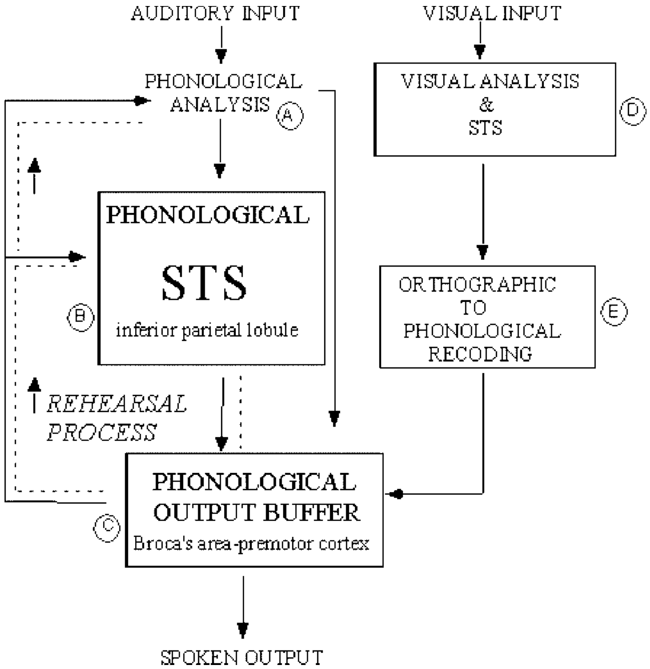

Figure 1 (Vallar). An anatomo-functional model of phonological short-term memory. Auditory-verbal material, after early acoustic and phonological analysis: (A) enters the main retention component of the system, the phonological short-term store (STS) (B), where material is coded in a phonological format. 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.

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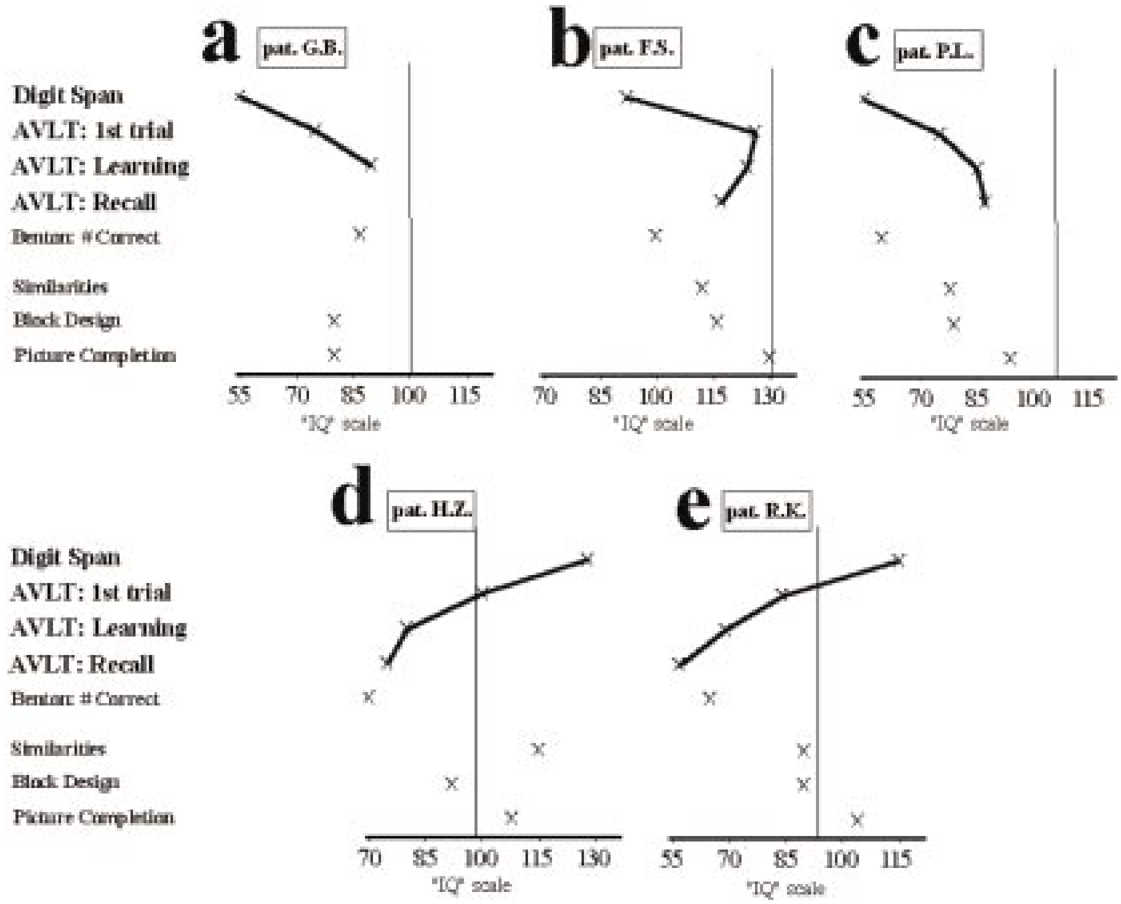

Figure 1 (Verleger). Double dissociation between memory functions measured by Digit Span and by AVLT. To have a common scale, all tests scores were converted to the IQ scale, transforming their means to 100 and their standard deviations to 15. Premorbid cognitive level, indicated by the vertical line, was estimated with a vocabulary test (Lehrl 1977), and basic aspects of cognitive functions were evaluated with the Wechsler Adult Intelligence Scale subtests: Picture Completion, Communalities, and Block Design (Tewes 1991). Benton's test of visual retention was included as an additional test of memory, but it did not clearly contribute to the double dissociation (being affected in all patients, except in Wernicke aphasia, panel a).

Neuronal synchronization accompanying memory processing

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Abstract: In their target article, Ruchkin et al. propose sustained neuronal interaction of prefrontal and posterior cortex involved in memory-storage mechanisms with respect to electrophysiological findings on the relationship of short-term and long-term memory processes. We will evaluate this claim in light of recent evidence from our laboratory on EEG coherence analysis of memory processes accompanying language comprehension.

Referring to several event-related potential (ERP) studies and one electroencephalographic (EEG) coherence study, Ruchkin et al. support the view that the same multiple memory systems serve short-term as well as long-term memory, and that only the degree of coactivation between the relevant memory systems differs. In contrast to models proposing specialized neural systems as short-term buffers, Ruchkin et al. postulate that short-term storage mechanisms involve an increase in neural synchronization during both the encoding/comprehension and the retention phases. In particular, they propose an increased synchronization between the prefrontal cortex, serving as a top-down controlling system, and the posterior cortex, which participates in perception and encoding.

One of the few methods suitable for measuring frequency band-related neuronal synchronization accompanying cognitive processes in healthy humans is the calculation of coherence between EEG or magnetoencephalographic (MEG) signals. During the last 20 years, several cognitive processes, such as memory, language, music processing, and thinking, have been studied with EEG coherence (for reviews, see Petsche & Etlinger 1998; Rappelsberger & Petsche 1988). Consistent with Ruchkin et al.'s results on EEG coherence accompanying memory processes, increased neuronal synchronization, in particular between signals at distant electrodes (large-scale coherence), was described for various different, complex cognitive tasks (for reviews, see Bressler & Kelso 2001; Petsche & Etlinger 1998). Other measures, such as phase synchronization (Varela et al. 2001) or phase relations (Schack et al. 2003), which indicate direction and propagation speed of information transfer, are even more promising for investigating large-scale synchronization. In general, high coherence correlates with long-lasting negativities in the ERP and is often found during increased task complexity and efficient information processing, whereas low coherence is often found in pathological conditions (for reviews, see Petsche & Etlinger 1998; Weiss & Mueller 2003).

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