processing, the severity of these phonological processing impairments was not related to the severity of the verbal STM impairments for both phonological and lexico-semantic information, thereby showing dissociations between STM storage capacity and the integrity of language representations. Altogether, our results suggest that posterior temporo-parietal areas are specifically related to verbal STM processing and could play the role of a verbal STM buffer, while the results cannot be easily explained by reducing the involvement of these areas during verbal STM tasks simply to the activation of lexico-semantic knowledge. Similar claims have been made by Collette et al. (2001), Giraud and Price (2001), Grasby et al. (1993), and Wise et al. (2001).

To conclude, we argue that the data reported by Ruchkin et al., although consistent with their view of STM as an activated state of language representations stored in posterior brain regions, do not rule out the existence of a verbal STM buffer, which might also be sustained by posterior brain regions very close to those encoding LTM lexico-semantic representations.

Cognitive neuropsychological evidence for common processes underlying generation and storage of language representations

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Abstract: Ruchkin et al. offer a compelling case for a model of short-term storage without a separate buffer. Here, I discuss some cognitive neuropsychological data that have been offered in support of and against their model. Additionally, I discuss briefly some new directions in cognitive neuropsychological research that bear on the role of attention in Ruchkin et al.'s model.

Speaking and comprehending language take place over time. It is this temporal component of language processing that marks the intersection of memory and language systems. Research efforts have devoted much attention to revealing the organization of each system. The target article by Ruchkin et al. reflects more recent efforts to understand how these two systems are related cognitively and neurophysiologically. The authors provide important evidence supporting a model that attributes temporary storage of language representations to short-term activation of long-term representations without the necessity of a buffer to house the contents of short-term memory (STM).

Cognitive neuropsychological data have been an important source of arguments both for and against the separate buffer model. Evidence supporting an independent buffer comes mainly from case studies of individuals with impaired processing of multiple words in the context of good processing of single words, forming what appears to be a dissociation between word processing and storage systems (Shallice 1988; Vallar & Shallice 1990). The logic of this argument rests on the counter-intuitive assumption that a buffer stores only multiple word sequences. The postulation of a separate buffer is independent of assumptions about the contents of the buffer. Independent buffers are incorporated into models that assume only phonological representations in STM (Baddeley 1986), as well as those that assume short-term stores for all "levels" of linguistic representation (R. Martin & Lesch 1996).

Neuropsychological evidence also supports the model advanced by Ruchkin et al., in which linguistic representations activated during single- or multiple-word processing are maintained

by virtue of the same activation processes that enable activation and retrieval of the representations in the first place. My colleagues and I (Martin et al. 2000) have framed this relationship of language and short-term memory within an interactive activation model of word processing (Dell & O'Seaghdha 1992), with additional components that encode serial order of multiple word sequences (Gupta 1996). In this model, maintenance of activated representations is achieved by two parameters of spreading activation, its strength and its duration. Impairments of single- and multiple-word processing are viewed as disturbances of either or both of these parameters and are assumed to lie on a continuum of severity. Milder activation impairments allow for maintenance and successful processing of single words, but not multiple words, giving the appearance of a selective deficit of verbal short-term memory. More severe activation impairments lead to difficulty in maintaining activation of linguistic representations, even during performance of single-word language tasks, leading to what are typically described as aphasic deficits. In addition to severity of impairment, the ability to maintain activation of linguistic representations in the short term is dependent on the locus of impairment (e.g., semantic, phonological) and task demands.

This model has received empirical support, in part, from studies revealing systematic associations between linguistic and STM impairments (N. Martin & Saffran 1997; R. Martin et al. 1994). Numerous studies indicate that span performance in normal and impaired subjects is sensitive to linguistic variables, including phonological (e.g., Conrad 1964), lexical (e.g., Berndt & Mitchum 1990; Saffran & N. Martin 1990), semantic (e.g., R. Martin et al. 1994; Shulman 1971), and conceptual (e.g., Potter 1993; Saffran & N. Martin 1999) aspects of words. Additionally, in aphasia, span varies based on the nature of the task used to assess span, in conjunction with the nature of the language impairment (N. Martin 1999; N. Martin & Ayala, submitted). Finally, although long-term learning of language is unaffected by impairments affecting storage of phonological representations (e.g., Vallar & Baddeley 1984), it is disrupted in the case of semantic and semantic-STM impairments (N. Martin & Saffran 1990; 1999; Freedman & R. Martin 2001).

Demonstration of these associations is necessary, but not sufficient, evidence for a model that presupposes common processes underlying generation and temporary storage of language representations. Two additional avenues of inquiry provide more definitive support. First, studies of corecovery of word-processing and verbal-STM impairments (N. Martin et al. 1994; 1996) indicate that increased capacity to temporarily store words coincides with improved ability to retrieve words without error. Second, N. Martin & Gupta (2004) demonstrated a severity continuum between impairments of single-word and multiple-word processing, showing that performances on three measures of word processing (auditory lexical decision, picture naming, and word comprehension) correlated with auditory-verbal spans in a group of 50 individuals with aphasia, ranging from mild to severe. These recovery and severity continuum data are consistent with the model advanced by Ruchkin et al. and offer an alternative to the separate buffer model as an account of good single-word processing coupled with impaired multiple-word processing.

Ruchkin et al. propose that prefrontal attentional systems serve to coordinate the short-term activation of posteriorly represented linguistic representations. The role of attentional systems in the breakdown of language and STM functions in aphasia is a relatively recent area of investigation. A study by Hamilton and R. Martin (2002) provides relevant evidence. They demonstrated the presence of inhibition and proactive interference effects in span performance of an individual with aphasia-related semantic impairment, secondary to a lesion affecting the inferior frontal cortex. This is a promising line of research and illustrates, once again, that behavioural studies of impaired cognitive processes, such as language, STM, and attention, can provide important insights into the coordination of multiple systems that bear on performance of verbal tasks.

Historically, many cognitive neuropsychological studies have focused on identifying dissociations among components of cognitive systems, a trend especially evident in the study of verbal STM and language. Recent years have witnessed an increasing focus on the identification of mechanisms underlying cooperation between systems with seemingly different functions. Again, this shift has been especially apparent in the study of relations between verbal STM and language. In this context, it is exciting to consider the converging cognitive neuropsychological, electrophysiological, and imaging data, as reviewed by Ruchkin et al., and their implications for a coherent theory of the coordinated function of attention, short-term (or working) memory, and language processing.

Retention of order and the binding of verbal and spatial information in short-term memory: Constraints for proceduralist accounts

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Abstract: Consistent with Ruchkin and colleagues' proceduralist account, recent research on grouping and verbal-spatial binding in immediate memory shows continuity across short- and long-term retention, and activation of classes of information extending beyond those typically allowed in modular models. However, Ruchkin et al.'s account lacks well-specified mechanisms for the retention of serial order, binding, and the control of activation through attention.

We summarize grouping effects and evidence of verbal-spatial binding in serial short-term memory (STM) that broadly favor proceduralist over modular accounts, but note the limited specification in the target article of mechanisms enabling the retention of serial order, binding, and the control of activation.

Grouping phenomena and mechanisms for retaining items in order. Ruchkin et al. make scant reference to how items are retained *in order* in STM. Two recently proposed mechanisms for the retention of order are that the constituents of a sequence are associated with (a) temporal context provided by oscillators (e.g., Burgess & Hitch 1999), or (b) serial position markers (e.g., Anderson & Matessa 1997). Patterns of recall errors for grouped lists of verbal items (e.g., 123–456–789) favor the second of these alternatives (Ng & Maybery 2002; 2003). An item recalled out of order typically retains its within-group serial position when it transposes to another group (e.g., item 5 will take the position of item 2 or 8 rather than item 3 or 7), and this pattern of errors is not perturbed when serial position and temporal position are unconfounded (e.g., by doubling the rate of presentation of items in the second group relative to the rate for the other groups). Also, the timing of recall is sensitive to group structure, but not to the precise timing of items at presentation (Maybery et al. 2002). Thus, items do not appear to be coded for order using temporal context provided by oscillators. Rather, order appears to be carried by a hierarchy of position markers that code each item's position in a group, and each group's position in a list. This proposed hierarchy for representing order is compatible with Ruchkin et al.'s proceduralist account, inasmuch as the hierarchy structure is retained within semantic memory (Anderson & Matessa 1997).

Further, grouping of verbal sequences can be induced by discontinuities in pitch, location, or semantic category, as well as time (see Maybery et al. 2002), consistent with the interactive processing of multiple stimulus dimensions, rather than the dedicated processing of phonology. There is also evidence of a longer-term influence of the association of items with serial-position codes, in

that when an item from the preceding trial intrudes on the recall of the current list, it adopts a position in the current list that matches its position in the earlier list (Ng & Maybery 2002). Thus, the purported involvement of a semantic structure in representing order in grouped sequences, the influence of various stimulus dimensions in inducing grouping, and the retention of serial-position coding across trials, are features of this research broadly consistent with a proceduralist account.

Binding of different classes of information in STM. That verbal and spatial information can be represented independently is indicated by experimental (e.g., Farmer et al. 1986), neuropsychological (e.g., Hanley et al. 1991), and neuroimaging (Smith & Jonides 1997) dissociations. However, these studies almost invariably test verbal and spatial STM independently. Maybery et al. (2003) demonstrated that when test conditions force the concurrent encoding of sequences of verbal and spatial information, spatial STM "inherits" susceptibility to irrelevant speech, an effect otherwise isolated to verbal STM. This suggests that concurrent encoding results in binding of the verbal and spatial information. More direct evidence of binding comes from Clissa and Maybery (2003), in which STM for sequences of spatially distributed acoustic stimuli was tested. Recognition judgements were substantially faster when probe stimuli preserved the linkage of acoustic identity and spatial location established in the to-be-remembered sequences than when the probe stimuli consisted of repaired verbal and spatial features. This evidence of identity-location binding was found for nonverbal, as well as verbal, acoustic stimuli, and for retention intervals exceeding the persistence typically presumed for auditory sensory memory. These results suggest continuity between object-based perceptual processes and object-based STM that is consistent with proceduralist accounts, although Ruchkin et al. (2003) do not develop the idea that multimodal "object-focused" perceptual processes might propagate to STM. Their article also does not address precise mechanisms for binding multiple stimulus features. Engel and Singer (2001) suggested that temporal synchrony of neurons processing specific features of stimuli might define those stimuli as integrated events. This possibility should be set against the conclusion from the previous section: Memory for the order of a sequence of events does not appear to rely on the precise temporal coding of those events. It is possible that bottom-up mechanisms relying on temporal contiguity allow the binding of stimulus features into objects, but that the temporal order of these objects is regulated by top-down semantic-based mechanisms detached from any form of temporal signal. However, binding based on temporal synchrony may not provide a complete explanation of the pattern of "inheritance" of interference observed by Maybery et al. (2003). If verbal representations held in one posterior network are corrupted by irrelevant speech, why should this corruption extend to spatial representations held in another posterior network, when all that unites the verbal and spatial representations is their temporal synchrony?

Control of activation through a prefrontal attention mechanism. Perhaps stimulus features could be integrated into more global events or objects through the involvement of pointers maintained in prefrontal cortex, consistent with Ruchkin et al.'s position that a prefrontal attention mechanism based on pointers is used to selectively maintain information in posterior networks. However, what constitutes a pointer and how attention very selectively influences activation in posterior networks remain to be specified. A popular conceptualisation of working memory (WM) is that it provides the workspace for the generation of novel information – either entirely new elements of information or new associations between existing elements. The target article does not explain how there can be selective activation and arbitrary association of informational elements without an excessively elaborate addressing schema for prefrontal pointers, or conversely, how the intrusion into WM of vicarious elements activated through long-term associations is prevented. It will take some care to develop an adequate functional description of pointers while avoiding the charge of duplication levelled against modular models.