

VTE task, it seems indeed difficult to exclusively assign a purely rehearsal role to this region. In accordance with this, the classical view of Broca's area as a major structure for speech production has been re-evaluated by Murphy et al. (1997), who found no activation of the IFG during automatic speech tasks, either overtly or covertly. Then, building on different studies that have demonstrated the implication of the IFG in phonological tasks (e.g., Pol-drack et al. 1999) and in the observation and mental imagery of actions (Buccino et al. 2001), we hypothesize that the role of the IFG is that of an attentional matching system for action understanding, which is well adapted to a linguistic processing such as syllable parsing during the VTE.

In summary, these results are strongly consistent with the authors' view of working memory entailing, in one part, activation in posterior brain systems for percept formation and meaning determination and, in the other part, processing shifts away from posterior input-driven mental states to a frontal top-down mode for conscious and attentional maintenance of information during the retention phase. Furthermore, because the VTE provides some language equivalent of the ambiguous image paradigm in vision, it could lead to brainweb asymmetries similar to those displayed by Rodriguez et al. (1999) and mentioned in the target paper. For example, the preference in the VTE for words over nonwords (Pitt & Shoaf 2002) could be a result of a learning-based larger synchronization pattern, just as the preference for a meaningful visual stimulus over a meaningless one. In this context, it is not without interest to notice that the perceptuo-motor loop involved in the (mental repetition + transformation search) task we used in our study, could induce some intrinsic synchrony resulting from enaction per se. Indeed, in a complementary study (Sato & Schwartz 2003), we raised the assumption that in a sequence of sounds like [laIflaIflaIflaI] (repeating "life" over and over), the articulatory speech production system would naturally synchronize the production of the fricative "f," the liquid "l," and the diphthong "I" into a group [laI], while in the sequence [laIf] the "l" in onset and the "f" in coda are naturally desynchronized. Hence, we expressed the prediction that "life" should be more often transformed into "fly" than the other way round. This is indeed the kind of pattern we found, both in overt and covert repetition, in an equivalent contrast in French. In this paradigm, it is likely that phase transitions in dynamical systems possibly involved in the speech production process (Tuller & Kelso 1990) would enhance the potential synchrony of one pattern over the other one, both at the stimulus production level, and at the brain wave level.

In conclusion, the verbal transformation effect seems to provide a nice pivotal point between perception, decision, attention, imagery, and memory, to test some of the ideas quite convincingly expressed by the authors of the present target paper.

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NOTE

1. This result of the use of verbal working memory during verbal imagery is also consistent with previous studies of imagining speech by McGuire et al. (1996) and Shergill et al. (2001).

New data: Old pitfalls

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Abstract: Ruchkin et al.'s theoretical conclusions reflect two venerable fallacies. They confound an experimental paradigm with a theoretical concept, and they assume that features of the paradigm that are most readily detected by their methods provide an adequate account of the operation of the theoretical system. This results in a simplistic theory that does not do justice to the richness of the available data.

Some forty years ago, Melton (1963) published a classic paper in which he argued that the concept of short-term memory (STM) was unnecessary, because all available data could be explained in terms of long-term memory (LTM) processes. His paper performed two important services: the first was to present a convincing case for the position that many STM paradigms shared characteristics with LTM; the second was to demonstrate two pitfalls – by falling into them. The first, the nominalist fallacy, assumes that if a paradigm and a theoretical concept are given the same name, then all characteristics of that paradigm can be attributed to the concept. The second, the correlationist fallacy, is to further assume that any variable that is broadly correlated with performance on the paradigm is crucial to it. These shortcomings were pointed out by Waugh and Norman (1965), leading to their distinction between STM, a paradigm label, and primary memory, a theoretical construct, and to the parallel distinction made by Atkinson and Shiffrin (1968) between STM, a paradigm, and STS, a hypothetical store. Ruchkin et al. appear to be intent on repeating Melton's mistakes, although they refer to their nominal system as working memory (WM), and base their argument primarily on electrophysiological data.

Ruchkin et al. report a range of STM studies primarily focusing on electrophysiological activity occurring between the offset of stimulus presentation and subsequent delayed recall. In short, they focus on maintenance rehearsal, an important but not essential feature of the STM paradigm, and even less central to the much broader concept of WM.

Like Melton, they find similarities between data from STM and LTM paradigms, in their case, patterns of activation, which they assert are highly similar. This, they argue, differentiates their theory from the Baddeley and Hitch WM model, which they seem to assume postulates no role for LTM in the operation of WM. We do indeed reject the generalization that WM is activated LTM, not because of denying the role of LTM, but because such a view offers a simplistic answer to a complex question. LTM influences WM in a range of different ways that go beyond the concept of simple activation (Baddeley 2000; 2002).

Consider, for example, the phonological loop, perhaps the simplest component of WM. Baddeley (2002) assumes a role for LTM operating in at least three different ways. The first of these is reflected in the recency effect, which we suggest involves an active WM strategy applied to a passive priming process (Baddeley & Hitch 1993). Such priming may occur within any of a wide range of representations, from brief post-perceptual stores to long-term episodic, autobiographical, or semantic memory representations.

The second contribution of LTM concerns the role of implicit learning. Consider, for example, the immediate recall of letter sequences. Those that resemble the phonotactic structure of the rememberer's native language are consistently better retained over a brief interval than are less word-like sequences (Gathercole 1995). Although this is a powerful effect for recall, it is virtually absent when performance is tested by recognition (Gathercole et al. 2001), a result that can readily be fitted into the phonological loop model by assuming that the store itself is relatively immune to language habits, whereas the rehearsal mechanism is very language-sensitive (Baddeley 2001a). LTM is clearly important, but in a way that is richer and more complex than simple activation.

A third level at which LTM might influence utilization of the phonological loop concerns the application of conscious strategy. For example, participants tested on immediate memory for word sequences typically ensure that all their responses are real words, and are taken from the appropriate set. This process presumably depends on executive control of both semantic memory and episodic LTM. Simply detecting activity in some or all of the brain regions thought to underpin such LTM storage and control systems, however, adds little to our understanding.

This relates to my second concern, the correlational fallacy; this assumes that activity that clearly coincides with an STM paradigm must be responsible for the behaviour observed. Figure 4a in Ruchkin et al., for instance, shows one of the clearest of the elec-

trophysiological differences reported, namely that between retention of visually and verbally presented items. As Penney's (1989) review indicates, modality effects do occur in STM. Under most conditions, however, their magnitude is quite small and largely limited to an increased recency effect (Conrad & Hull 1968; Laughery & Pinkus 1966; Murdock 1972); this contrasts with phonological coding, which has a substantial and pervasive influence on verbal STM regardless of whether input is visual or auditory (Baddeley 1966a; Wilson 2001). It therefore seems likely that Ruchkin et al.'s interpretation of their modality effect reflects the correlational fallacy, being readily detected by ERP techniques, but having only a limited impact on memory performance.

Finally, Ruchkin et al. make much of the differences between my own approach and that of Cowan. In fact, our genuine differences are really quite small (Baddeley 2001b; Cowan et al. 2003). We both agree that activated LTM plays an important role in WM, but to do so requires the maintenance and manipulation of some kind of representation. I postulate the episodic buffer as a possible mechanism, whereas Cowan refers to holding "pointers" to activated LTM. To me, this seems too passive a concept to capture the creative manipulation capacity, which in my view, allows WM to serve as a workspace capable of both representing the past and planning for future action.

Working memory is a complex multifaceted system. By using a combination of techniques from cognitive psychology, neuropsychology, and neuroimaging, we have made progress in teasing apart its varied components. Electrophysiological methods offer a valuable additional tool, particularly for analyzing active processes such as maintenance rehearsal. Despite their technological sophistication, however, electrophysiological techniques, like other existing methods, provide a useful, but still rather blunt, instrument. For that reason, it is important to use them wisely, in combination with other methods, and with due regard to the theoretical pitfalls that have ensnared us in the past.

Tidying up sensory stores with supraordinate representations

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Abstract: In attempting to integrate the authors' proposed model with results from analogous human event-related potential (ERP) research, we found difficulties with: (1) its apparent disregard for supraordinate representations at posterior multimodal association cortices, (2) its failure to address contextual task effects, and (3) its strict architectural dichotomy between memory storage and control functions.

In support of their proposal, Ruchkin et al. rely mostly on human event-related potential (ERP) research with delayed matched-to-sample (DMS) task paradigms. In particular, scalp distributions of modality-specific ERP waves measured during the retention S1-S2 interval of DMS tasks are taken to support a common anatomical substrate of short-term (STM) and long-term memory (LTM) representations. In order to become a truly parsimonious – rather than an overly simplistic – explanation of working-memory retention mechanisms, the proposed model should be able to account for ERP results from other paradigms also involving short-term retention of information. Here we attempt to integrate the authors' views with recent ERP results from selective attention (Barceló et al. 2000a) and task-switching paradigms (Barceló et al. 2000b; 2002). Although our ERP results are partly consistent with the authors' proposal, we found difficulties with: (1) their relative disregard for supraordinate memory representations at posterior multimodal association cortices; (2) their failure to address con-

textual (i.e., prestimulus) task effects; and (3) their strict architectural dichotomy between memory storage and control functions.

There are some straightforward similarities between DMS and selective attention tasks. In a DMS task, memory representations for S1 need to be retained on-line for the 3 to 10 sec duration of a S1-S2 interval. Instead, in selective attention tasks, memory representations for target stimuli are to be retained for 3 to 10 min, the typical duration of a block of trials. In these tasks, the memory representations for target stimuli are called "attentional templates," as they are to be matched with all incoming stimulation for target selection. In line with the authors' proposal, this template-matching process involves prefrontal activation of modality-specific cortical regions devoted to the analysis and long-term storage of stimulus features. This process, however, can be further fractionated into a sequence of stages, each reflecting distinct interactions between higher- and lower-ordered memory representations leading to object identification. For example, both tonic and phasic top-down modulations contribute to the early analysis of target features (e.g., visual P1; Barceló et al. 2000b), although not all such modulations depend exclusively on prefrontal cortex (e.g., visual N1 to standards; Barceló et al. 2000b). Importantly, there is concurrent phasic activation of prefrontal and posterior multimodal association cortices after target identification (e.g., N2, P3b components; Barceló et al. 2000b). It is not clear how this multimodal posterior ERP activation may lend support to the authors' proposal.

Like DMS tasks, task-switching (TS) paradigms also require on-line maintenance of task-relevant information during a variable S1-S2 time interval. Yet these two task paradigms differ substantially in the level of abstract memory representations involved. For example, in a visuospatial DMS task, subjects need to apply just one fixed task-rule throughout (i.e., "if S1 equals S2, then y, else z"; where S1, S2 are exemplars of a given semantic or perceptual category, e.g., line orientation; whereas y and z designate different motor programs, e.g., go/no-go responses). In contrast, the S1 stimulus in a TS paradigm prompts subjects to update, maintain, and transform information about the current task rules (also, task set, attentional set, or task context), hence involving a higher class of supraordinate memory representations (i.e., "if S1 equals <shift>, then rule 2, else rule 1"; where rule 1, rule 2 denote two different task sets; i.e., rule 1 = "if S2 equals <vertical line> then y, else z"). In accord with the authors' proposal, one would expect enhanced neural activation at modality-specific cortical areas devoted to the sensory analysis of S1 features. On the contrary, in our TS paradigm we found enhanced ERP activation across a multimodal fronto-parietal network in response to S1 stimuli (e.g., involving both P3a and P3b responses; Barceló et al. 2002). Admittedly, a shift S1 cue prompts for both the updating and reconfiguration – not mere retention – of contextual task information in working memory. In addition, memory retention and consolidation of individual task rules can be examined over a series of nonshift trials. A gradual post-shift build-up in the amplitude of endogenous ERP responses to target S2 stimuli was observed across nonshift trials. Such a steady enhancement mostly affected the target P3b response, and was attributed to a gradual strengthening and consolidation in memory of the recently established task-rule. These results from TS paradigms emphasize the importance of context-dependent supraordinate memory representations (i.e., task-rules) in accounting for target-related ERP effects in working memory tasks (Barceló et al. 2000b; 2002).

With their emphasis on modality-specific ERP effects from DMS tasks, Ruchkin et al. might overlook the relative importance of multimodal memory representations in a variety of working-memory processes. For example, it has been proposed that clusters of multimodal rule-coding neurons in prefrontal cortex may combine subsets of feature-coding neurons to allow for rapid shifts of activation across entire sets of posteriorly-distributed sensory memory representations (Dehaene & Changeux 1995). In general, such a type of multimodal memory representation is con-