The short-term/long-term memory distinction: Back to the past?

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Abstract: The view that short-term memory should be conceived of as being a process based on the activation of long-term memory is inconsistent with neuropsychological evidence. Data from brain-damaged patients, showing specific patterns of impairment, are compatible with a vision of memory as a multiple-component system, whose different aspects, in neurologically unimpaired subjects, show a high degree of interaction.

In the late 1960s, neuropsychological evidence showing that brain damage may bring about selective patterns of memory impairment, closely mapping onto current functional constructs of putatively independent components, such as short-term and long-term memory, provided the main and definitive evidence supporting the distinction between short- and long-term retention systems. This two-stage distinction paved the way to the further fractionation of memory, which took place in the following two decades (Baddeley et al. 2002). The arguments developed by Ruchkin et al., though largely based on electrophysiological evidence, are logically similar to the view put forward in the 1960s by Melton (1963), who basically argued that the same functional variables (e.g., repetition effects) are operational under both short-term and long-term retention conditions, with no compelling need for separate memory systems. The similarities between the approaches of Melton and Ruchkin et al. are evident in the discussion of the fMRI findings of Prabhakaran et al. (2000), in terms of a consolidation process shared by both short- and long-term episodic memory. In this commentary I shall consider the neuropsychological evidence that counters Ruchkin et al.'s conclusion, suggesting a view of memory in terms of separate, though interacting, systems.

The electrophysiological evidence from neurologically unimpaired subjects reveals the time course of the contributions of different systems to behavioural performance. As such, it is fully adequate to reveal interaction and cooperation among systems, because this is the "normal" state. The behavioural evidence that short-term memory performance is also based on long-term memory systems, is well known (Brener 1940; Watkins 1977). Electrophysiological and behavioural experiments in unimpaired individuals may be less likely, however, to show the independence of discrete components. Experiments in brain-injured patients typically provide this type of evidence: One single component may be selectively impaired, but the remaining parts of the system are still fully operative.

The neuropsychological evidence is mentioned in the introduction, but not further discussed in the following sections of the target-article. The main neuropsychological point raised by Ruchkin et al. concerns a case study (patient AB), reported by Romani and Martin (1999), who shows a deficit in word learning and a mild reduction of memory span, particularly for words. Ruchkin et al. state that patients such as AB "with a semantic short-term memory deficit also have difficulty forming semantic but not phonological long-term memories" (sect. 1.2, last para.), and this impairment at the lexical-semantic level of representation argues against a distinction between short-term and long-term memory. Patient AB (Romani & Martin 1999, pp. 59 and 61), however, in addition to a lexical-semantic impairment, has some deficit of phonological memory (as revealed by his low nonword span and reduced recency effect). AB's phonological learning (i.e., of novel words) was not assessed, but on the basis of the patient's mild deficit of phonological short-term memory, some impairment may be predicted (Baddeley et al. 1988). Patient AB is not, therefore, a "pure" (with a single functional deficit) case (Vallar 2000), and interpretation is more complex. With these limitations in mind, a deficit at some level of lexical-semantic representations (according to Romani & Martin 1999, specific lexical-semantic memory resources) may account for AB's neuropsychological pattern, considering that immediate verbal-memory performance (e.g., in span tasks) has a long-term memory component. The additional inference that no independent short-term store exists, however, does not follow. For instance, AB's digit span of three and word span of two-to-three is in the upper range of the performances of short-term memory patients. In the meta-analysis by Vallar and Papagno (2002), digit span is 2.38 (range 1–3.6) and word span is 2.00 (range 1.05–3). This level of performance may reflect the combined effects of a (mild) phonological deficit and of a (more severe) lexical-semantic impairment, and is fully compatible with the view that span performance, which is mainly based on the operation of the phonological short-term store/rehearsal system, also reflects a contribution from lexical-semantic long-term memory-based representations.

Ruchkin et al. interpret the patterns of impairment of patient AB in terms of a deficit of a particular type of representation (lexical-semantic), with the short-term/long-term dimension being related only to the time course of the task, with no reference to discrete anatomo-functional components. Deficits involving specific levels of representation indeed exist, both at the phonological level (see Shallice & Vallar 1990, for discussion; Strub & Gardner 1974) and at the lexical-semantic level (Romani & Martin 1999), which may give rise to impairments in both short- and long-term memory paradigms. Here, again, Ruchkin et al. are back to the past, with a view of memory systems in terms of discrete levels of processing, each of which encompasses both short-term and long-term storage (Craik & Lockhart 1972). Levels of representation and processing are, however, articulated in a number of specific components. In the phonological domain, for instance, an anatomo-functional distinction may be drawn between a phonological short-term store and a process of rehearsal. Within the phonological domain, deficits of these systems may bring about selective patterns of impairment: Dysfunction of the process of articulatory rehearsal (but not damage to the phonological short-term store) disrupts the patients' ability to make some phonological judgements about stress position and initial sound for written words (Vallar et al. 1997). These processes have discrete anatomical counterparts (Vallar et al. 1997), revealed by neuropsychological studies in brain-damaged patients and neuroimaging-activation experiments in normal subjects (Paulesu et al. 1996). This neurofunctional architecture (Fig. 1) also provides an account of the interactive effects of the sensory modality of the input, of phonological and item-length effects, and of articulatory suppression (Vallar & Papagno 2002). The neuropsychological evidence for a distinction between short-term and long-term components is even more compelling in the visuo-spatial domain, in which double dissociations between immediate retention and long-term learning for spatial locations have been reported (Vallar 2002; Vallar & Papagno 2002).

In the schematic of the timing of stores and processes that contribute to the operations of visual and verbal short-term memory (target article, Figs. 3 and 7), the concept of distinct systems – which, however, cooperate to support optimal retention performance – is visually conveyed to the reader. The neurophysiological data reviewed by Ruchkin et al. emphasize the interactions among systems and their partly parallel activation, and the neuropsychological evidence reveals their multicomponential nature. The proper weighting of each source of evidence provides a balanced view of the multicomponent architecture of memory.

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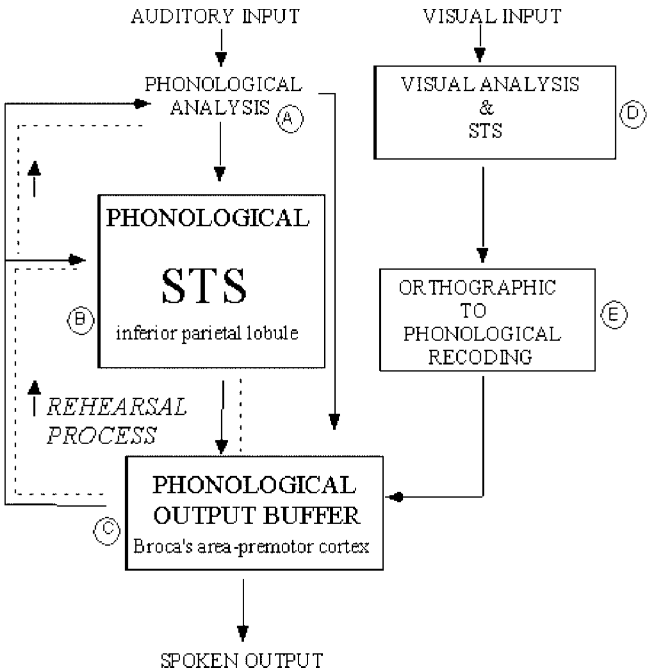

Figure 1 (Vallar). An anatomo-functional model of phonological short-term memory. Auditory-verbal material, after early acoustic and phonological analysis: (A) enters the main retention component of the system, the phonological short-term store (STS) (B), where material is coded in a phonological format. The phonological STS is an input system, to which auditory material has a direct and automatic access. The process of rehearsal is conceived of as involving a recirculation of the memory trace between the phonological STS and a phonological-output system, the phonological output buffer, or phonological assembly system (C), primarily concerned with the articulatory programming of speech output, with a recurring translation between input (acoustic) and output (articulatory) phonological representations. The phonological-output buffer provides access for visually presented verbal material to the phonological STS, after phonological recoding or grapheme-to-phoneme conversion (E). The model also illustrates the multiple-component nature of short-term memory, showing a visual STS (D), where material is likely to be encoded in terms of shape. (*Source:* Vallar & Papagno 2002).

Double dissociation in the effects of brain damage on working memory

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Abstract: As revealed by standard neuropsychological testing, patients with damage either to the frontal lobe or to the hippocampus suffer from distinct impairments of working memory. It is unclear how Ruchkin et al.'s model integrates the role played by the hippocampus.

Dissociation between two different aspects of working memory is a standard finding in my neuropsychological practice. The two critical tests are Wechsler's Digit Span and Rey's Auditory Verbal Learning Test (AVLT). Denoting an inconspicuous outcome by "+" and a pathological outcome by "−" all four possible combinations can be observed in distinct populations: ++ (both scores are normal), −− (both scores are pathological) and, theoretically most important, +− and −+, forming a double dissociation.

In the Digit Span test, the tested person has to immediately repeat series of numbers with increasing lengths, or has to reverse the series in memory and then repeat them backwards. (Unfortunately, the current German version does not provide separate norms for forward and backward tests). In the AVLT, the same list of 15 words is read to the person five times. Each time, the person has to say immediately afterwards the words he or she remembers. The number of words remembered at the fifth presentation is the "Learning" measure, and the number of words freely recalled after being presented with an interfering list is the "Recall" measure. Norms were taken from Geffen et al. (1990) and Ivnik et al. (1992).

Figure 1 gives examples for the dissociating patterns. Not illustrated are cases where both Digit Span and AVLT yield pathological results (which occurs most often in dementia-causing illness). Rather, Figure 1a–c shows patients with relatively good AVLT performance, but severely restricted digit span, and Figure 1d–e shows patients with normal (or perhaps even compensatorily enhanced) digit span, but severely impaired learning and recall (AVLT scores).

Figure 1a is from a patient with mild sensory aphasia after infarction of the left middle artery. Digit Span was severely affected. But, nevertheless, the patient was able to learn verbal material in the AVLT. (Some verbal tests, e.g., "Similarities," and also "AVLT-Recall," were not performed because of the clinically obvious aphasic syndrome.) Figures 1b and 1c show the typical residual deficit after left frontal-lobe contusion caused by a closed-head injury: The contusion produces a bottleneck in getting information into the brain (impaired digit span), without affecting the core ability of learning and recall. Figure 1b is from a medical practitioner who, after the accident, had resumed her work but complains about difficulties in dealing with this work. Figure 1c is from an elderly man who was multiply affected by the accident, lowering his overall performance, but most severely, his digit span.

The patients in Figures 1d–e had completely intact digit span but were basically unable to learn and remember, as indicated by the AVLT scores. They had isolated, severe damage of both hippocampi, the patient in Figure 1d by simultaneous infarction of both posterior hippocampi, and the patient in Figure 1e by carbon monoxide poisoning. By this double dissociation, these cases show that, indeed, two separate systems contribute to auditory working memory. The closest interpretation of the functions of these two systems is that the first component (affected in Figs. 1a–c) contributes to a short-term buffer and that the hippocampal component (affected in Figs. 1d–e) contributes to encoding and retrieval. Elaborating on this interpretation with regard to the first component, Ruchkin et al. make the point that the frontal areas (damaged in patients, as shown in Figures 1b and 1c) might in fact not contain the short-term buffer, but rather, might provide pointers that refer to items stored in parietal areas, in this case perhaps Wernicke's area (which is directly damaged in Fig. 1a). This interpretation is in complete agreement with these neuropsychological data. However, Ruchkin et al.'s model is tacit with respect to the function of the hippocampal system. Describing and labeling the function of this system seems essential, because, as shown by the double dissociation, working memory may be severely damaged when the frontal lobes are intact and, correspondingly, damage to the frontal lobes may impair the short-term buffer but not necessarily the ability to encode and retrieve. Ruchkin et al.'s model mainly draws from event-related potential (ERP) data, and directly assessing the hippocampal contributions by means of event-related potentials might be difficult. (Cf. the discussion on assessment of the hippocampal pathology in Alzheimer's disease by means of event-related potentials in Verleger 2002.) Nevertheless, these contributions should be appreciated when modeling the function of working memory.