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Developments in the Concept of Working Memory

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The authors summarize developments in the concept of working memory as a multicomponent system, beginning by contrasting this approach with alternative uses of the term *working memory*. According to a 3-component model, working memory comprises a phonological loop for manipulating and storing speech-based information and a visuospatial sketchpad that performs a similar function for visual and spatial information. Both are supervised by a central executive, which functions as an attentional control system. A simple trace-decay model of the phonological loop provides a coherent account of the effects of word length, phonemic similarity, irrelevant speech, and articulatory suppression in verbal short-term memory tasks. This model of the loop has also proved useful in the analysis of neuropsychological, developmental and, cross-cultural data. The notion of the sketchpad is supported by selective interference with imagery in normal adults and by specific neuropsychological impairment. Analysis of the central executive is illustrated by work on deficits in the ability to coordinate subproccesses in Alzheimer's disease.

Some 20 years ago, we proposed that the concept of a unitary short-term memory system should be replaced by that of a multicomponent working memory (Baddeley & Hitch, 1974). The proposal appears to have been a fruitful one. The term *working memory* has become increasingly common, and we suspect that the majority of those of our colleagues who continue to prefer the older terms of *short-term* or *primary memory* would be sympathetic to the emphasis on the functional role of the system that is implied by the term working memory.

At the same time, it is important to note that the term working memory is used in a number of different ways. Leaving aside the very different concept of working memory used in the animal literature (Olton, Walker, & Gage, 1978), there are at least three separate uses of the term in cognitive psychology. First, computational models using a production system architecture use the term to refer to that part of the architecture that holds the relevant productions. It is, however, important to note that working memory in such systems is an assumption that underpins this method of modeling rather than an attempt to represent an important component of human cognition. In Newell's (1990) SOAR architecture, working memory is assumed to be of unlimited capacity and is not in any sense modeled on empirical evidence. That does not of course mean that production system architectures are not, under certain circumstances, used in ways that explicitly attempt to reflect the empicial evidence, and in these cases, some form of limitation on working memory capacity is typically assumed (Just & Carpenter, 1992; Kintsch & van Dijk, 1978).

A second interpretation focuses on working memory as a system that combines storage and processing, measuring this capacity using a range of tasks that are assumed to demand both, and then using the individual differences found to study the role of working memory in a range of complex cognitive tasks. Carpenter, Just, and their colleagues have used this approach extensively to study reading comprehension and reasoning tasks (Carpenter & Just, 1977; Daneman & Carpenter, 1980, 1983; Just & Carpenter, 1980), whereas Oakhill and her colleagues have used a similar approach to study the development of comprehension skills, paying particular attention to children whose capacity to read single words is normal but who show impaired capacity to comprehend (Oakhill, 1982, 1984; Oakhill, Yuill, & Parkin, 1986, 1988). Although much of this work has been concerned with the understanding of reasoning and comprehension rather than working memory per se, others such as Engle and his co-workers have been more concerned with questioning the implications of such findings for analyzing the structure of working memory (Turner & Engle, 1989). More recently, they have been concerned with linking this approach based on individual differences in performance to models such as Anderson's (1983) ACT* production system model. Although such a link might not seem obvious, given that Anderson's model does not assume a limited capacity working memory system, Cantor and Engle (1993) proposed that differences in working memory capacity reflect variation in the amount of activation available within the working memory system. A similar proposal has been made by Kimberg and Farah (1993) in an attempt to account for the attentional and executive deficits shown by patients with frontal lobe damage. Such approaches seem to hold considerable promise for linking work using individual differences with the more theoretically based production system modeling approaches.

One final area in which the approach based on individual differences is proving fruitful is in providing an alternative to the classical approach to psychometrics. Kyllonen and Christal (1990) have shown that working memory measures correlate very highly with measures of IQ based on reason-

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ing tests while being less dependent on prior education or background. Furthermore, such measures provided a somewhat better predictor of subsequent performance on a computer programming course than did the more traditional measures.

The third approach to working memory follows our original proposal in concentrating on the fractionation of the system into subcomponents. Of course, such an approach is not inconsistent with those based on individual differences, but so far this approach has emphasized the fractionation of working memory and has been more closely associated with neuropsychological issues. For that reason, we will discuss this approach in somewhat more detail, concentrating in turn on each of the following three subcomponents: the *phonological loop,* which holds and manipulates speech-based information; the *visuospatial sketchpad,* which performs a similar function for visual and spatial information; and the *central executive,* an attentional control system that is aided by two subsidiary systems (Baddeley, 1986).

The Phonological Loop

This component is probably the simplest and most extensively investigated aspect of working memory. It is assumed to involve a phonological or acoustic store within which memory traces fade after about 2 s unless they are revived by an articulatory control process that is capable of refreshing the memory trace by subvocal rehearsal. The same process is also capable of using subvocalization to name a visual stimulus and hence register it in the phonological store.

Evidence Supporting the Loop

There are four main clusters of evidence supporting the phonological loop, each based on a robust phenomenon. The phonological loop model provides a simple and coherent account of both the phenomena and their interaction, although in recent years the exact mode of operation of the model has been increasingly questioned as part of a series of attempts to provide a more detailed understanding of the operation of phonological memory. We will consider each in turn.

The phonological similarity effect. Immediate serial recall is impaired when items are similar in sound (Conrad & Hull, 1964). This phenomenon is extremely robust under standard conditions, but it is important to bear in mind that with visual presentation at least, phonological coding is an optional strategy. Hence, it can be abolished by articulatory suppression (Murray, 1968), is typically not found in children younger than 8 years (Halliday, Hitch, Lennon, & Pettipher, 1990), and does not occur in patients with acquired impairment in the operation of the phonological loop (Vallar & Shallice, 1990). In normal subjects phonological coding is often abandoned when the memory span is grossly exceeded (Gathercole & Baddeley, 1990; Salamé & Baddeley, 1986). When not taken into account, this can give the misleading impression that certain groups, such as poor readers, do not use phonological encoding (see Johnston, 1982, for a discussion).

The irrelevant speech effect. Spoken material that the subject is instructed to ignore may nevertheless impair immediate verbal serial recall (Colle & Welsh, 1976). The effect does not appear to be due to general distraction, nor is it dependent on the lexical or semantic characteristics of the irrelevant material (Salamé & Baddeley, 1982). White noise does not disrupt performance, whereas speech or music does (Salamé & Baddeley, 1989), with the degree of disruption being a function of the extent to which the irrelevant auditory stimulus changes state (see Jones, 1993, for a review). The irrelevant stimulus appears to corrupt the memory trace in some way, although the exact mechanism remains in doubt. Salamé and Baddeley (1982) found a slightly greater impairment from words comprising the same phonemes as digits than from disyllabic irrelevant words, suggesting a possible phonological involvement. On the other hand, Salamé and Baddeley (1986) failed to observe any interaction between the phonological similarity of the items remembered and the presence of irrelevant speech. If the irrelevant items added noise to the store, then one might expect this to have a greater effect on recall of similar items for which distinguishing cues are fewer. Although such predictions might seem plausible, it would be unwise to rely too heavily on them in the absence of an adequate quantitative model of the phonological store. We shall return to this point later.

The word length effect. Immediate memory span declines systematically with the spoken length of the items remembered (Baddeley, Thomson, & Buchanan, 1975). The crucial factor appears to be the spoken duration of the items, hence digit span in Welsh is typically less than in English, which in turn is less than in Chinese. The digits in each case are typically monosyllabic, but nevertheless differ in the maximum rate at which they can be articulated (Ellis & Hennelly, 1980; Stigler, Lee, & Stevenson, 1986). The effect is quite robust when differences in spoken length are substantial, as with words varying in number of syllables, but becomes less so when syllabic length is held constant and when the words used can be truncated during rapid rehearsal (e.g., *balloon* to *b'loon*) (Caplan, Rochon, & Waters, 1992).

The simplest interpretation of the word length effect is that it reflects the speed of subvocal rehearsal, which in turn limits the rate at which the memory trace can be refreshed. The process of rehearsal does not require the intact operation of the speech musculature, given that patients who have lost the capacity for vocal articulation nevertheless show a normal operation of the phonological loop (Baddeley & Wilson, 1985; Vallar & Cappa, 1987). Even children who have never developed the power of speech still appear to be able to rehearse subvocally (Bishop & Robson, 1989). One interpretation of these results is that rehearsal involves the central programming of speech but does not require its overt output. As predicted by this view, dyspraxic patients who presumably have disrupted programming of speech production show impaired verbal memory span (Rochon, Caplan, & Waters, 1991).

In the case of children, the word length effect is found from as early as age 4 upwards for auditorily presented items (Hitch, Halliday, Dodd, & Littler, 1989; Hulme, Thomson, Muir, & Lawrence, 1984). The size of the effect for words containing different numbers of syllables is related to speech rate in just the same way in children as in adults. Moreover, the same relationship holds between developmental improvements in recall and the increase in speech rate with age (Hitch, Halliday, & Littler, 1993; Hulme et al., 1984). These findings show that the characteristics of the phonological loop remain remarkably constant as development proceeds. The simplest interpretation of the developmental data is that changes in the speed of subvocal articulation enable the loop to be used more efficiently. Memory for nameable pictures produces a different developmental pattern in which the word length effect emerges much later in development (Hitch, Halliday, et al., 1989). However, this difference between presentation modalities can be readily understood in terms of the adult model, according to which auditory inputs feed directly into the phonological loop while visual inputs have to undergo an optional recoding process (Baddeley, 1986). Training young children to recode and rehearse visual items induces the word length effect (Johnston, Johnston, & Gray, 1987), confirming that its absence is due to a failure to perform these operations spontaneously.

The discussion so far has assumed that the word length effect operates by means of its impact on the process of subvocal rehearsal. However, Cowan et al. (1992) have presented evidence for the importance of the word length effect at output: Longer words take longer to reproduce, leading to a greater delay between presentation and test, particularly of late items. However, whereas this is likely to be one component of the effect, and possibly the only one in young children (see Gathercole & Hitch, 1993), the fact that word length is still an important variable when performance is tested by probed recall suggests that it is only part of the story (Henry, 1991).

Articulatory suppression. When subjects are required to utter an irrelevant sound such as the word *the* during immediate serial recall, performance is impaired and the word length effect is abolished (Baddeley, Lewis, & Vallar, 1984). This is typically interpreted as resulting from the abolition of subvocal rehearsal. When articulation is overt, the possibility exists that the effect may be contaminated by the presence of irrelevant self-generated speech. However, Gupta and MacWhinney (in press) have shown that this is not a major component of the effect.

Modeling the Phonological Loop

For a number of years, the further development of the phonological loop model has been handicapped by the lack of a model that is sufficiently precise to allow testable detailed predictions. However, with the development of connectionist modeling techniques, the picture is changing rapidly, with models such as that of Burgess and Hitch (1992) offering the possibility of much more detailed accounts. It seems likely that these in turn will demand more precise empirical information, leading to an increase in research in this area over the next few years.

Functional Significance of the Phonological Loop

What evolutionary benefit, if any, might be provided by the phonological loop? Setting aside the possibility that it was bestowed on us by a beneficent deity in anticipation of the development of the telephone, most approaches have concentrated on its possible role in the use of language. The first possibility to be explored was that it is necessary in order to hold sentential material during parsing and subsequent comprehension (Clark & Clark, 1968). This would suggest that patients with a deficit in the phonological loop should show problems in language comprehension. Such deficits are frequently reported, ranging from severe (Baddeley & Wilson, 1985; Wilson & Baddeley, 1993) to nonexistent (Butterworth, Campbell, & Howard, 1986). They are typically relatively modest, occurring only with certain structures that require the maintenance of surface information across intervening text (Vallar & Shallice, 1990). Although some would argue that there is no evidence for an involvement of the phonological loop in comprehension (Butterworth et al., 1986; Caplan & Waters, 1990), the modal view is probably that the phonological store provides a backup system for a comprehension process that typically operates on-line and in real time (Vallar & Shallice, 1990; although for an alternative possibility see Baddeley & Wilson, 1985).

Although patients with short-term memory deficits do not typically show major problems in comprehension, they do show a gross impairment in new phonological learning, suggesting that the phonological loop system may have evolved as a mechanism for the acquisition of language (Baddeley, 1993; Baddeley, Papagno, & Vallar, 1988). Further evidence for this view came from the observation that children with normal intelligence but a specific language disability were dramatically impaired in the capacity to repeat an unfamiliar nonword, a capacity that was assumed to reflect a memory deficit given that they showed impaired memory span coupled with apparently normal audition and speed of articulation (Gathercole & Baddeley, 1990). Within a sample of normal 4-year-olds, nonword repetition proved to be highly correlated with receptive vocabulary score. Furthermore, cross-lagged correlation indicated that nonword repetition at age 4 predicted vocabulary 1 year later to a significantly greater extent than vocabulary at age 4 predicted subsequent nonword repetition, implying that at this age nonword repetition forms the basis for the acquisition of vocabulary rather than the reverse (Gathercole & Baddeley, 1989).

Further evidence for the importance of the phonological loop in the acquisition of second language vocabulary comes from a range of sources. Articulatory suppression, word length, and phonological similarity all influence the acquisition of foreign vocabulary while not impairing paired associate learning in the subject's native tongue (Papagno, Valentine, & Baddeley, 1991; Papagno & Vallar, 1992). Vallar and Papagno (1993) studied the unusual case of a Down's syndrome patient who had the expected low IQ, surprisingly accompanied by an excellent digit span. She was able to speak two foreign languages and showed a normal rate of learning the vocabulary of an unfamiliar foreign language while showing impaired learning of pairs of words in her native language, exactly the opposite pattern to that shown by patients with short-term memory deficits. Service (1992) studied the acquisition of English by young Finnish children and found that the best predictor of their subsequent language learning was their capacity to repeat English pseudowords.

Although the evidence so far has focused primarily on the acquisition of vocabulary, there is a small amount of evidence to suggest that the phonological loop may also be involved in the learning of syntax. Adams and Gathercole (1993) observed that nonword repetition was significantly associated with level of syntactic development in preschool children, and Service's (1992) previously described study found an association between nonword repetition and a whole range of subsequent foreign language skills, including syntax. The role of the phonological loop in the development of grammatical competence clearly merits further investigation.

The Visuospatial Sketchpad

This subsystem is needed to account for evidence that visuospatial and verbal working memory involve separate resources. For example, Brooks (1967) compared memory for highly imageable sentences describing the locations of digits in a spatial matrix with memory for more abstract sentences. Recall of the spatial material was worse with visual than auditory presentation, whereas the opposite was true for the abstract material. Visual imagery and visual perception evidently share resources that are not used by the verbal system. Neuropsychological evidence also indicates this type of dissociation. For example, patients with right posterior lesions can be markedly impaired on Corsi blocks, a test of memory span for movements to different spatial locations, despite having normal auditory-verbal memory spans (De Renzi & Nichelli, 1975). Although the sketchpad is presently less well understood than the phonological loop, different methods of investigation are beginning to converge on a common interpretation.

Dual-Task Interference

As in the case of the phonological loop, selective interference effects have been a major source of evidence about the nature of the sketchpad. For example, Baddeley, Grant, Wight, and Thomson (1975) found that concurrent visuospatial pursuit tracking disrupted performance on Brooks's (1967) spatial task but not the corresponding abstract task. Subsequent work showed that selective interference is obtained when subjects track an auditory source while blindfolded but not when they perform a brightness monitoring task with no spatial content (Baddeley & Lieberman, 1980). This finding implies the use of a spatial, nonvisual storage system. Maintaining information in the store may involve eye movements (Baddeley, 1983). However, performance on Brooks's spatial task is impaired by passive movement of the subject's arm (Quinn & Ralston, 1986), suggesting that the characteristic feature of the rehearsal process may be its spatial directedness rather than the type of movement (see Smyth & Scholey, 1994). Other evidence indicates a dissociation between memory for spatial pointing movements, as in the Corsi task, and memory for nonspatial hand movements (Smyth & Pendleton, 1989).

A limitation of the evidence implying a spatial system is that it is derived from tasks that are themselves largely spatial. It therefore leaves open the possibility of a visual component of working memory that is not tapped by these spatial tasks. In an interesting series of experiments, Logie (1986) investigated whether the ability to use a visual but nonspatial imagery mnemonic might be sensitive to visual interference. He found that passively watching a series of irrelevant visual patterns disrupted the imagery mnemonic, an effect analogous to that of unattended speech on the phonological loop, whereas watching the patterns had no effect on verbal rote memorization. Conversely, listening to irrelevant speech interfered with rote memorization without affecting use of the imagery strategy. These results imply a visual component of the imagery system and they raise the question of whether the sketchpad can usefully be subdivided into two components, one specializing in information about spatial location and the other visual identity. Such a separation would be consistent with evidence of neurophysiologically distinct systems for processing the appearance of visual objects and their location in space (the so-called what and where visual systems; Ungerleider & Mishkin, 1982).

Neuropsychological Dissociations

A stimulating review by Farah (1984) illustrated how neuropsychological disorders of imagery can be related to a model of normal performance consisting of a long-term visual store and a limited-capacity buffer analogous to the sketchpad. Recent neuropsychological evidence has begun to influence our understanding of the sketchpad itself. Farah, Hammond, Levine, and Calvanio (1988) reported a case study of a patient with brain damage as a result of a car crash affecting bilateral temporo-occipital regions together with right temporal and right inferior frontal areas. There was a clear dissociation between the patient's severely impaired performance on some imagery tasks and his ability to perform others quite normally. He found it very difficult to perform highly visual tasks such as rating the similarity of the shapes of U.S. states or judging which of two named items was the bigger. On the other hand, he performed normally on a spatial task involving rating the proximity of U.S. states, Brooks's spatial task, and tasks involving mental image rotation (e.g., Shepard & Metzler, 1971). Farah et al. (1988) interpreted their patient's problem in terms of the distinction between visual and spatial components of the imagery system, with restriction of damage to the visual component.

A contrasting pattern of impairment has recently been observed in a patient who suffered brain damage as a result of a right-hemisphere aneurysm (Hanley, Young, & Pearson, 1991). This patient performed poorly on Brooks's spatial task, Corsi blocks, and mental image rotation, but had no difficulty on the visual tasks of rating the similarity of the shapes of countries or judging which of two named items was the bigger. However, her deficit cannot be interpreted as the converse of that shown by Farah et al.'s (1988) patient, given that she had difficulty on a nonspatial task involving short-term memory for faces but no problems with the spatial task of rating the proximity of British cities. It seems that Hanley et al.'s patient can best be interpreted as having a general impairment of the sketchpad, affecting both spatial and visual information, along with a preserved ability to generate images from long-term memory.

Among the interesting questions these neuropsychological studies raise is whether generating a familiar image from long-term memory and maintaining a recent percept involve different buffers (Hanley et al., 1991; Riddoch, 1990). Recent experiments on normal subjects indicate that the visual properties of the two types of images are similar, suggesting that it would be premature to abandon the simpler notion of a single buffer (Hitch, Brandimonte, & Walker, in press).

The Representation of Visuospatial Information

Whereas the phonemic similarity effect has played an important role in investigating the phonological loop, studies of visual similarity have not figured equally prominently in studies of the sketchpad. One reason may be that its effect is typically rather small, as in immediate memory for visually presented items such as Chinese characters or nonsense shapes (Walker, Hitch, & Duroe, 1993; Yik, 1978). It seems that visual similarity disrupts recall when verbal recoding is unlikely, as for example in very young children (Hitch, Halliday, Schaafstal, & Schraagen, 1988; Longoni & Scalisi, 1994), or when verbal recoding is prevented by articulatory suppression (Hitch, Woodin, & Baker, 1989; Walker et al., 1993). The theoretical significance of the visual similarity effect is to indicate that item information is represented in the sketchpad in terms of visual features and can undergo partial forgetting. However, in the absence so far of manipulations of spatial similarity, this work currently says little about the organization of visual and spatial information.

An alternative approach is provided by studies of memory for displays containing simple geometric shapes (Nissen, 1985). In these experiments, the spatial location of an item, or one of its visual features (color or shape), is given as a cue for recall of its remaining features. The results show that memory for which visual features belong to the same item is dependent on memory for the spatial location of the item. However, no corresponding dependence is found in memory for the links between the spatial location of an item and its visual features. Nissen's interpretation is that spatial information plays a special organizing role in memory. She suggests that different visual features are represented in separate spatial maps, such that spatial cross-referencing is necessary to recall the visual features belonging to any given object. Because Nissen's task is novel, firm conclusions about the sketchpad are premature. However, extension of this methodology holds considerable promise.

A further line of investigation involves manipulating the visual characteristics of pairs of stimuli whose images have to be combined. One such task uses pairs of simple line drawings that form a novel figure when superimposed (see Brandimonte, Hitch, & Bishop, 1992). Detection of the novel figure is impaired when the two stimuli appear in incongruent black-and-white contrasts rather than the same (Hitch et al., in press). Similar experiments with drawings of solid objects on plain backgrounds show that although a change in the contrast of the object is disruptive, an equivalent change in the background has no effect (Walker, Hitch, Whiteley, & Dewhurst, 1994). This result indicates that the sketchpad is concerned with representations of visual appearance that are organized at the level of objects and is helpful for locating them in relation to visual perceptual analyses. For example, any feature maps of the type suggested by Nissen (1985) clearly cannot correspond to the output of peripheral visual feature detectors.

Functional Significance of the Sketchpad

The assumption that the sketchpad is a work space for holding and manipulating visuospatial information suggests that it may serve a wide range of functions. However, as yet there has been little in the way of systematic exploration, and suggestions remain somewhat speculative. One possibility for which there is some support is that the sketchpad is involved in planning and executing spatial tasks. For example, Japanese abacus experts who are so skilled that they can perform complex calculations without the aid of the abacus appear to do so by simulating the apparatus using visuospatial working memory (Hatano & Osawa, 1983). More generally, updatable visuospatial models may be involved in keeping track of changes in the visual perceptual world over time (see, e.g., Kahneman, Treisman, & Gibbs, 1992) and in maintaining orientation in space and directing spatial movement (Thomson, 1983). Visuospatial mental models may even be involved in the comprehension of certain types of verbal information (see, e.g., Mani & Johnson-Laird, 1982). Whether a single mechanism could plausibly serve such disparate roles is of course an intriguing question. However, because considerations of function can provide powerful clues to structure, future work will surely pay considerably more attention to this important but so far somewhat neglected aspect of visuospatial working memory.

The Central Executive

The central executive is the most complex and least well understood component of working memory. Indeed, in the earlier years we used the concept primarily as a reminder of the importance of executive processes and the need to incorporate them within the model. A first stage in doing so came with the proposal that Norman and Shallice's (1980) supervisory attentional system (SAS) might provide a basis for modeling the central executive (Baddeley, 1986). We followed Norman and Shallice's suggestion that patients showing the characteristic disruption in behavior following bilateral damage to the frontal lobes might be reflecting a deficit in this system. We proposed that the more traditional term of *frontal lobe syndrome* be replaced by the term *dysexecutive syndrome* on the grounds that this allowed the analysis of executive processes to be pursued independent of the question of their anatomical localization (Baddeley & Wilson, 1988). Both issues are important, but it is entirely appropriate to be concerned with analyzing the nature of executive processes whether one has precise information as to their anatomical basis or indeed whether such processes prove to be exclusively located within the frontal lobes.

An example of the application of this approach comes from the investigation of the possibility of a deficit in executive processes in Alzheimer's disease (AD). The executive process we chose was that involved in coordinating the operation of two separate subsystems, in our case the phonological loop and the visuospatial sketchpad. We used two tasks, digit span and tracking, in which the level of difficulty could be adjusted so as to be equivalent for AD patients and normal elderly and young control subjects. We found that although performance on the individual tasks was matched, when subjects were required to perform them simultaneously, the AD patients showed substantial impairment, whereas the normal elderly subjects were no more impaired than the young subjects (Baddeley, Logie, Bressi, Della Sala, & Spinnler, 1986). When a sample of AD patients was studied longitudinally, we found that capacity to perform the individual tasks was maintained, whereas capacity to perform two tasks simultaneously showed systematic deterioration over time (Baddeley, Bressi, Della Sala, Logie, & Spinnler, 1991). The question of whether this particular executive deficit represents a dysfunction located within the frontal lobes is currently under investigation. Although the capacity to coordinate two or more subprocesses appears to be one important component of the central executive, it is clearly by no means the only, or necessarily the most important, capacity. We are currently engaged in developing methods to investigate other executive processes, including those involved in attentional control and in the switching of retrieval plans.

Conclusion

Although the concept of working memory continues to be a fruitful one, it is clear that the extent to which it has developed has varied substantially from one area to another. In the case of the phonological loop, we seem to have a reasonably good account of the broad operation of the system and of its functional significance. Furthermore, the development of connectionist modeling techniques offers the promise of much more specific models on the detailed operation of phonological memory. In the case of the visuospatial sketchpad, progress has been rather slow but is beginning to accelerate through the increasing impact of both neuropsychological evidence and new experimental tasks. For example, it now seems clear that the system has separate visual and spatial aspects, the former dealing with the appearance of objects and the latter concerned with location and direction. However, important questions concerning the functional significance of the sketchpad, its relationship to long-term visual memory, and the nature of visual and spatial rehearsal remain firmly on the agenda for further investigation. The central executive is the most important but least understood component of working memory. Although it seems unlikely that we shall have an adequate detailed understanding of this component within the next few years, we are at least beginning to make progress in identifying and studying the breakdown of some of the constituent executive processes. Overall, then, although the study of working memory has undoubtedly made progress over the first 20 years, we are in no danger of running out of good questions regarding both its normal function and its breakdown in neuropsychological patients.

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P&C Board Appoints Editor for New Journal: *Psychological Methods*

The Publications and Communications Board of the American Psychological Association has appointed an editor for a new journal. In 1996, APA will begin publishing *Psychological Methods.* Mark I. Appelbaum, PhD, has been appointed as editor. Starting January 1, 1995, manuscripts should be directed to

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Psychological Methods will be devoted to the development and dissemination of methods for collecting, understanding, and interpreting psychological data. Its purpose is the dissemination of innovations in research design, measurement, methodology, and statistical analysis to the psychological community; its further purpose is to promote effective communication about related substantive and methodological issues. The audience is diverse and includes those who develop new procedures, those who are responsible for undergraduate and graduate training in design, measurement, and statistics, as well as those who employ those procedures in research. The journal solicits original theoretical, quantitative empirical, and methodological articles; reviews of important methodological issues; tutorials; articles illustrating innovative applications of new procedures to psychological problems; articles on the teaching of quantitative methods; and reviews of statistical software. Submissions should illustrate through concrete example how the procedures described or developed can enhance the quality of psychological research. The journal welcomes submissions that show the relevance to psychology of procedures developed in other fields. Empirical and theoretical articles on specific tests or test construction should have a broad thrust; otherwise, they may be more appropriate for *Psychological Assessment.*