The Quarterly Journal of Experimental Psychology Section A
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713683590

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To cite this Article Morton, John(1997) 'Free Associations with EPS and Memory', The Quarterly Journal of Experimental Psychology Section A, 50: 4, 924 — 941
To link to this Article: DOI: 10.1080/713755733
URL: http://dx.doi.org/10.1080/713755733

THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 1997, *50A* (4), 924–941

Free Associations with EPS and Memory

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In celebrating 50 years of EPS involvement in memory, I have taken a personal line rather than trying to achieve even coverage. Accordingly, the paper is in three parts. In the first, some early papers that have resonance for today's debates are described. Their framework was Bartlettian, with versions of schema theory as the guiding principles, and they were formative in my undergraduate education. This phase ended in the 1950s. From then, there was an explosion of work in memory in the U.K., the most important parts of which saw light at the EPS. This requires a proper history, which requires a proper space. In the second part, then, rather than show favourites or sample at random, my own involvement in EPS and memory is fallibly revisited, to give some flavour of the excitement, as well as some of the ideas. In the final part, some current work is described, and the Current State Buffer is introduced, in the hope of anticipating a little of the next 50 years.

1. MEMORY IN THE FIRST FEW YEARS

The EPS tradition in memory research was, of course, Bartlettian. Bartlett's students were at the heart of the original Experimental Psychology Group, and were important influences in my own undergraduate education in Cambridge in the late 1950s. The mixture of experimental method and intuition was, for me, a heady change from the aridity of inorganic chemistry. The early volumes of the *Quarterly* were standard sources of essay material, and going back again has been rewarding.

Oliver Zangwill and others had carried on Bartlett's semi-experimental, analytic methods, but by 1947 clinical interests were already clear. Indeed, the very first paper published in Volume 1 of the *Quarterly Journal* in 1948, which had been read before the EPG on 20 July 1947, was by Richie Russell from the Radcliffe Infirmary, Oxford (Richie Russell, 1948). The topic was Traumatic Amnesia. The paper was informal and, seemingly, the transcript of his talk.

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This paper is based on an invited presentation to the Experimental Psychology Society in Cambridge, July 1996, in celebration of the 50th anniversary of the founding of the Experimental Psychology Group, from which the Society subsequently evolved.

This paper was devised as a very personal oral entertainment or celebration rather than as a work of historical scholarship. I am grateful to Jon Bartrip for his contributions and to John Marshall for some interesting observations on a draft version, to which Alan Baddeley and Philip Smith also kindly offered some correctives.

His interest was in the study of recovery following concussion. The first focus was on memory for recent events. He observed:

> It is, of course, a commonplace observation that minor degrees of mental confusion due to illness or intoxication are associated with failure to remember current events. These bear many resemblences to the mental picture in the later stages of recovery from concussion.
>
> Comparisons of this nature suggest that the physiological mechanisms disordered in toxic confusional states are the same as are still temporarily paralysed in the confused patient recovering from concussion. It is also evident that cerebral physiology must be in a very healthy state for current events to be retained for future recall. (p. 2)

He was impressed with clear memories for events that occurred just before the concussion:

> there seems to be little time . . . for any process other than the full appreciation of the incident, no doubt at a high level, and that subsequent recall after recovery depends simply on reopening of the neuronal circuits established in registering the incident. (p. 3)

We have here a pre-echo of the mechanism sometimes ascribed to post-traumatic stress disorder (e.g. van der Kolk & Fisler, 1995). Russell also commented on the decontextualization of such images, illustrating the idea by reference to the patient who has the occasional vision of some striking event immediately preceding the injury, such as a horse galloping—but who could not recall the precise horse that had caused the accident.

From his studies of war-time head injuries he reported that deep posterior parieto-temporal wounds in the dominant hemisphere reliably led to a period of retrograde amnesia with a long post-traumatic amnesia. However, he cautioned that it is unwise to assume that all people use the same region of the brain for storing their memories. Frontal injuries, for example, cause a great variation in the degree of memory loss.

The age of the memories was of importance, as was the relation between the extent of the retrograde amnesia and the duration of the post-traumatic amnesia. Severe closed head injury not only impaired memory for recent events but also damaged the mechanism whereby long-past incidents were recalled. A patient returning from the Middle East after a severe injury was anxious to get home soon to see what his wife looked like, as this memory was entirely beyond his recall. Overall, Russell was impressed by the vulnerability of ``recently established memory circuits'' and included the example of a soldier who took a signalling course just prior to a moderately severe injury and had to retrain, ``though in other respects he had little disability''. This is a rare example of the loss of what might have been thought of as procedural knowledge.

Russell's neural theorizing is difficult to classify in today's frameworks. Thus, he suggested that the unusual event must always have an advantage so far as memorability is concerned, for it will open up a circuit rarely if ever used before and one which is unlikely to be used again. He continued later:

> The strength of a circuit available for recall may depend on its relative isolation from competing stimuli, and, whether these precede or follow the incident under consideration, they tend to confuse the clarity of the circuits concerned. There may, therefore, be simple physiological

> explanations for forgetting, and also, similarly, for the preservation of memories which are of no possible importance to the individual. (p. 5).

He finished by speculating that ECT closely reproduces the clinical features of concussion and suggested that the memory loss of patients being treated with ECT might be interesting to study. Parkin (1987) has a good summary of all except the most recent work in this area.

At the same meeting in Oxford as the talk by Russell was one by Oliver Zangwill. This was published the following year in the *Quarterly* under the title, ``Amnesia and the Generic Image'' (Zangwill, 1949).

The *generic image* is of ancient origin, discussed extensively by James, for example, and is something like what we might now call the prototype image. In Zangwill's words, it arises from ``the blending or fusion of a large number of particular images of identical or related content''. (p. 7). Zangwill pointed out that the generic images we entertain in childhood differ appreciably in content from those that we entertain in adult life. Our general image of a given individual or class of individual undoubtedly changes in content as we grow older. Then there is what, for some, would be a surprising move. One might expect that if the generic image is an accumulation or averaging of images, then it would be thought ahistorical—that it becomes updated, with a loss of previous versions. Zangwill drew the opposite conclusion, however:

> If it is agreed that the images in question depend on some kind of cumulative disposition, it might be expected that they would show regressive changes in cases of organic amnesia associated with brain injury or disease. (pp. 7–8)

All of this was a preamble to the description of a case of alcoholic Korsakoff psychosis that Zangwill had examined in 1939 or 1940 and had written about previously, in the *British Journal of Psychology* in 1941. The patient was a 57-year-old spinster with a retrograde amnesia for 10 or 15 years. Memory for events of childhood and early adult life was intact, though the chronology was confused. She knew her date of birth and the actual year but consistently underestimated her age by some 10 or 11 years. She thought it was only 3 or 4 years since the Armistice but had some accurate knowledge of current affairs. Thus, she believed that the current king was the ``Duke of York'' and ``had some vague appreciation'' that the country was again at war with Germany. The patient had retained her knowledge of shorthand, which she had learned as a girl, and she had good sketching ability.

Zangwill tested his theory of the nature of generic images in the following way. He asked the patient to think of a woman such as she might see any day in the street outside her home. She was particularly asked to represent the latest fashion in dress that she could remember. Her drawing is shown in Figure 1. Zangwill was at pains to stress that the patient was entirely satisfied that this was the latest fashion—that is, 1939. Judges dated it somewhere between 1917 and 1924.

The patient being a Londoner, the second test was to ask her first to visualize and then tp draw a bus of the type habitually found in London during the year preceding her admission to hospital. In fact, she drew a picture representing an open-topped bus, which had been withdrawn from general circulation in the early 1930s (see Figure 2).

FIG. 1. A drawing made by an alcoholic Korsakoff patient in 1939, supposedly of the latest fashion; actual fashion is between 1917 and 1924 (from Zangwill, 1949).

In the discussion, Zangwill supposed that generic images ``are constructions based upon a large number of discrete past experiences''. He followed Bartlett in using the term *schema* to denote an active organization of related past experiences, with the generic image seen as an active construction by the schema. In the normal individual, more recent images dominate this construction; with the Korsakoff, the recent images are lost and the generic image becomes one from the past. With this view, then, the schema does not exist at all until its moment of creation. It is not just dynamic, it is *only* dynamic. Zangwill

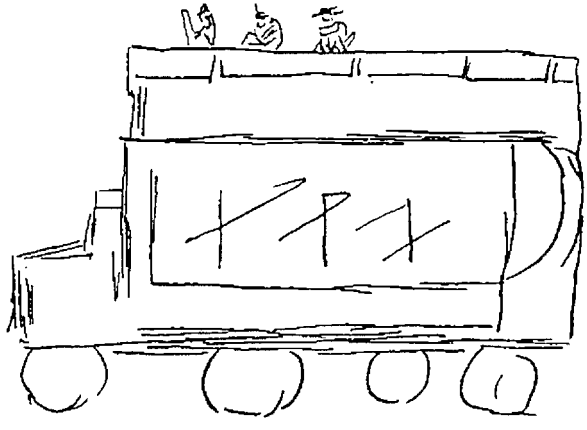

FIG. 2. A drawing by an alcoholic Korsakoff on the road in 1939, supposedly of a contemporary bus; in fact the bus depicted had not been seen for 7 or 8 years (from Zangwill, 1949).

threw in the supposition that the patient, prior to her illness, would have found it extremely difficult to represent a woman in the fashions of 15 years before as the generic image would be up-to-date, and retrieval of the earlier fashion, one supposes, would not be under voluntary control. Perhaps nowadays, with more rapidly changing fashions, each with its label, the task of retrieving the image of old fashions would be simpler.

Zangwill followed up in December of that year with a talk on déjà vu, another topic on the borders of memory and neuropsychology, but there was nothing more on memory at the EPS for another four years, when Moyra Williams talked on selective retention in amnesic states.

Meanwhile, in the *Quarterly Journal*, Davis and Sinha (1950a) were anticipating one of the current hot topics—the Misinformation Effect. A story was followed four days later by presentation of a picture, Pieter Breughel's ``The Village Wedding'', which illustrated more or less accurately a part of the story. There was then recall of either the story or the picture.

What the data showed was, first of all, that the perception and recall of the picture were governed by the attitudes induced by the story, which talked about a feud between two families. In particular, attention was directed at those parts of the picture that played an important part in the theme of the story. In addition, seeing the picture brought about changes in the points of emphasis, favouring the recall of those aspects of the story that the picture illustrated. Details from the picture that were not a part of the original story were recalled as if they had been part of the original. Davis and Sinha argued that such data supported Bartlett's position that memories are retained as schemata or active organizations of related experiences, which are subject to irreversible modification or reconstruction as the result of new experiences of a relevant kind. (It is not clear to me how this is to be fitted in with Zangwill's notion of a schema that was eminently reversible. Then, as now, the term was not universally defined.) This is opposed to Freud's view that ``nothing once formed in the mind could ever perish''. Those wishing to support Freud against their experimental findings, according to Davis and Sinha, would see the changes in memory performance ``not as evidence of changes in the engrams but merely as changes in the operation of the mechanism of repression''.[1] Within current models there is a somewhat simpler account, which we come to in the second section.

In a second experiment, involving recognition memory, however, only 5 of the 20 subjects preferred the story based on the picture to the original story (Davis & Sinha, 1950b). The conclusion, then, depends on the method of testing—though, amusingly, the authors' conclusions focused on the 5 who were confused rather than the ones who were not and did not behave ``in a manner corresponding to Bartlett's notion''!

[1] At around the same time, Zangwill, in a burst of extreme reductionism, made a further comment on the relation between psychodynamic and psychological theory:

> In our view, both abstraction and conventionalisation are to be regarded as dynamic processes in precisely the same sense as is the process of repression postulated by Freud. Indeed, it may be hazarded that Freudian ``primary repression'' is no more than a special case of what we have called *conventionalisation by omission* and that it is subject to the same principles as governs memory activity in general. (Zangwill, 1956, p. 143)

Another experiment from the Cambridge stable in 1950 was by Belbin (1950), looking at the influence of interpolated recall upon recognition. The subjects had been left waiting for a couple of minutes facing a wall relieved only by a poster of traffic, including a cyclist and a boy running out into the street, with the wording ``Pedestrians—he may have faulty brakes''. The experimental group were simply asked to recall as much as they could. Then a single poster (either the original or one with different wording) was presented, and the subjects were simply asked to state whether it was identical ``irrespective of the wording''. Of these subjects, 28/ 32 said the picture was different, compared with only 9/ 32 control subjects who had not gone through the recall phase.

Items that were omitted from the recall on some occasions were crucial—thus, after having omitted the cyclist from recall, a subject rejected the picture in the recognition test because of the cyclist. For the rest, in Bartlettian fashion, the subjects recalled dominant details and then erroneously imported items into recall to fill the gaps. Any importations into the recall were made the basis of rejection in the recognition phase. What we have, then, is not a single memory of the poster, which is then probed in a couple of ways, first by recall and then by recognition. Rather, the recall phase itself produced a memory, which was used as the comparison representation in the recognition phase, creating a self-misinformation effect.

An Interlude of Short-term Memory

These studies of recall seem to hang together better now than they used to. At the time, the overall theoretical position was not developed, Bartlett himself was no longer active, and there was increasing influence from clinical and applied problems. Thus, a few years later, short-term memory began to play a role in the intellectual life of the EPG, with a paper by John Brown in 1953, published in the *Quarterly* the following year. He presented subjects with stimuli that were a combination of an arrow, pointing to the left or to the right, and a two-digit number. The subjects had to draw lines in the direction of the arrows and read the numbers aloud. After 4 pairs of such stimuli, the subjects had to recall either one or both kinds of stimuli. The recall matched the original response, with the arrows being drawn. Instructions as to recall were given either before the presentation or afterwards. There was both proactive and retroactive interference, even with post-presentation instructions. This might seem surprising, as the arrows might be thought to be ideal spatio-temporal scratchpad material and, as such, should not interfere with the phonological code. A possibility is that the arrow directions, ``left'' or ``right'', were rehearsed subvocally along with the digits, and the interference occurred that way.

Overall, in the early and middle 1950s, there was very little on memory, either at the Society's meetings or in the *Quarterly*. The next real boost came with Donald Broadbent's work. As always with Broadbent's work, it started with an applied problem. He had been asked to look at the situation of air traffic controllers and the comprehension of multiple messages. His simplification of this situation was the well-known dichotic listening experiment where three pairs of digits are presented. Broadbent found that it was virtually impossible to recall the digits by alternating channels. This could be done only if the digits were alternated between the ears. In another *Quarterly* paper, in 1956, Broadbent replicated the results using channels of different kinds, in one experiment having one

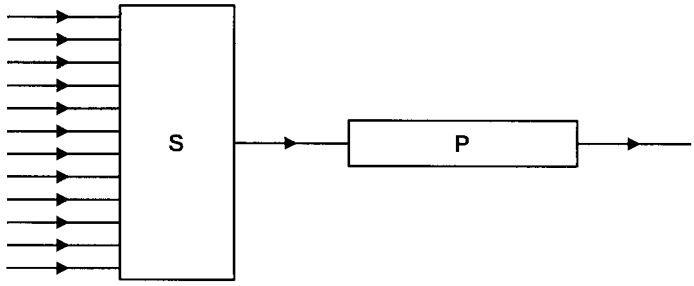

FIG. 3. A figure from Broadbent (1956) showing the flow of information from a parallel sensory system to a serial perceptual system.

set of digits low-pass- and the other high-pass-filtered, and in another experiment having one set of digits presented visually and the other auditorally (Broadbent, 1956).

On the basis of these findings, Broadbent put forward what is probably the first information processing model in the literature, shown in Figure 3. He argued that the channel that was recalled second must be stored while the first channel is read out. The sensory, or S system, then, was a parallel system, which preceded the perceptual, or P system. The P system was a single channel that would nowadays be thought of more as a response organizing system. The S-system turns out to be precategorical, as Bryden (1971) showed that the unattended channel is recalled equally well or equally badly whether it is recalled first or second.

2. BOOM TIME

In the 1960s and 1970s the EPS was possibly the most important forum for the development of ideas in short-term memory. The reason for this was that the verbal learning tradition of empiricism never fully took hold. Thus it was that Americans such as Sperling and Norman had a better reception here than in the States. Influences were found from information theory, then information processing. Memory was used as a tool to study attention and language, and new frameworks were developed and explored, such as levels of processing and working memory. Disorders of memory were studied, and many lines of work were laid down which continue still. EPS meetings were full of spirited discussion. There is too much here to cover, even were I capable of doing so with equilibrium. Instead, let me attempt to give some flavour of the times by describing my own involvement with the EPS and memory.

PAS

My own first communication on memory to the EPS was in 1961, though I thought at the time that it was on word recognition.[2] It was not until 25 years later that I learned that I had been working on implicit memory all my life (Schacter, 1990). For me, this news was

[2] Published as Morton, 1964a.

as surprising and delightful as learning that he had been speaking in prose for the previous 40 years came to Molière's M. Jourdain.

I had started work at the APU the year before. The degree of interaction there astonished me, and, over coffee or tea, you could always rely on getting the latest information on house prices and car reliability. However, one day in 1965, Conrad said to me, ``You know, John, it is funny, I can always tell whether an experiment used visual or auditory presentation just by looking at the error curves.'' He explained what he meant.

He had started running experiments that were relevant to the interests of the Post Office, and he was looking into various aspects of the recall of strings of digits. He was, I think, the first person to look carefully at serial position effects. One of his significant experiments was with Audrey Hull and involved the subjects reading a string of digits either silently or aloud, prior to serial recall (see Figure 4). To people's surprise, this made a difference (Conrad & Hull, 1968). And he established that it was to do with acoustics, and not with the difference in rehearsal.

Conrad's findings had only one interpretation for me. At the time I functioned with the Mark I logogen system where the process responsible for categorizing the stimulus, making the link to meaning, that is, was shared by both the acoustic and visual modalities (Morton, 1964b; see Figure 5). There was a reason for this error, by the way—the existence of cross-modality identity priming, where auditory pre-training resulted in facilitation of visual perceptual recognition (Weissman & Crockett, 1957). The trouble was that such experiments had been carried out on nonsense syllables, and the difference between the way in which nonsense syllables and real words were processed had up to then escaped us. Within the model, the only basis for a difference between visual and auditory presentation would be if the properties of the acoustic analysis system differed from those of the visual analysis system in respect of residual information left behind following decoding. This information would concern the final item, and, according to the

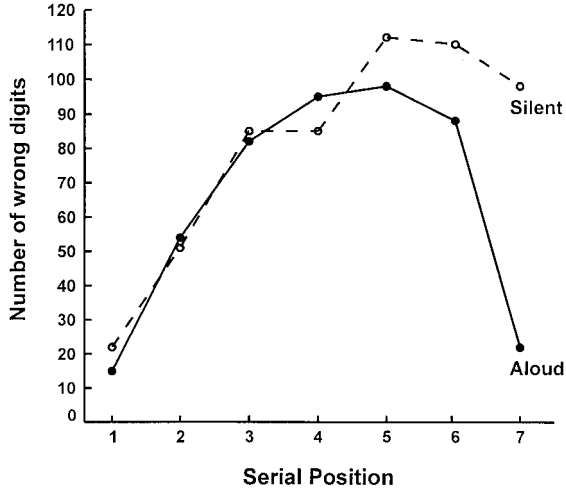

FIG. 4. From Conrad and Hull (1968): subjects were presented with a string of digits, which they read either silently or out loud and then recalled.

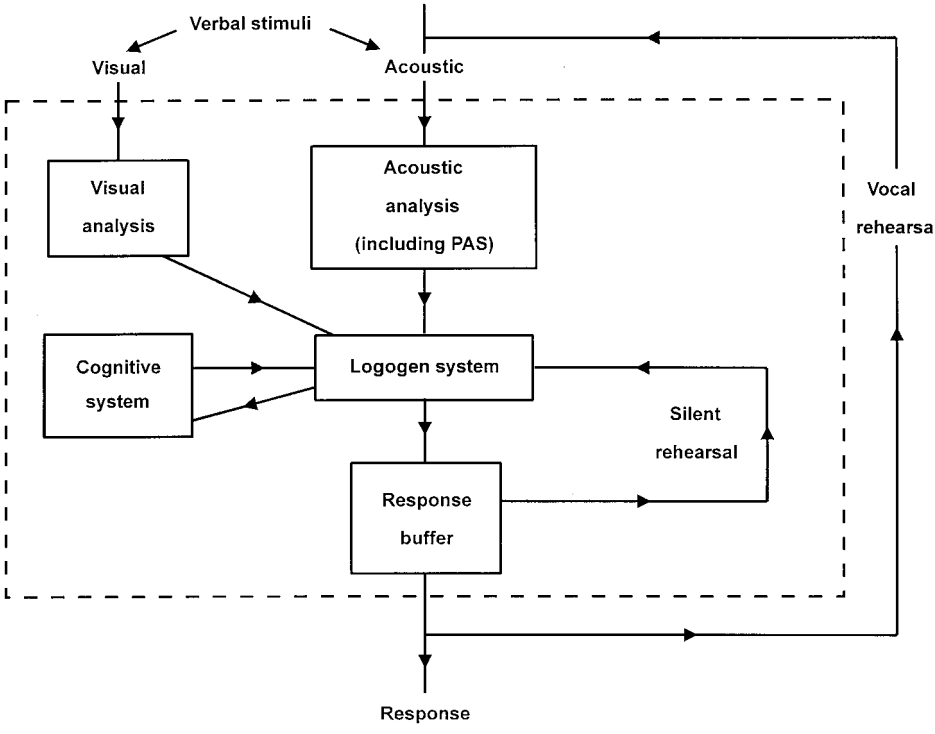

FIG. 5. The earliest logogen model from Morton (1964b): in this model, the same categorization system was shared by acoustic and visual modalities.

theory, would be wiped out by any acoustic event which followed. I proudly rattled on about this prediction until Alan Baddeley muttered, ``Why not do the experiment?'' My design was unnecessarily complicated but came out with the now classic pattern of data (Morton, 1968; see Figure 6). The effect of the suffix was indeed to impair performance on the final item and made the serial position curve look more like that obtained following visual presentation.

I wrote it up, together with the theory, and sent the paper to the *Quarterly*. It was turned down on the grounds that we did not need to know about yet another source of interference. Conrad had already carried out his prefix experiments (Conrad, 1958, 1960). These were designed to find out what the effects would be of the near universal ``zero'' prefix on telephone numbers. The results were very clear: there was a surprisingly large decrement in performance. In fact, there was an increase in the errors at all serial positions—when the stimuli were presented visually. Such niceties, and the conceptual difference between stimulus suffix and response prefix, were not in keeping with the philosophy of the referees. Both these events were a ``zero'' between the presentation of the stimulus and the initiation of the response!

At the same time, Bob Crowder had carried out both suffix and prefix experiments (See Figure 7). I found myself at Yale in 1967 and discovered that Crowder did not believe my modality story and thought that the effect of a suffix would be as great on a

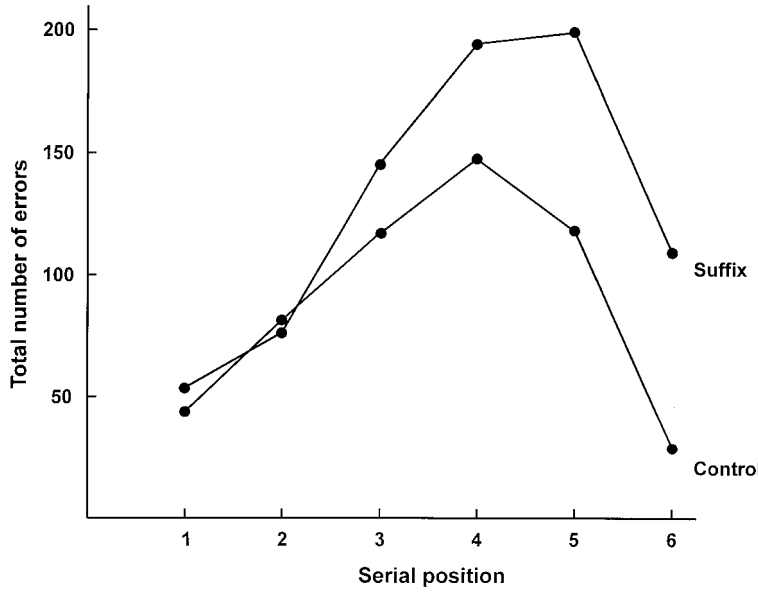

FIG. 6. Adapted from Morton (1968), showing the effect of an auditory suffix on the serial recall on an acoustically presented list of digits.

visually presented list. Thus it was that we did the experiment published in the Crowder and Morton (1969) paper about which I told the Society in 1969. This showed that a stimulus suffix did not have a selective effect on the final serial position following visual presentation (Figure 8) and established Precategorical Acoustic Storage, PAS, as the reason for the difference in serial position curves between the modalities.

One notable EPS moment in the history of PAS was a paper, ``Where is the modality effect in STM located?'' given by Mike Watkins, in Oxford, in 1972, published as Watkins and Watkins (1973). This claimed to show that the modality (and, thus, recency)

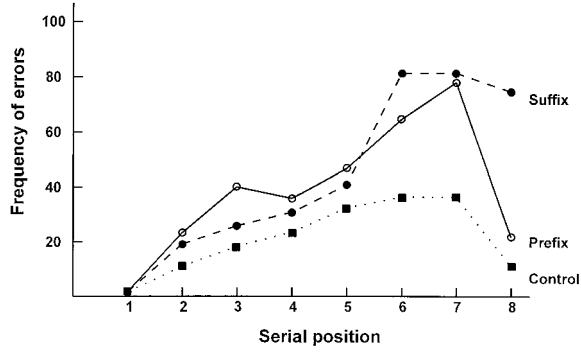

FIG. 7. Data redrawn from Crowder (1967), showing the effects of a response prefix and an auditory stimulus suffix on recall of auditorily presented list of digits.

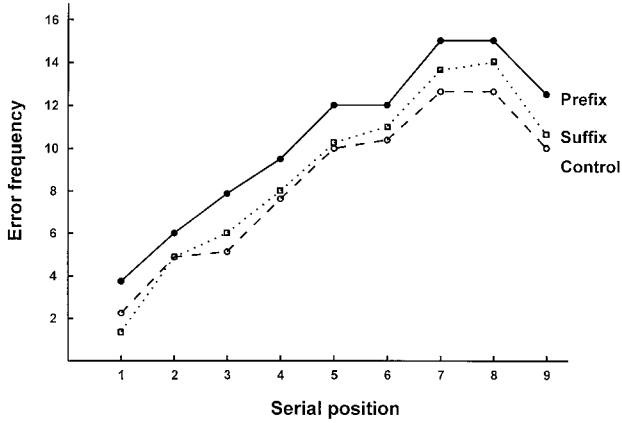

FIG. 8. Figure from Crowder and Morton (1969), showing the lack of serial position effect of an auditory stimulus suffix on recall of a visually presented list of digits.

effects in serial recall enshrined in PAS were actually post-categorical. Basically, the experiment compared the serial recall of 8-word lists, using either monosyllabic or quadrisyllabic words presented visually and auditorally. Watkins' argument was that if the modality effect was precategorical, then its extent should vary inversely with the acoustic length of the list items. Watkins and Watkins say: ``whatever the nature of the precategorical acoustic unit, long words will contain more of these units than short words, and hence the precategorical acoustic system will hold fewer long than short words'' (pp. 227–228). There should, then, be a modality effect over more serial positions with monosyllabic words than with polysyllabic words. The data showed a small overall effect of word length, a large recency advantage for the auditory lists, and no interactions. I was aware that something was wrong with the reasoning, but I did not feel that I had found the right argument at the time, when I was called upon to ask the first question in the discussion, without having seen the paper.

One problem is that a suffix, which completely removes the modality advantage, does not show a length effect (the vowel ``ah'' has as large an effect as ``recall''), nor a semantic effect. If conventional notions of capacity are appropriate, then a single vowel sound suffix could only remove the contents of PAS if that capacity is a single monosyllable. In fact, work by Crowder (1971) and Darwin and Baddeley (1974) indicates that the PAS effect is limited to the rime of the final syllable. Small wonder that there was no difference between the two word lengths.

Headed Records

My next major encounter with memory and the EPS came in Cambridge in 1980, when I gave the first paper on Headed Records, with Richard Hammersley and Debra Bekerian. The paper, called ``Do records have headings?''—basically an extension of Norman and Bobrow (1979)—was very theoretical, and I was rather apprehensive as to the way it would be received. When I finished, there was polite applause, and my heart sank some-

what. Then rescue was at hand. The first person to rise to ask a question was Pat Rabbitt. He started with the silky ``John, once again I must congratulate you . . .''—and I knew the day was saved. He had adroitly spotted that the theory was actually a framework—that is, that there were major aspects to it that could not be falsified—and he was objecting to that. It was, and still is, clear to me that all scientific theories have this feature—something that seems obvious only to physicists. So it was a feature we had actually discussed extensively, and I was able to lead off with, ``Pat, once again I must congratulate you on having understood one of the essential features . . .'', and the discussion took off on its amiable course.

As a footnote, we originally tried to publish the paper in *Cognitive Psychology*, treating Headed Records as a theory and claiming that we made predictions that current network theories could not make. One reviewer responded by showing how a particular network theory could be modified to accommodate our objections at all such points. They were not always elegant modifications, but they worked. Accordingly, we reworked the paper explicitly as a framework, with network models and schema models as contrasting frameworks, and using the material of the first referee as support. However, one reviewer of the second round called it ``Southern Californian soft-porn philosophy'', and we ended up re-rewriting the paper back to a model and changing journal to get a different set of reviewers (Morton, Hammersley, & Bekerian, 1985).

Another reason for mentioning Headed Records is that it is a framework within which some of the experiments described in the first section can be thought about. One feature of Headed Records is that a separate record is laid down for each event. Thus, if you are questioned about a previous event, the activities involved in the questioning will lead to the formation of a second record, accessible separately from the first. When tested later, one might access the record of the original event or the more recent one. In Belbin's (1950) experiment, there would be the original fragmentary registration of the picture, acquired incidentally as a part of the record of what happened in the waiting room. Recalling this picture would give rise to another record, augmented by Bartlettian reconstruction. When the subjects were presented with the original picture, then it was compared with the more recent record, the product of recall.

The studies by Davis and Sinha (1950a, 1950b) can be accounted for in a similar way. In this case the story was followed by the picture. When subjects attempted to recall the story, the conditions of the experiment led to the more recent record of the picture being retrieved. However, the recognition memory technique enabled the subjects to get back to the original record of the story, which was free from contamination from the picture. This is similar to the account given for the release from misinformation reported by Bekerian and Bowers (1983; see also Morton, 1991).

3. MOVING ON: THE CURRENT STATE BUFFER

The strongest trend through the last 50 years has been the internalization of memory—the move away from description of performance (initially information theory in this country, the verbal learning tradition in the States) to theorizing about internal structure. The early focus on schema, noted in Section 1, predated this trend. Since the mid-1950s,

the number of separable constructs has slowly been increasing under the pressure of dissociations in the data.[3]

The fragmentation in memory structures continues as we think increasingly about function in more natural environments. The latest in a long line is what I call the Current State Buffer. This is information about the current environment that is continually in need of updating on some time-scale or other. So, if we are travelling—to a conference, for example—we know what city or town we are in. If we close our eyes, we still know what room we are in, and if it had changed when we opened our eyes, we would be very surprised. Most of us know where our money is and whether we are wearing a watch. And if we were at home or in our office environment, there would be no problem in maintaining orientation, no matter how quickly we were moving from room to room. The opportunity for proactive interference is immense but does not happen.

In a group of people, if we close our eyes, we still know where other people in the group are. We keep track of where people are and update who is in the room, where they are, what they are doing; we can manage a number of people in this way. In addition, the location of key objects will be readily to hand. In other words, we have a mental construction of our local environment, where we track objects and individuals around.

It does not seem to me to be plausible that such a function would be shared by the other standard memory functions. What about the phonological loop? It seems that we can talk to someone without forgetting who they are or what part of the room they are in. And we can remember a telephone number for a minute without adverse affects on our social interactions. So the phonological loop does not seem to be a good candidate. However, as we will see, we have an experiment of classical design and conception to back up the intuition.

There are two things to do with a new construct. One is to use it to generate ideas, and the other is to test its independence. Let me talk now about the work of a couple of my students, which has already been presented in detail to the Society. First an experiment by Sofi Barreau (1995). The context is that of the Smarties Experiment, by now a classic experiment in the developmental literature.

The Bag Experiment

The experimental procedure is very simple. A three-year-old child is shown a Smarties tube and asked what she thinks is in it. The child will usually give the correct answer: ``Smarties''. Then the tube is opened and the contents are revealed as pencils. These are replaced in the tube, and the tube is closed.

``What is in the tube?'' the child is asked.

``Pencils'', comes the expected reply.

``What did you think was in the tube when you first saw it?''

``Pencils'', is the unexpected answer given by three-quarters of the young children.

[3] Another influence has been from psycholinguistics, where theorists have pointed out that the multiple structures needed for word recognition and language production would have properties that made them usable during memory experiments (e.g. Barnard, 1985; Monsell, 1984).

By the age of four, on the whole, there is no problem for the child in finding or constructing the correct answer. A large number of variations have been carried out on this theme. Let me summarize by saying that most people argue for some kind of competence short-fall—an inability to represent or create a false belief, for example (Gopnik & Astington, 1988; Perner, 1991).

This may well be the case, but it is nonetheless odd that children cannot simply remember how they represented things ten seconds ago. We tried to think about this situation in terms of the child's memory systems. First of all, a child who sees the tube will instantly create a representation of the tube and its (inferred) contents:

in(tube, Smarties)

This would, of course, be a part of the current state buffer, the tube and its contents being very much in the forefront of the child's attention. What would happen when the true contents are revealed? There would be a new representation:

in(tube, pencils)

As the current state buffer is a representation of the state of affairs here and now, we would have what is sometimes called ``destructive updating'', and the previous representation, *in(tube Smarties)*, would be wiped out. If the child is asked a question about her former beliefs concerning the tube, where would she get the information from? The answer she gives is that which can be found in the current state buffer. One hypothesis is that no permanent record was created before the updating of the current state buffer took place. If this was so, then there would be no way of retrieving the relevant information from event memory. On the other hand, we might be able to force the child to create a record of the initial state by changing the procedure slightly.

What determines when a new record is created? Our intuitions to date suggest that records are created when there is a change of context, and we hit upon the following: The child is shown the Smarties tube and asked about its contents. Then the top is taken off the tube, and its contents are emptied into a bag without the child being able to see them. The bag is closed. The top is put back on the tube, and it is put away.

At this moment, according to our intuitions, the child will have created a record containing the information that Smarties have been transferred from the tube to the bag. The current state buffer will now have in it:

in(tube, nothing)
in(bag, Smarties)

The child is then asked what she thinks is in the bag. The child will reply, ``Smarties''. The bag is then opened and the contents revealed. The Current State Buffer would then be updated, and *in(bag, Smarties)* would be replaced by *in(bag, pencils)* in order to represent the current state of the world.

The bag is then closed, and the child is asked ``What is in the bag?'', and ``What did you think was in the bag before I opened it?'' Most three-year-old children tend to make

the same error here as they do in the original Smarties tube experiment, but, then, the conditions are the same. The Current State Buffer has current information in it, and the previous information has been destructively updated. In Barreau's experiment, only 8 out of 24 children got this question correct.

Finally, the tube is produced, and the child is asked what she had thought was in it when she first saw it. Nearly all children remember that the tube is actually empty, and 15 out of 24 children can now remember their belief about the contents of the tube when they first saw it. The difference between the number of children correct on the bag and on the tube was highly significant. According to the theory (which led to the prediction) this is because, under the conditions of the experiment, the child had created an event record with information about the tube, which she was able to retrieve when questioned. There might have been destructive updating in the Current State Buffer, but information in the record would be preserved.

Our way through to this experiment was by thinking in terms of the Current State Buffer and how it might be used in a particular environment. The more traditional way of examining a construct is by testing its independence from other constructs. The most obvious question is the extent to which the Current State Buffer is independent of the components of the traditional Working Memory (Baddeley, 1986). How might we do this?

The basic design of the experiment is to hide a number of objects in containers of different kinds, in full view of the child. The child is then asked, ``Where is the X?'', for each object that was hidden. Under standard analysis of this task, the locations will be registered in one of the classical components of working memory, either the visuo-spatial scratch-pad, the phonological loop, the central executive, or some combination of these. It is possible, perhaps, that the child will create a special kind of dynamic memory for locations of objects. In any case, wherever such material is, it will not be in the same place as material in the Current State Buffer. What this means is that material in the Current State Buffer will not interfere with recall of the other material.

The technical question is how to establish material in the Current State Buffer. Recall that one idea for the Current State Buffer is that it is used to track significant parts of the environment. If this is correct, then the location of an object that has been made personally significant will be automatically tracked in this store. If you are instructed to remember the location of another object without it having been made significant, it will not be tracked in Current State Buffer.

The Tidy Emu Experiment

The experiment, designed and carried out by my student Paul Abeles had the following form (Abeles, 1997). On the table in front of a three- or four-year-old subject are a set of 3 or 4 objects and 7 potential containers. The objects include a car, a plastic brick, and, most important, a small Teddy. The containers include a covered basket, a sock, and a box. First of all the experimenter checks that the child knows names for all the objects and containers. What happens next depends on how Teddy is classified for the particular child. In various experiments the child either has Teddy-as-object or Teddy-as-character. In the latter case, the child is introduced to Teddy and interacts with him extensively, with the child being asked to repeat Teddy's telephone numbers (a device for measuring

the child's digit span). The three other objects are described as Teddy's toys. Then Teddy ``goes to sleep'' in one of the containers. A glove puppet called *Tidy Emu* then arrives and puts the three other objects away, each in its own container.

With the second group of children there is no focus on Teddy. In one condition the children are introduced to a baby lion, Simba, who plays the same role as Teddy in the first group, interacting with the child. Teddy remains on the table as an object, with no special attention paid to him. After the telephone number game is over, Simba ``goes away'', off the table and out of sight. *Tidy Emu* then appears and puts away Teddy, then the three other objects, in the containers. Children in both groups are then asked first for the location of the other objects in the order they were hidden and lastly for the location of the Teddy.

The casual observer might think that the group that was focused on Teddy will remember where he is but do much worse with the other objects, because of the relative lack of attention. In fact, not only did all the Teddy-as-character group remember where Teddy was, but they did significantly better than the Simba group on the other objects. The data are given in Table 1. They show that recall of Teddy-as-character is 100% for three-year-olds as well as for four-year-olds. These subjects also recalled correctly significantly more locations for the other objects. Thus, the attention to Teddy does not interfere at all with recall for the location of the other objects.

The problem that the Current State Buffer is designed to address, that of orientation in time and space, has not escaped the attention of others. Most recently, Baddeley (1986, chapter 7; Baddeley & Hitch, 1993) has suggested that the recency component of ``an active, multicomponent, working-memory system'' could serve this function. Note that there seems to be agreement that the phonological loop and the visuo-spatial scratch-pad are not involved here. Recency is also an important factor in the Headed Records model (Morton et al., 1985). In a formalization of the model (Morton & Bekerian, 1986), the first assumption of the theory (as opposed to the framework) is that ``Search is effectively serial and backwards in time''. Thus, the misinformation effect, referred to a number of times above, is a consequence of the prioritizing of the most recent exemplar of a particular search specification. This would not be seen as equivalent to the Current State Buffer. With recency in the working memory framework, retrieval is a probabilistic matter that results from the ``application of a very basic retrieval mechanism to an isolable memory store or memory domain'' (Baddeley & Hitch, 1993, p. 149). Contents of the Current State Buffer, on the other hand, are effectively guaranteed recall. The distinction

TABLE 1
Performance in the Tidy Emu Experiment

Group		*Number of Subjects/ 28 Recalling Teddy's Location*[a]	*Mean Number of Other Objects Correct*[b]
Experimental	Teddy-as-character	28	2.5
Simba	Teddy-as-object	15	1.5

Note: There were 14 three-year-olds and 14 four-year-olds in each group (data from Abeles, 1997).
[a] Difference between the groups, $\chi^2 = 11.31$, $p < .008$.
[b] Difference between groups, $F = 19.84$, $p < .001$.

between the two is clearly capable of experimental refinement, and the EPS will be the first to know what is happening.

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Original manuscript received 3 January 1997
Accepted revision received 23 June 1997