactic parameters, and second, refrain from relating their own data on semantic parameters to available imaging studies.

Although the authors admit that sentence comprehension involves processes of semantic and syntactic binding, they consider the number of "propositions and the thematic role relations they express" (sect. 3.7, para. 2) and the semantic short-term memory processes thus drawn upon, to be of crucial relevance during language comprehension. This may well be the case when considering the *postsentence retention interval,* but not necessarily when considering *on-line sentence processing.* Rather, it appears that syntactic aspects of working memory are of major relevance during sentence comprehension, in particular when the sentence is syntactically complex. Thus, it has been shown that additional working-memory resources are necessary when comprehending syntactically complex compared to syntactically simple sentences, even when the number of propositions remains the same (Cooke et al. 2001; Fiebach et al. 2001; 2002). Syntactic working memory, in this context, can be operationalized as a function of the distance between two critical positions in a given sentence. In object-first sentences, for example, the object noun phrase (the "filler") is moved away from its original position in the sentence, leaving behind a trace (the "gap"). During on-line sentence processing the system first encounters the object noun phrase (filler), which, however, must be maintained in working memory until the original object position (gap) is encountered. A long filler-gap distance thus requires more syntactic working-memory resources than a short filler-gap distance. In an event-related brain potential study, Fiebach et al. (2002) demonstrated that a left frontal sustained negativity was observable between the filler and its gap, but not beyond the gap position. This finding suggests that it is syntactic working memory (i.e., maintaining the filler in working memory until its original position in the sentence is encountered) that involves left prefrontal areas. Note also that, in this study, the semantic content of fillers was minimal, thereby excluding the possibility that the sustained negativity reflects semantic aspects of maintenance. In a functional magnetic resonance imaging (fMRI) study (Fiebach et al. 2001) using similar materials, it was found that activation of the left inferior frontal gyrus, more specifically BA44 and BA44/45, varied as a function of syntactic working memory (distance between filler and gap). Interestingly, activation in the superior and middle temporal region also increased as a function of this factor. A further fMRI study used sentences of increasing syntactic complexity as induced by dislocated noun phrases that had moved only a small distance (Fiebach et al., in press). A parametric analysis indicated that the activation of BA44 selectively increased as a function of syntactic complexity, thereby suggesting that, although syntactic working memory may involve inferior frontal and temporal areas, BA44, in particular, holds responsible for aspects of syntactic complexity. The temporo-frontal network, including the superior and middle temporal gyri and BA44/45, in contrast, appears to support syntactic working memory. Within this network, the temporal areas most likely provide the knowledge-based identification of lexical and syntactic information, whereas frontal areas subserve the procedures operating over this knowledge (for a review, see Friederici 2002).

A similar view of a temporo-frontal network is proposed by Ruchkin et al. as the basis for short-term memory processes, when they claim that the "short-term memory process evidently depends in part on interactions between frontal and posterior cortex implemented by the operation of frontal-posterior projection loops" (sect. 3.7, para. 3). However, neither empirical evidence nor references are given to support their neuroanatomical statements concerning the projections between frontal and posterior regions. The main data set they base their claims upon is a study by Haarmann et al. (submitted) which is still under review and, therefore, unfortunately inaccessible in any greater detail at present. In this study, sentences containing related nouns were more easily processed than those containing unrelated nouns. For sentences containing related nouns, a sustained negativity over centro-posterior sites is reported, both during sentence processing and during retention. Unfortunately, however, the figure in which the activations for different brain regions are plotted (Fig. 10) only contains the activation for the sentences with the unrelated nouns, and therefore does not allow for a direct comparison of the effect of semantic relatedness on particular brain regions during sentence processing versus retention. As a key finding, the authors highlight their observation that a number of posterior areas were active both during sentence processing and retention. Figure 10, however, suggests that the right posterior middle temporal gyrus increases its activation systematically during the retention phase only. This seemingly contradictory finding is interpreted as being a result of hemispheric differences, with more fine-grained semantic processes in the left hemisphere being active during sentence processing and coarse semantic processes in the right hemisphere being active during retention. An alternative interpretation of the differential hemisphere involvement, which is moreover supported by a number of fMRI studies on sentence processing, is that on-line sentence processing requires more syntactic resources localized in the left hemisphere than retention of meaning (Dapretto & Bookheimer 1999; Friederici et al. 2003; Kuperberg et al. 2000; Newman et al. 2001, Ni et al. 2000). More generally, the observation that sentence comprehension involves a much greater degree of syntactic processing than retention, appears problematic for the authors' assumption that similar representations are activated during sentence comprehension and retention. Finally, the authors only loosely interpret activation in additional brain areas, without taking into consideration available fMRI findings. The right prefrontal cortex and left insular activation is not even functionally discussed, although the former area has been shown to reflect aspects of episodic memory (e.g., Dünzel et al. 1999; Wiggs et al. 1999), and the latter has been shown to increase as a function of retrieval effort (e.g., Buckner et al. 1996; 1998), two aspects worth considering in the present context.

In conclusion, we have identified two insufficiencies in the application of Ruchkin et al.'s approach to language comprehension. On the one hand, the authors only loosely relate their own findings to recent fMRI studies and, on the other hand, they disregard syntactic aspects of working memory and sentence comprehension altogether. This weakens their description of sentence processing and retention, though not their general view that the posterior and prefrontal cortex work together during working memory.