Working Memory and Language Processing

A brief account of the concept of working memory is presented, followed by a more detailed description of one sub-component of the system, namely the phonological loop. The question of the functional significance of this component of working memory is discussed. Evidence suggests a minor role in language comprehension, together with a much more substantial role in the capacity to acquire novel phonological, and possibly grammatical forms. It is suggested that the phonological loop has evolved as a mechanism for language acquisition.

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In his classic work *Principals of Psychology*, William James (1890) proposed to distinguish between what he termed *primary* and *secondary* memory. The former was assumed to reflect material held in a temporary form so as to be readily accessible to conscious awareness, while the secondary system was assumed to reflect a much more durable system for the long term storage of information. Many years later, Donald Hebb (1949) speculated that the temporary system might reflect the electrical activity of the brain, while the more durable seat of long term memory was probably based on more permanent neurochemical links, a view that has been revived in recent years and implemented in a range of neural network models, for which the term Hebbian's Learning represents one possible representation of the process of acquisition.

At an empirical level, long term learning formed an active area of research throughout this century (Bartlett, 1932; McGeoch & Irion, 1952; Crowder, 1976), whereas the more temporary or short-term system received comparatively little attention until the late 1950's, when Brown (1958) in England and Peterson and Peterson (1959) in the US first reported that even small amounts of information would show marked forgetting over a matter of seconds if the subject were prevented from active rehearsal by a simple task such as counting backwards. They proposed that their results reflected the operation of a short-term memory store (STM) which differed from long-term memory (LTM) in being based on a memory trace that would spontaneously fade within a matter of seconds unless maintained by rehearsal.

The 1960's saw a period of intense controversy, with some arguing that the new results were entirely compatible with existing unitary theories of memory (e.g., Melton, 1963), while others argued for a two component view, while accepting that any given experimental task may well show the simultaneous evidence of both components (Waugh & Norman, 1965). By the late 1960's, the evidence seemed to be favouring a dichotomous view; many models were proposed, but the most influential and probably most characteristic was that of Atkinson and Shiffrin (1968), which consequently became known as the *modal model*. This proposed that information passed through a parallel series of sensory memory systems that are essentially part of the processes of perception, before entering a limited capacity *short-term store* from which information faded unless rehearsed. The store was capable of encoding and elaborating the information, and was responsible for feeding it into and out of the *long-term store*. The probability of transferring an item from short to

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long-term storage was assumed to be a simple function of how long the item stayed in the short-term system.

Probably the strongest evidence for a dichotomous view came from the study of patients with neuropsychological deficits. The classic amnesic syndrome is one in which patients appear to have lost the capacity to lay down new memory traces although they may retain the capacity to recall memories from the time before their amnesia. Such patients, however, typically have preserved immediate memory span as reflected in their capacity to repeat back a string of numbers such as a telephone number, or, provided they are intellectually otherwise intact, they may well be able to perform normally on the Brown-Peterson Short Term Forgetting Task mentioned earlier (Baddeley & Warrington, 1970). They appear in short, to have impaired LTM but preserved STM. The second type of patient was reported by Shallice & Warrington (1970), showing the opposite pattern of memory performance. The patients suffered from what would probably have previously been categorised as *conduction aphasia*, but showed a pattern of behaviour that was consistent with the hypothesis of a very specific STM deficit, with extremely rapid forgetting on the Brown-Peterson task, coupled with a digit span limited to one or two items, while at the same time showing apparently normal LTM performance.

Although the Atkinson and Shiffrin model initially appeared to give a good account of the data, problems rapidly began to appear. One concerned the assumption that maintaining items in STM was enough to guarantee learning. Evidence failed to support this (e.g., Bjork & Whitten, 1972) resulting in an influential paper by Craik and Lockhart (1972) proposing their *levels of processing* hypothesis, whereby the probability of long term retention of an item was a function not of the frequency of rehearsal, but of the depth at which it was processed. Hence if a word were processed only in terms of its visual appearance, a very short duration trace would result, whereas processing the sound of the visually presented word would lead to somewhat more durable learning, while the deeper process of encoding the meaning and relating it to existing knowledge, would produce an even more durable trace.

A second problem for the modal model was implicit in the data from the patients with an STM deficit. If this limited capacity store played a crucial role in long term learning, then surely a deficit to that store should lead to impaired learning, and indeed to impairment in a wide range of other tasks such as comprehension and reasoning for which the limited capacity STM was assumed to provide a crucial link. This was clearly not the case: not only did such patients show excellent long term learning, but they appeared to have remarkably few problems in their everyday life, one was a successful secretary, while another ran a shop and a family.

In the early 1970's, a colleague, Graham Hitch and I set out to tackle this problem. We did not have access to suitable patients, and so simulated them by providing "functional lesions" for our undergraduate subjects. We did this by requiring our subjects to remember sequences of digits, at the same time as they were performing a range of tasks such as learning, reasoning and comprehending, that were assumed by the modal model to depend upon a limited capacity short-term store. If the model was correct, then the longer the digit sequence the subject was maintaining, the less STM capacity would remain, and the greater the impairment on the reasoning or learning task.

The results were consistent across a range of studies, suggesting that longer digit sequences did indeed cause impairment, but this was by no means as dramatic as the model would predict. When our subjects were maintaining eight digits, the limit of their capacity, they were taking about 50% longer to perform a reasoning task, but were still keeping the error rate constant at well below 10%. On the basis of these data we proposed to abandon the idea of a unitary STM system, postulating instead a multi-component system which we labelled *working memory* (Baddeley & Hitch, 1974).

The tripartite model we proposed suggested that the system was controlled by a limited capacity attentional system, the *central executive*, aided by two slave systems, the *articulatory* or *phonological loop* which maintained acoustic or speech based information, and the *visuo-spatial scratch pad* or *sketch pad* which performed a similar function for visual and spatially encoded material. The digit span task was assumed to rely principally upon the phonological loop, the system that was also assumed to be impaired in the STM patients studied by Shallice and Warrington. Long-term memory was not dramatically affected in such patients because the central executive and visuo-spatial systems were intact. Similarly concurrent digit span would principally disrupt the phonological loop, having a much smaller effect on the crucial executive processes that set limits to reasoning and learning.

Over the last twenty years, this relatively simple model has proved remarkably useful in providing a framework for tackling a wide range of questions relating to the role of working memory in cognition. It has provided a spring board for analysing activities ranging from day dreaming (Teasdale et al., 1995) to chess playing (Robbins et al., 1996) and has been applied to a wide range of subject populations, from learning-disabled children (e.g., Hulme & MacKenzie, 1992) to expert mnemonists (Ericsson & Kintsch, 1995). For present purposes, however, the discussion will be limited to the role of working memory in language, with particular attention to the function of the phonological loop.

Spoken language, by its very nature demands memory for its adequate comprehension, and at one point it was suggested that an important role of STM was to hold sentence-length chunks of speech, thus allowing them to be syntactically and semantically analysed (Clarke & Clarke, 1977). Such a view would predict massive problems in spoken comprehension in patients with STM deficits, leading to a range of studies on comprehension in such patients. In one characteristic study, Vallar and Baddeley (1984; 1987) tested PV, a patient with a phonological memory deficit on the task of comprehending sentences of three types. The first comprised simple statements about the world that PV had to classify as true or false, for example, *rabbits have ears* or *donkeys have wings*. The second type of sentence was essentially equivalent, but was extended by adding verbiage *it is commonly believed that rabbits belong to the class of creatures which typically possess ears*. The third class of material was designed intuitively so as to demand retention of the surface characteristics of the sentence over a considerable number of intervening words, as in *ships, it is said are typically lived on by sailors as part of their occupation or sailors, it is said are often lived on by ships as part of their occupation.* PV had no difficulty in responding rapidly and correctly to the first two types of sentence, but performed at chance with the more complex reversible sentences. She could, however, respond correctly when the sentences were shortened to give *ships are lived on by sailors,* or *sailors are lived on by ships*. However, although this is a typical result (see Vallar & Shallice, 1990, for a review), other patterns have been observed. Hence, Butterworth, Campbell and Howard (1986) described a patient with a developmental STM deficit who appears to perform remarkably well on prose repetition and comprehension (see Howard & Butterworth, 1989; Vallar & Baddeley, 1989, for a discussion of this case). At the other extreme, Baddeley and Wilson (1988) describe case TB, a professional mathematician who was intellectually well preserved apart from a marked STM deficit, possibly associated with an epileptic episode. He could process short sentences perfectly, but failed when the same syntactic structure was used, but padded with extra words. Hence when asked to point to the appropriate one of four illustrations in response to the sentence *The girl is pushing the horse* he was correct, but was unable to cope with a "padded" version such as *The girl with long blonde hair is busily pushing the large brown horse*.

We were able to revisit TB some years later, by which time his digit span had completely recovered to an impressive nine digits, and with it his capacity to comprehend (Wilson & Baddeley, 1988). There was however still some slight evidence of a phonological deficit reflected in his difficulty in performing certain complex phonological tasks, such as the spoonerism test whereby a subject must switch the initial consonants of someone's name, hence given *Margaret Thatcher* they should respond *Thargaret Matcher*.

It is however, important to emphasise that patient PV who shows difficulty only in carefully selected complex sentences is far more typical than either of the latter two patients (Vallar & Shallice, 1990). What are the implications of such results for the role of the phonological loop in language comprehension? One possibility is that comprehension does place demands on the phonological loop, but that given the fact that language is redundant, then supplementary syntactic and semantic information is sufficient to boost the capacity of the phonological store to a point at which comprehension becomes possible for all except particularly demanding sentential material. Support for this view comes from the fact that patients who have a span of only one or possibly two unrelated words can typically repeat back *sentences* of five or six words. On this interpretation one might suggest that the typical patient has severely reduced phonological storage, but that sufficient storage remains to provide sentence comprehension under most circumstances, whereas TB perhaps has an even more serious STM deficit. Unfortunately this is difficult to test, since our capacity for the precise measurement of span at these very impaired levels is not well developed.

An alternative interpretation that is probably more widely held proposes that the phonological loop is not necessary for most straightforward comprehension, which essentially operate on-line; however, with particularly complex material, or with ambiguous or garden-path sentences, it may be helpful to use the phonological loop as a backup, allowing the subject to do a "double take" on what has just been said. This is the modal view as reflected in the symposium convened by Vallar and Shallice (1990). It attributes a useful but rather modest function to the phonological loop, one that scarcely justifies the amount of attention that has been given to the system and to tasks such as digit span which purport to measure it. In this respect it is consistent with the rather limited degree of everyday handicap shown by patients with specific STM deficits.

There is however another side to the story. The fact that digit span forms a component of many measures of intelligence from the Stanford Binet onwards suggests that it is a measure that practitioners find useful. It is indeed the case that reduced digit span provides one of the most prominent markers of developmental dyslexia (Miles, 1978). Perhaps the system is particularly important for children who are in the process of acquiring language. An adult who has already developed a rich and complex language system may perhaps no longer need the phonological loop, unless further language learning is required. On this hypothesis then, the phonological loop has evolved as a mechanism for facilitating new phonological learning.

We decided to test this by asking our STM patient PV to attempt some new phonological learning in the form of Russian equivalent of words in her native Italian (Baddeley, Papagno & Vallar, 1988). We contrasted this with her capacity to learn to associate pairs of words in her native language, a task that we know typically depends upon semantic rather than phonological coding. The results were very clear. Her capacity to associate pairs of familiar words was just as good as that of control subjects matched for age and education. On the other hand, after ten trials, whereas control subjects had typically mastered the full list of eight Russian vocabulary items, PV had not mastered a single one. Our results thus provided strong support for the hypothesis of the phonological loop as a device that has evolved to facilitate the acquisition of new phonological forms, and hence an important part of the system for acquiring language. A detailed discussion of this hypothesis and the related evidence is provided by Baddeley, Gathercole and Papagno (In press). A briefer account is given below.

While this result seems to offer a promising hypothesis, it was based on what was basically one day's testing of a single highly unusual subject. Given the importance of the conclusion for the working memory model, it was clearly necessary to replicate. Unfortunately, we did not have access to a second subject with such a pure phonological memory deficit. We therefore set out to generalise our result and test it in other ways.

One opportunity occurred a few years later, when on sabbatical in the US, I discovered that one of the graduate students I was teaching, SR, reported having a much reduced memory span. At four digits, it was of course substantially greater than that shown by our patient PV, but when his learning performance was compared with that of fellow graduate students, his phonological, but not visual span was consistently reduced, and more importantly, this was associated with problems in learning the vocabulary of an unfamiliar language. He was not dyslexic but had very poor spelling, and despite extensive efforts to master a second language as a university entrance requirement, had failed to do so (Baddeley, 1993).

The second means of further testing our hypothesis was to attempt to disrupt the operation of the phonological loop in normal subjects, predicting that this would impair the acquisition of new vocabulary items much more substantially than it would harm the capacity to learn to associate meaningful words in the subject's native language. Papagno, Valentine and Baddeley (1991) therefore presented their subject with the two paired associate learning tasks used with PV, namely learning to associate pairs of native language words, and native language-Russian vocabulary learning, both tested under control conditions and under conditions whereby the phonological loop was interfered with by the requirement to suppress articulation. As predicted, this manipulation had little or no effect on associating meaningful words, a task that tends to rely on semantic coding, while having a marked negative effect on foreign language acquisition. In a subsequent series of studies, Papagno and Vallar (1992) studied the impact on the learning of word pairs and foreign language vocabulary of word length and phonological similarity, two variables that are known to have a marked influence on phonological immediate memory. Both manipulations impaired the learning of novel vocabulary items but not meaningful paired associate learning.

In two further studies, Papagno and Vallar took advantage of individual differences to further test the hypothesis. One study showed that polyglot subjects, who had mastered several languages, had significantly greater memory spans than subjects of an equivalent educational level who had mastered no more than one foreign language (Papagno & Vallar, 1995). A second study (Vallar & Papagno, 1993) was concerned with a young woman with Down's syndrome, who unusually for this condition, appeared to have very good language capacity. Her parents had lived abroad, and in addition to her native Italian she spoke English and French. Although her non-verbal intelligence was well below that expected by her age, her digit span was within the normal range, and when given the task of learning the Russian vocabulary items, she performed just as well as normal subjects. In contrast however, her capacity to associate words in Italian, her native language, was substantially impaired, presumably reflecting her more general cognitive deficit.

Both these latter studies are consistent with the hypothesis that the phonological loop is necessary for the long-term learning of new phonological forms, such as is required for mastering vocabulary of a second language. Further evidence for this is provided by Ellis and Beaton (1993) in a study in which students were required to learn the vocabulary of a foreign language under varying strategies. In particular visual imagery and rote rehearsal were contrasted. While visual imagery was preferable when the task was to translate *from* the foreign language into the native tongue, when the subject had to be able to articulate the foreign word, then rote rehearsal proved preferable, implicating the phonological loop in acquiring productive vocabulary.

The evidence we have discussed so far has been concerned almost exclusively with the capacity of adults to acquire the vocabulary of a second language. The evidence is consistent with the hypothesis that the phonological loop may be important for children for acquiring their native language, but certainly does not require this, since many features differentiate the two situations. Second language is typically done explicitly while children tend to absorb their first language implicitly through immersion in the language culture. The state of development of the child's nervous system is clearly very different from that of an adult, with the likelihood that language may be subject to sensitive periods during which acquisition is particularly strongly favoured. Finally, the studies we have described typically involve relatively small amounts of learning, whereas the child is acquiring an enormous amount of new information at a remarkably rapid rate.

Fortunately, at the same time as studies of PV were being performed, Gathercole and Baddeley (1990) were beginning to investigate vocabulary learning in both normal children and in those with specific language impairment (SLI). Our SLI study focused on a group of six children who had been identified as having normal non-verbal intelligence, together with a language delay of approximately two years. We began by giving them the Goldman Fristoe Woodcock test of verbal memory, observing that one particular sub-test showed particularly marked degree of impairment. This was the sub-test known as *sound mimicry*, in which subjects heard a one or two syllable nonsense item and attempted to repeat it. Our eight-year-old subjects, who had the language capacity of six-year-olds performed like four-year-olds on this measure, suggesting that it might be tapping a crucial component of language development. We were however somewhat unhappy with the test itself, and with the help of a psycholinguistically sophisticated colleague, developed the non-word repetition test (Gathercole, Willis, Baddeley & Emslie, 1994), which involved presented pseudo words ranging in length from one to four syllables, and requiring the subject to repeat them back. We found that performance declines with length of sequence (as in the case of digit span), with the SLI subjects performing more poorly than either children of the same age and nonverbal intelligence, or of younger children matched with the SLI group on verbal intelligence (Gathercole & Baddeley, 1990). Simple tests of auditory discrimination and of speed of articulation suggested that neither of these factors showed any marked impairment in our SLI children, whereas memory span for familiar words was impaired, suggesting that impaired phonological storage presented at least one plausible hypothesis of our findings.

Our data so far then are consistent with the hypothesis of a crucial role for phonological memory in language acquisition in children, at least to the extent that gross impairment may be associated with gross language deficiency. That does not of course necessarily imply that differences within the normal range will be of any significance. To investigate this, Gathercole and Baddeley (1989) studied a group of children at starting school age between four and five years, measuring their performance on the non-word repetition test, their intelligence as measured by Raven's Matrices, and their vocabulary. This was estimated using the British Picture Vocabulary Scale (BPVS) in which subjects are shown four pictured objects, one of which is named by the tester, with the child being required to point to the item named. We observed a substantial correlation between non-word repetition and vocabulary, a correlation that remains when the effects of IQ and differences in age within the group are partialled out. The original sound mimicry measure was also significantly associated but to a lesser extent, an association that was eliminated when NWR score was partialled out.

We followed up this group over the next four years, and at the same time began studying a parallel group in another city (Gathercole, Willis, Emslie & Baddeley, 1992). Both studies showed a clear association between vocabulary and non-word repetition, across a range of ages.

It is of course, important not to assume that correlation demonstrates causation. In the present instance, our assumption that a good NWR performance, implying good phonological memory causes good vocabulary acquisition, is intrinsically no more plausible than the opposite assumption, namely that subjects who have rich vocabularies can use them to help performance on the non-word repetition task. One way of attempting to tease apart these two possible causal pathways is to use cross-lagged correlation, in which the relevant variables are measured at two successive points in time. If variable A causes a change in variable B, then there should be a stronger association between A at Time 1 and B at Time 2, than between B at Time 1 and A at Time 2. In the case of our four-year-old children,non-word repetition at four did predict vocabulary a year later significantly more highly than vocabulary at four was able to predict non-word repetition at five (Gathercole, Willis, Emslie & Baddeley, 1992).

As children grow older however, the pattern changed to a more equal degree of association between the two measures one year and the next, suggesting a more interactive process whereby, once vocabulary reached a critical level, it began to contribute to non-word repetition performance just as strongly as factors underlying non-word repetition led to the acquisition of new vocabulary. Indeed, it seems likely that adult vocabulary is determined by many factors other than simple phonological memory capacity. One factor is likely to be the extent to which the speaker is exposed to new words, something that will be associated with level of educational achievement. Another factor is likely to be the extent to which the subject can work out the meaning of a novel word from the context in which it is encountered, something that is likely to depend on general intelligence. Bearing that in mind, it is not perhaps too surprising that a highly intelligent subject such as SR should have an excellent vocabulary, despite having poor phonological memory (Baddeley, 1993).

A second way of assessing the importance of causation is to attempt to model the process of vocabulary acquisition experimentally. This was attempted by Gathercole and Baddeley (1990b) in a study requiring children to learn the names of a set of toy monsters. Half of the names were familiar such Peter and Michael, while half comprised unfamiliar combinations of the same phonemes such as Pichael and Meeton. Two groups of children were selected from the school population, being matched for non-verbal intelligence, but differing in non-word repetition performance. As predicted, the low NWR group were significantly slower at acquiring the unfamiliar names.

In a much more extensive and naturalistic study, Service (1992) investigated the factors predicting the capacity of young Finnish children to learn English over a two-year period. She observed that the strongest predictor proved to be a non-word repetition task involving pseudo-English words. The capacity to repeat back non-words resembling Finnish proved to be a less good predictor of subsequent language acquisition, a result that is consistent with later work by Gathercole (1995), who notes that although non-words resembling English are easier to repeat back accurately, subsequent language development is better predicted by the non-words that are rated as less like English in their phonological structure. This in turn leads on to the question of the processes and mechanisms underlying non-word repetition performance. We will return to this issue after discussing the extent to which non-word repetition and the phonological loop may be assumed to underlie other aspects of language acquisition, including that of syntax.

Since the classic work of Chomsky (1965), attempts to understand the nature and acquisition of grammar have formed an important topic within developmental psycholinguistics. The early controversy tended to be dominated by a relatively extreme polarisation between a nativist view that syntax represented the flowering of an innate language organ, as opposed to a simplistic learning hypothesis based on Skinnerian stimulus-response associations. This period seems now to have passed, with the general acceptance that the brain clearly has evolved in such a way as to make language acquisition possible, while the wealth of different languages points to the need to assume that the particular grammar of a specific language develops as a result of learning. It is entirely plausible to assume that syntax, which is based on rules that extend across several words or utterances will require the storage of the relevant material, and that the phonological loop might play an important role in this task. What however is the evidence for such a view?

The issue has been investigated much less extensively than that of vocabulary. There is however evidence for association between non-word repetition and performance on the Test for the Reception Of Grammar (TROG), in which the subject listens to a sentence and attempts to point to the one of four pictured scenes that match the sentence. The test begins with simple active declarative sentences, increasing steadily in complexity so as to test negatives, passives and more complex syntactic structures such as self embedded sentences. However, while children with poor non-word repetition do poorly on this task (Gathercole, Willis, Emslie & Baddeley, 1992) patients who have acquired a short-term phonological memory deficit as a result of brain damage also do poorly at such a test, despite showing no evidence for grammatical impairment (Baddeley & Wilson, 1988), making it difficult to interpret such a result unequivocally.

More convincing is a subsequent study by Gathercole and Adams (1993), which examined the spoken language of two groups of three-year-olds, matched for non-verbal intellectual capacity but differing in NWR performance. Low NWR children exhibited significantly less rich language skills as measured by measures such as syntactic complexity and mean length of utterance.

Evidence is also beginning to accumulate from second language learning, to indicate that the phonological loop may be involved in syntax as well as semantics. The previously described study by Service (1992) found for example that the capacity to repeat back unfamiliar English non-words predicted not only vocabulary, but language acquisition more generally. In the case of adults learning Welsh as a second language, Ellis and Sinclair (1996) showed that requiring subjects to rehearse enhances the acquisition of receptive and expressive knowledge of both phonological and syntactic features of the second langauge. Finally, in an as yet unpublished study, Andrade, Kolodny and Baddeley studied the capacity of subjects to learn an artificial grammar, in which certain sequences of items tend to occur frequently, while others are not permissible (Reber, 1989) we used Chinese words that were selected so as to phonologically similar to each other in one condition and dissimilar in the other. As predicted by the phonological loop hypothesis, subjects exposed to the similar sequences were less good at categorising subsequent strings as "grammatical" or "ungrammatical" than those who had experienced sequences of dissimilar items. Evidence for the role of the phonological loop in the acquisition of grammar therefore appears promising, but clearly requires further investigation.

We have so far discussed the non-word repetition task as though it were a simple and generally accepted measure of short-term phonological memory. It is important to bear in mind that this is not the universally agreed view of non-word repetition, nor of course were Gathercole and Baddeley the first people to note the association between non-word repetition and other language skills, as the presence of this sub-test in the Goldman et al. battery suggests. In particular Snowling (1981) noted the poor performance on non-word repetition of children with reading difficulties, interpreting it as one of many possible measures of an underlying phonological processing deficit. Snowling, Chiat and Hulme (1991) suggest that non-word repetition measures the general level of phonological development, rather than phonological storage. Gathercole and Baddeley (1993) prefer the storage assumption, while accepting that other interpretations are possible.

There is no doubt that non-word repetition is a complex task involving perception, storage and production of speech sounds, each of which in turn may be broken down into a number of sub-processes. The process of phonological memory itself also is likely to involve encoding, storage and retrieval processes, which may or may not be equivalent to those implied by Snowling et al. If we are to make progress, then it is important to move beyond general terms such as "level of phonological development" to test more specific hypotheses regarding these processes, and their mapping onto the as yet little understood mechanisms of short-term phonological memory in children. I would see this as an area of likely development in the next few years, but in the meantime, would suggest that, although non-word repetition is turning out to be a very productive clinical tool, its detailed theoretical interpretation remains equivocal.

Fortunately however, there is much less doubt about the interpretation of the extensive data from neuropsychological cases and from normal subjects in whom the operation of the phonological loop has being disrupted by articulatory suppression, word length or phonological similarity. I can see no way in which the whole range of data can be explained by a hypothesis of general phonological impairment. Patient PV shows no evidence of language perception or production problems. It is also hard to see how the data from vocabulary learning in normal subjects can be interpreted as reflecting impaired general phonological processing, whereas the working model gives a precise and accurate account of the influence of articulatory suppression, phonological similarity and word length. Since the phonological loop hypothesis gives a very good account of these data, together with that of developmental deficits, it is surely to be preferred on the grounds of the range of phenomena it is capable of explaining, and its coherence within the working memory framework. In the meantime, it is important to continue to investigate the mechanisms and processes underlying the observed association between non-word repetition and language acquisition, an enterprise that will I am sure continue to throw light on the subtle interrelations between memory and language.

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