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Phonological Short-term Memory and the Learning of Novel Words: The Effect of Phonological Similarity and Item Length

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Phonological Short-term Memory and the Learning of Novel Words: The Effect of Phonological Similarity and Item Length

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The investigation of a patient with a selective impairment of phonological short-term memory has recently provided evidence that this system may be involved in long-term learning of novel words, for which a pre-existing semantic representation is not available (Baddeley, Papagno, & Vallar, 1988). The present series of experiments in normal subjects explored this hypothesis. We assessed the effects of phonological similarity and item length, which reflect the operation of the phonological short-term store and the rehearsal component of verbal memory, upon paired associate long-term learning of auditorily presented words and non-words. Phonological similarity affected the learning of novel words more than known words (Experiment 1); when a delay was interposed between presentation and recall, the disruptive effect was confined to novel words (Experiment 2). Also word length disrupted the learning of novel words, but not of known words (Experiment 3). These results tie in with neuropsychological evidence to suggest a role for phonological short-term memory in the learning of new words, and they have developmental implications for the study of language acquisition.

Neuropsychological studies of patients with selective impairments of auditory–verbal short-term memory have provided clear evidence that such a deficit does not necessarily disrupt long-term learning and retention, as predicted by the serial models of memory function developed in the late 1960s (Atkinson & Shiffrin, 1968; Waugh & Norman, 1965).

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Patients with a grossly reduced auditory–verbal span may show an entirely normal performance in a range of tasks assessing long-term learning and retention, such as paired-associate learning and short story recall (Basso, Spinnler, Vallar, & Zanobio, 1982; Shallice & Warrington, 1970). In addition, tests of immediate free recall of auditorily presented words, which assess long-term and short-term components of memory, show that these patients may have normal performance in the early portion of the list, reflecting that long-term memory function has been preserved. By contrast, list recency, which represents the output of the phonological (auditory–verbal) short-term store is typically absent or reduced (Basso et al., 1982; Vallar & Papagno, 1986; Warrington, Logue, & Pratt, 1971). That short-term storage is not necessarily required for long-term learning and retention is also suggested by evidence from normal subjects indicating that the length of an item's stay in short-term memory is not related to long-term learning (Craik & Watkins, 1973). Taken together, these neuropsychological observations and these findings in normal subjects suggest a functional architecture where information has parallel and independent access to short-term and long-term verbal memory systems (Shallice & Warrington, 1970).

However, the empirical data base upon which this conclusion is founded is limited to meaningful material, such as the lists of unrelated words used in free recall tasks and the passages of prose of a short story. These meaningful stimuli have pre-existing lexical–semantic representations in long-term memory. Such representations may suffice for efficient learning, even in the more or less complete absence of short-term storage capacity, which, in these specific instances, may not be crucial. This may not necessarily be the case for material such as non-words, or words of a foreign language unknown by a given individual, or words unknown to a growing child. As, in the case of non- or novel words, pre-existing lexical–semantic representations are not available, it is possible that for such items long-term learning requires short-term storage.

Neuropsychological evidence that this may indeed be the case has been provided by Baddeley, Papagno, and Vallar (1988). They have shown that in patient PV the selective deficit of the phonological short-term storage component of verbal short-term memory dramatically disrupts learning of novel words, as assessed by a word–word paired-associate task, where the second item was a Russian word unknown to the patient. PV's learning performance in a classical word–word paired-associate task was, by contrast, entirely preserved.

Similarly, Gathercole and Baddeley (1989a) have recently shown in 4- and 5-year-old children a close correlation between the acquisition of vocabulary and immediate repetition of auditorily presented non-words, a task that is likely to require the temporary storage of the non-word.

If indeed temporary storage in phonological memory is needed for the stable acquisition of novel words, it follows that the variables that are known to affect immediate verbal memory in normal subjects should also selectively interfere with non-word learning. For instance, it is known that the concurrent articulation of an irrelevant speech sound (e.g. "the, the, the") significantly reduces recall performance in immediate memory tasks, disrupting the subject's ability to rehearse the memory items stored in short-term memory (e.g. Baddeley, Lewis, & Vallar, 1984; Baddeley & Lewis, 1984; Baddeley, Thomson, & Buchanan, 1975; Levy, 1971). Some relevant evidence comes from recent work by Papagno, Baddeley, and Valentine (1989), who found selective interference by articulatory suppression on the learning of non-words, but not of real words.

In the present series of experiments we have addressed this issue by assessing whether two widely investigated short-term memory effects (the phonological similarity effect and the word length effect) influence the learning of novel words. It has long been known (see Baddeley, 1966a; Conrad, 1964; Conrad & Hull, 1964; Wickelgren, 1965) that immediate memory span for phonologically similar letters or words is lower than for dissimilar ones (e.g. *B, C, T, G*, vs. *F, K, Z, R; cat, can, cap, cad*, vs. *cow, day, bar, few*). This detrimental effect of phonological similarity among the items to be retained reflects the phonological nature of the code available to immediate verbal memory, and the suggestion has been made that in the case of similar items more storage capacity is required (Sperling & Speelman, 1970). Were storage in phonological memory required for the learning of non-words, a disruptive effect of phonological similarity would be predicted. This interference should not extend to real words, which may use lexical–semantic codes, available in long-term storage (see Baddeley, 1966b).

A similar line of reasoning may be applied to the effect of word length, whereby immediate memory span is greater for short words than for long ones. This effect, which is abolished by articulatory suppression, reflects the time-limited activity of an articulatorily based component, which may store and rehearse more short than long words (Baddeley et al., 1975, 1984). Were articulatory rehearsal required for the learning of novel words, detrimental effects of item length, not extending to real words, would occur.

The verbal short-term memory model adopted in this study (see Salamè & Baddeley, 1982; Shallice & Vallar, 1990; Vallar & Baddeley, 1984) comprises two sub-components: (a) a phonological short-term store, non articulatory[1]

[1]A discussion of the nonarticulatory nature of the phonological short-term store, suggested by both normal and neuropsychological evidence, is beyond the scope of this paper and may be found in Shallice and Vallar (1990). An observation relevant here is the selectivity of the effects of articulatory suppression upon phonological similarity. The detrimental effects of phonological similarity upon immediate retention are not abolished by suppression in the case of auditory input, suggesting that auditory material has access to a nonarticulatory store. When input is visual, the phonological similarity effect is disrupted by suppression, suggesting that phonologically recoded items are conveyed to the phonological short-term store via the rehearsal process.

in nature, to which auditory stimuli, encoded phonologically, have direct access; (b) an articulatory rehearsal process that refreshes the phonological trace held in the phonological short-term store, preventing its decay. The phonological similarity effect reflects the phonological nature of the code of this temporary storage system; the word length effect, abolished by articulatory suppression, reflects the activity of the articulatory rehearsal component.

The role of the phonological short-term store and of the rehearsal process in learning of novel words was investigated by assessing the effects of phonological similarity (Experiments 1 and 2) and of item length (Experiment 3) on learning performance in a paired-associate paradigm. The selectivity of the effects of these variables upon learning of novel words was assessed by having a control condition in which subjects were required to learn real words.

EXPERIMENT 1

Method

Subjects. Twenty-four Italian subjects, postgraduate students and medical doctors (16 females and 8 males, mean age 31.5 years, range 22–43 years) took part in the experiment.

Materials. Four lists of paired associates were prepared, each comprising eight pairs. In all four lists the stimulus member of the pair was a two-syllable word. In two lists also the response member of the pair was a two-syllable word: In one list responses were phonologically dissimilar [e.g. "*volpe*"–"*segno*", ("fox"–"sign"), "*piede*"–"*zona*", ("foot"–"zone")], in the other similar [e.g. "*bomba*"–"*conto*" ("bomb"–"account"), "*gatto*"–"*collo*" ("cat"–"neck")]. In two lists, the response member of the pair was a two-syllable (4–6 letters) pronounceable non-word, phonologically similar in one list [e.g. "*bocca*" (mouth)–"*zuro*", "*tetto*" (roof)–"*zibro*"], dissimilar in the other [e.g. "*dente*" (tooth)–"*faglio*", "*pesce*" (fish)–"*berba*"]. Non-words were constructed by changing one letter of a real word [e.g. "*taglio*" (cut) became "*faglio*", "*libro*" (book) became "*zibro*"]. The phonologically similar words and non-words had identical initial and final letters. The real words had a frequency greater than 10.2 per million (VELI, 1989). The stimuli are listed in Appendix 1.

Procedure and Design. The eight pairs were read out at a rate of one item per second, with a 2-sec gap between pairs and a 5-sec gap between the last pair and the first test stimulus. Responses were spoken and subjects were allowed a maximum of 7 sec per response. There was a maximum of five trials (presentation and recall sequences) per list, and the trials were terminated if the subject recalled all eight associates correctly in two successive trials. In each trial the presentation and recall lists were presented in a random fixed order. A 2 × 2 within-subjects design was used. The order in which the subjects carried out the four experimental conditions was counterbalanced using a Latin square design. In each trial, the score was the number of correctly recalled response words in the list (range 0–8), with a criterion of two successive lists recalled entirely correctly. If a subject reached the criterion of two lists recalled correctly before the fifth trial, the maximum score (8) was entered for the remaining trials for the purposes of analysis.

Results

Figure 1 shows the learning curves for words and non-words. It is apparent that subjects learnt both words and non-words, that overall level of perform-

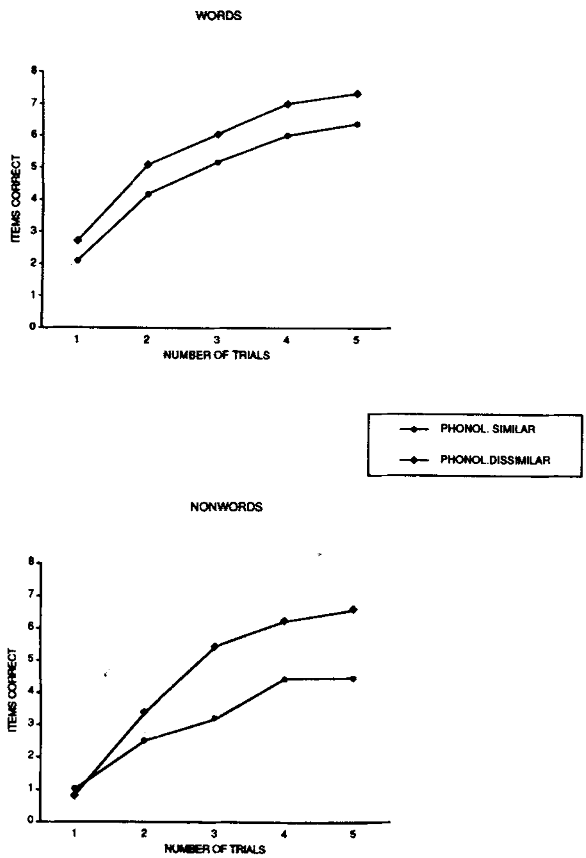

FIG. 1 Experiment 1. Paired-associate learning of auditorily presented phonologically similar and dissimilar word and non-word items (for means and standard deviations see Appendix 3: Table 1).

ance was higher in the case of words, and that phonologically dissimilar items were recalled better than similar items. In the final trials the phonological similarity effect appeared, however, more pronounced for non-words.

The learning scores were subjected to an analysis of variance with three main within-subjects factors: item type (words, non-words), phonological similarity (similar and dissimilar items), and trials (the five learning trials). The main effects of item type, $F(1, 23) = 20.78$, $p < 0.001$, of phonological similarity, $F(1, 23) = 21.693$, $p < 0.001$, and of recall trials $F(4, 92) = 210.91$, $p < 0.001$, were significant. The interactions between item type and phonological similarity [$F(1, 23) = 1.88$, n.s.] and between item type and recall trials [$F(4, 92) = 1.03$, n.s.] were not significant. The interaction between phonological similarity and recall trials, $F(4, 92) = 9.39$, $p < 0.001$, and the three-way interaction Item Type × Phonological Similarity × Recall Trials, $F(4, 92) = 5.03$, $p < 0.001$, were significant. Pairwise comparisons by the Newman–Keuls procedure showed that the difference between phonologically similar and dissimilar words was significant at the second, third, fourth (all at the $p < 0.05$ level), and fifth ($p < 0.01$) trial. In the case of non-words the difference was significant at the $p < 0.05$ level at the second trial and at the $p < 0.01$ level at all the following trials. The difference between similar and dissimilar items did not attain significance level at the first trial for either words or non-words.

Discussion

This experiment shows that phonological similarity affects learning of both words and non-words. On the one hand, this finding indicates that storage in phonological memory contributes to the acquisition of both lexical and non-lexical material. On the other hand, no evidence for a specific role of phonological storage in the learning of novel words emerges. However, there is a hint that this is so in the significant three-way Item Type × Phonological Similarity × Recall Trials interaction. This indicates that over trials the detrimental effect of phonological similarity is greater for non-words than for words. This may reflect the availability of semantic coding to learning of real words (see Baddeley, 1966b), which makes the contribution of phonological memory comparatively less relevant. On the other hand, in the case of non-words, subjects would rely upon phonological coding and storage in the absence of pre-existing lexical–semantic representations.

Consistent with the present findings, Baddeley (1966b) found that phonological similarity interferes with word learning in a paradigm where, as in the present experiment, recall was assessed immediately after presentation of the word list. However, he found no detrimental effects of phonological similarity in a subsequent experiment, in which a distracting activity was interposed between presentation and recall. Taken together, the present and Baddeley's (1966b) data suggest, at variance with the evidence reviewed in the introduction, that storage in phonological memory, at least in specific circumstances, may contribute to word learning.

In Experiment 2 we assessed the role of phonological memory in word and non-word learning by a paradigm similar to that used in Experiment 1, except that a filled delay was interposed between presentation and recall. This should eliminate the contribution of short-term phonological storage to learning. Under these conditions phonological similarity should affect only non-word learning, as no pre-existing lexical–semantic representations are available and subjects can only rely upon phonological coding and storage. On the other hand, interference with short-term retention by the interpolated task should induce subjects to make use of non-phonological (semantic) codes (see Baddeley, 1966b) in learning words.

EXPERIMENT 2

Method

Subjects. Twelve Italian subjects, postgraduate students and medical doctors (9 females and 3 males, mean age 34.8 years, range 27–65 years), different from those employed in Experiment 1, took part in the study.

Materials, Design and Procedure, Scores, and Statistical Analyses. These were the same as in Experiment 1, with one difference. Subjects were instructed that, after presentation of each list, they would be given auditorily a series of eight digits for immediate serial recall. After this interpolated auditory–verbal span task, recall of the paired-associate list was required.

Results

The learning curves for words and non-words are shown in Figure 2. It is apparent that subjects learnt both words and non-words; that performance level was higher in the case of meaningful stimuli; and that the effect of phonological similarity was much more pronounced and present in all trials only in the case of non-words. In the case of words the advantage of the phonologically dissimilar items was confined to the initial two trials. The analysis of variance revealed significant main effects of item type, $F(1, 11) = 36.47$, $p < 0.001$, of phonological similarity, $F(1, 11) = 11.91$, $p < 0.01$, and of recall trials, $F(4, 44) = 98.09$, $p < 0.001$. The interaction between item type and phonological similarity, $F(1, 11) = 9.48$, $p = 0.01$, and the three-way (Item Type × Phonological Similarity × Trials) interaction, $F(4, 44) = 6.73$, $p < 0.001$, were significant. The Item Type × Recall Trials [$F(4, 44) < 1$, n.s.] and the Phonological Similarity × Recall Trials [$F(4, 44) < 1$, n.s.] interactions did not reach significance level. Pairwise comparisons by the Newman–Keuls procedure showed an advantage of phonologically dissimilar words over

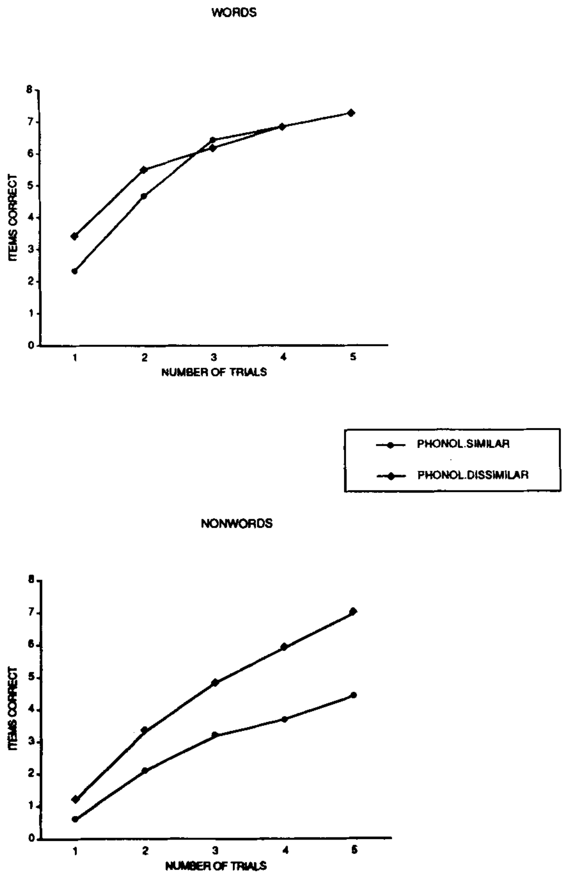

FIG. 2 Experiment 2. Paired-associate learning of auditorily presented phonologically similar and dissimilar word and non-word items, when an auditory digit span task is interpolated between presentation and recall (for means and standard deviations see Appendix III: Table 2).

similar only in the first trial ($p<0.05$); in the following four trials the difference did not attain significance level. Conversely, in the case of non-words, the difference between phonologically dissimilar and similar items was not significant at the first trial but attained a $p<0.01$ level of significance in the following four trials. In the interpolated auditory verbal span task no significant differences in the level of accuracy among conditions were found.

Discussion

The absence of any significant disruptive effect of phonological similarity upon word learning after the first trial indicates that normal subjects can shift to non-phonological learning codes. This, however, is not a practicable strategy for non-words: the persistence of the phonological similarity effect suggests that subjects continue to make use of phonological coding and storage. Experiment 2 shows therefore that phonological short-term memory is substantially involved in non-word learning.

Experiment 3 explored the role of the articulatory rehearsal component of phonological short-term memory by assessing the effects of item length upon learning of words and non-words. If the rehearsal process was selectively involved in non-word learning, one would predict that item length selectively interferes with the acquisition of meaningless stimuli, words being unaffected.

EXPERIMENT 3

Subjects. Twelve Italian subjects, postgraduate students and medical doctors (8 females and 4 males, mean age 32 years, range 23–65 years), different from those employed in the previous experiments, took part in the study.

Materials. Four lists of paired associates were used: two lists consisted of two-syllable words and two-syllable non-words and two lists of four-syllables words and non-words, respectively. The two-syllable word–word and word–non-word pairs were the phonologically dissimilar items used in Experiment 1 [e.g. "*volpe*"–"*segno*" ("fox"–"sign"), "*vetro*" (glass)–"ligo"]. The four-syllable word–word and word–non-word lists were constructed by using the same word stimuli as in the other two lists of Experiment 1, whereas responses were four-syllable words or non-words constructed with the same criteria as in Experiment 1 [e.g. "*gatto*"–"*semaforo*" ("cat"–"traffic light"), "*mela*" (apple–"*altrisenti*"]. The long words and non-words are listed in Appendix 2.

Design, Procedure, Scores, and Statistical Analyses. These were the same as in Experiment 1.

Results

The learning curves for words and non-words are shown in Figure 3. It is apparent that subjects learnt both words and non-words, that performance level was superior in the case of words, and that item length affected only non-word learning. An analysis of variance showed significant main effects of item type, $F(1, 11) = 50.37$, $p < 0.001$, item length $F(1, 11) = 6.35$, $p < 0.002$, and recall trials, $F(4, 44) = 104.09$, $p < 0.001$. The interactions between item type and item length, $F(1, 11) = 12.64$, $p < 0.001$, and between item length and recall trials, $F(4, 44) = 5.99$, $p = 0.001$, and the three-way Item Type × Item

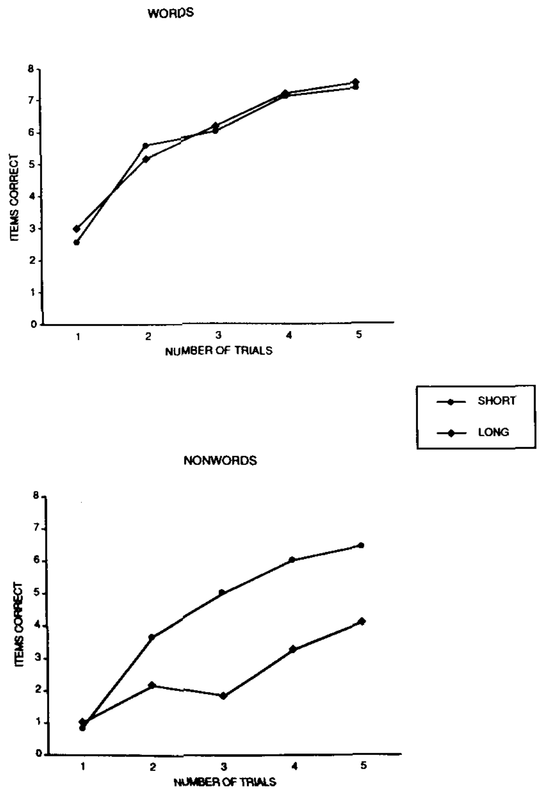

FIG. 3 Experiment 3. Paired-associate learning of auditorily presented two- and four-syllable word and non-word items (for means and standard deviations see Appendix III: Table 3).

Length × Trials interaction, $F(4, 44) = 6.09$, $p < 0.005$ were all significant. Pairwise comparisons by the Neuman–Keuls procedure showed that the difference between short and long words was not significant in any trial. In the case of non-words the difference between short and long items was significant ($p < 0.01$) at all trials, except the first.

Discussion

The observation of a selective effect of item length on learning of non-words indicates that the rehearsal process is involved in the acquisition of items for which no pre-existing lexical–semantic representations are available in long-term memory. By contrast, the learning of words does not appear to require a contribution from this component of verbal short-term memory.

Before concluding that the item length effect observed in Experiment 3 reflects the rehearsal process, one should consider possible differences in the availability of lexical–semantic strategies that subjects might use to improve their learning of short and long non-words. Even though both short and long items were pronounceable (legal) non-words, shorter non-words might contain parts that are more word-like than longer non-words. So, for example, the short non-word "*faglio*" contains "*fa*" and "*aglio*". The long non-word "*paratrezza*" contains "*para*". "*Altrisenti*" may be split into the two real words, "*altri*" and "*senti*", "*quadritoglio*" includes "*quadri*" and "*qua*"; "*cololetta*" includes "*letta*". Subjects might therefore try to learn non-words as connected bits of words. We did not assess subjects' learning strategies directly, but the hypothesis that the strategy of splitting the items into shorter words favours short items appears unlikely. An examination of the short and long non-words shows that more real function and content words are embedded in long non-words (Appendix 2.2) than in short non-words (Appendix 1.4). The mean number of embedded real words is 6.75 (*SD* 3.61, range 2–11) for long items and 2 (*SD* 1.85, range 0–5) for short items. Therefore, the use of the strategy of remembering non-words in terms of shorter real words would favour long items rather than short. Nevertheless a significant recall advantage of short non-words was found.

GENERAL DISCUSSION

This series of experiments has shown that the effects of phonological similarity and word length, which are the main features of immediate serial recall (see e.g. Baddeley et al., 1975, 1984; Conrad, 1964; Conrad & Hull, 1964), may also be found in the learning of novel words. In Experiment 1 we found detrimental effects of phonological similarity on both word and non-word learning, even though the latter stimuli were more affected. In Experiment 2, when storage in phonological short-term memory was disrupted by an interpolated task of immediate memory span, the detrimental effects of phonological similarity upon word learning were confined to the first trial. Learning of novel words, by contrast, was disrupted by phonological similarity up to the fifth trial. Experiment 3 showed that the detrimental effect of item length was confined to the learning of novel words, real words being unaffected.

Taken together, these data indicate that both the phonological short-term store and the rehearsal subcomponents of verbal short-term memory are involved in learning novel words. The present experiments also suggest, however, that the contributions of these two systems may differ in a number of important respects.

1. Phonological Short-term Store and Learning of Words and Non-words

A first issue concerns the observation that phonological similarity affects both word and non-word learning (Experiment 1), even though the role of the phonological short-term store appears crucial only in the case of novel words (Experiment 2). A comparable observation was made by Baddeley (1966b, Experiment 1), who found detrimental effects of phonological similarity in word learning when recall immediately followed the presentation of the memory list: In his experiment the advantage of the phonologically dissimilar items was significant in all four learning trials. When, however, storage in phonological short-term memory of items in the learning list was interfered with by an immediate memory span task that was interpolated between presentation and recall, the detrimental effect of phonological similarity was much reduced, being significant only in the second trial. Inspection of Baddeley's (1966b) Figure 3 shows an advantage of the phonologically dissimilar lists in the first three trials, which was reversed in the fourth learning trial. This pattern is remarkably similar to that observed in our Experiment 2: Phonologically dissimilar words were better recalled in the first two trials, but no effects of phonological similarity were present in the third, fourth, and fifth trials. These data indicate that in classical long-term memory paradigms such as paired-associate learning, normal subjects' performance reflects a contribution from both short-term memory and long-term memory systems. The present data on normal subjects undermine the inference, from the neuropsychological evidence reviewed in the introduction, that long-term learning of meaningful material is entirely independent of short-term storage. In the case of lists of unrelated words, such as those used in the present study and by Baddeley (1966b), temporary storage in the phonological short-term store may be useful in an early learning phase, as it would allow subjects to build up semantic relationships among the items, thus ensuring better retention. Storage in phonological memory is, however, no longer needed in a later stage, when such semantic processes have been completed. This issue might be further explored by assessing the contribution of phonological memory to the learning and retention of different types of material, ranging from unrelated lists of words to passages of prose, where semantic links among the different items already exist. In this case one might expect a comparatively minor role for phonological memory.

However, the results of Experiment 2 show that while in the case of words normal subjects may shift to alternative semantic codes (see Baddeley, 1966b), non-word learning relies heavily upon storage in phonological memory. This probably reflects the absence of pre-existing lexical–semantic representations of non-words. The present data do not specify the precise nature of the non-phonological codes used by normal subjects in word learning but indicate that their contribution appears to increase over time. The involvement of the phonological code has, by contrast, an opposite temporal pattern. Baddeley (1966b, Experiment 3) showed that the phonological and semantic similarity effects had opposite temporal courses. As in the present Experiment 2, the phonological similarity effect was present only in the early trials. Conversely, the effect of semantic similarity was found only in the final learning trials and in the 20-min delay recall condition.

The first two experiments of this study provide some information about the temporal pattern of the involvement of the phonological short-term store in the learning of words and non-words. In Experiment 2, the concurrent short-term memory task was interpolated between presentation and recall, and during the presentation of the paired-associate lists no concurrent memory load was given. The persistence of a detrimental effect of phonological similarity upon non-word learning (see Figure 2) shows that subjects during the presentation phase encode and store phonologically the items to be recalled, even though the phonological short-term store is going to be used subsequently also in the concurrent retention task. This finding probably reflects the lack of effective alternative codes for non-word learning. A possible way to explore the contribution of phonological memory throughout presentation and recall would be to use a condition in which the concurrent retention task is given before presentation. This procedure would totally prevent subjects from using phonological memory in non-word learning. On the basis of the present findings a dramatic reduction of performance level, possibly together with the absence of any effect of phonological similarity, may be expected. In the case of words, the disappearance of the effect of phonological similarity, when a concurrent retention task is given after presentation (cf. Figures 1 and 2) indicates that subjects, who in a non-interference condition use phonological coding to retain the presented items, may shift to alternative codes. The persistence of the effect of phonological similarity in the first trial of the interfered word learning condition suggests that, in the initial phase of learning, subjects continue to use phonological storage during the presentation of stimuli, even though the phonological short-term store will be subsequently used in the concurrent retention task. This involvement of phonological memory rapidly vanishes, however, due to the development of effective non-phonological codes. By contrast, under non-interference conditions subjects continue to make use of the phonological store at least up to the fifth trial. The present experiment did not explore longer delays, but Baddeley (1966b, Experiment 1) found no detrimental effects of phonological similarity on word learning in a 20-min delay condition. However, the interpretation of this result is not straightforward because the absence of the effect is due to the significant forgetting that took place only in the phonologically dissimilar list after the fourth learning trial.

2. Rehearsal and Learning of Words and Non-words

Experiment 3 shows that the *rehearsal* component of verbal short-term memory is also involved in non-word learning. In contrast to the effect of phonological similarity assessed in Experiments 1 and 2, word length does not affect paired-associate learning of words. This might indicate that the rehearsal component is involved only in learning novel words, though this conclusion should be treated with some caution, as it is based on a null result. The different roles of the phonological short-term store and of articulatory rehearsal in word and non-word learning suggest that comparatively shorter maintenance in phonological memory is required for meaningful than for meaningless items. This might suffice to activate lexical–semantic codes adequate for learning and retention. Conversely, the acquisition of non-words will require more prolonged storage in phonological memory, and rehearsal would then be necessary to prevent the decay of the phonological trace.

3. Neuropsychological and Developmental Implications

The present data from normal subjects thus provide converging evidence, in line with the neuropsychological findings, that the phonological storage and rehearsal subcomponents of verbal short-term memory are substantially involved in learning of novel words. They also make it unlikely that the inability of patient PV to learn novel words could be attributed to an additional (and so far undetected) cognitive deficit, associated with the abnormally reduced capacity of her phonological short-term store. As normal subjects make use of phonological memory in learning non-words, and PV has a selective impairment of this component, the more direct and economical explanation of her impaired performance in non-word learning is in terms of her deficit of the phonological short-term store.

As noted in the Introduction, developmental data also argue for a role of phonological memory in the learning of novel words, even though they do not provide information concerning the specific contributions of the phonological short-term store and rehearsal subcomponents of verbal short-term memory. Gathercole and Baddeley (1989b) investigated the memory capacities of children who had been categorized as "language-disordered", as their vocabulary and reading ages were at least two years behind their age expectations, despite a normal or "supernormal" non-verbal intelligence. The single most striking deficit of these children was their impaired ability to repeat spoken non-words correctly, a task involving immediate retention in phonological memory. In a further study they found that non-word repetition was a better predictor of vocabulary than vice-versa, suggesting that an adequate capacity of phonological short-term memory is necessary for vocabulary development, rather than the reverse. Also, data from normal children, showing significant correlations between non-word repetition and acquisition of vocabulary, corroborate the view that phonological memory is involved in the learning of novel words (Gathercole & Baddeley, 1989a).

Finally, additional converging evidence comes from recent work by Service (1989), who investigated the teaching of English as a second language to Finnish children. A battery of tests were given to the children before they began to learn English. One of these measured the children's capacity to repeat back immediately unfamiliar English words, a task equivalent to the non-word repetition test of Gathercole and Baddeley. Service then correlated the children's performance on this repetition task with their level of accuracy in a range of English language tests given two years later. It was found that non-word repetition was the best predictor of the subsequent acquisition of English; a high correlation was found also for word copying; the correlation was less high for a syntactic comparison task.

The present experiments show that phonological short-term memory is involved in non-word learning in a paired-associate paradigm. The developmental studies mentioned above also show a role of phonological memory in the acquisition of vocabulary, that is, of new words unknown to the child. Perhaps the main common feature shared by acquisition of vocabulary and non-word paired-associate learning is the associative nature of both conditions. Our subjects were taught to associate a word with a non-word; children associate phonological patterns (words unknown to them) to objects, pictures, and some meaning. A second common characteristic is that in both the present paradigm and vocabulary acquisition, learning occurs through the repeated presentation of the association. Children of course do not acquire vocabulary by a fixed paradigm whereby strings of eight paired associates are presented in five trials, but learning is distributed over time in a less regular fashion. Components of the cognitive system different from phonological memory are involved in vocabulary learning by children. One such component may be episodic memory (Tulving, 1983), as the successive instances in which children learn to associate a phonological pattern with an object and some meaning may be considered as temporally discrete autobiographical events. Verbal learning and retention tasks may, however, be regarded as experimental analogues of episodic memory (e.g. Coughlan & Warrington, 1981). The conclusion that learning new words and their meaning requires a contribution from episodic memory is also suggested by the observation of a dramatic impairment in the amnesic patient H.M. (Gabrieli, Cohen, & Corkin, 1988). H.M.'s inability to learn the meaning of even one new word may be contrasted with the acquisition skills of children who, it has been suggested (Carey, 1978), may learn between the ages of 1.5 and 6 years the equivalent of nine new words a day. Having pointed out a number of analogies between vocabulary acquisition in children and the paired associate learning paradigm we used in normal adults, we note that the present results suggest predictions that can be tested experimentally. For instance, phonological similarity and item length should negatively affect the acquisition of new words in children.

To summarize, the present data, in line with both neuropsychological and developmental evidence, suggest an important role for both the phonological short-term store and the articulatory rehearsal sub-components of verbal short-term memory in the learning of novel words. They also indicate that, while verbal short-term and long-term memory may still be conceived as independent systems (see e.g. Baddeley, 1986; Shallice & Vallar, 1990), they interact in a complex fashion in the process of acquisition of novel words. Finally, the present results may have potentially relevant implications for elucidating the role of short-term and long-term components of human memory in the developmental acquisition of language.

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APPENDIX 1

1. Phonologically similar word–word

arco–canto
bomba–conto
rosa–calo
gatto–collo
viso–corto
gamba–colpo
cane–costo
volo–casco

2. Phonologically dissimilar word–word

volpe–segno
labbro–scusa
grano–spada
pietra–fatto
piede–zona
quadro–pelle
topo–banca
muro–golfo

3. Phonologically similar word–non-word

tetto–zibro
bocca–zuro
orso–zapo
noce–zacco
mano–zago
lupo–zipo
mela–zebo
scala–zabbro

4. Phonologically dissimilar word–non-word

uva–raggo
pesca–patro
letto–talpo
vetro–ligo
dente–faglio
pesce–berba
verde–speccio
petto–nomo

APPENDIX 2

1. Long word–word

gatto–semaforo
volo–telefono
rosa–bicicletta
viso–biblioteca
gamba–terremoto
bomba–elefante
arco–colpevole
cane–colonnello

2. Long word–non-word

mano–paratrezza
tetto–fubercolo
mela–altrisenti
orso–esplorione
bocca–arramplico
noce–quadritoglio
scala–reggolpetto
lupo–cololetta

APPENDIX 3

TABLE 1

			Mean	*Standard deviation*
W1	F1	T1	2.08	1.76
W1	F1	T2	4.16	2.20
W1	F1	T3	5.16	2.35
W1	F1	T4	6.00	1.97
W1	F1	T5	6.37	2.03
W1	F2	T1	2.70	1.98
W1	F2	T2	5.08	2.33
W1	F2	T3	6.04	1.78
W1	F2	T4	7.00	1.64
W1	F2	T5	7.33	1.20
W2	F1	T1	1.00	1.18
W2	F1	T2	2.50	1.06
W2	F1	T3	3.16	1.68
W2	F1	T4	4.41	1.97
W2	F1	T5	4.45	2.06
W2	F2	T1	0.79	0.93
W2	F2	T2	3.37	1.61
W2	F2	T3	5.41	1.99
W2	F2	T4	6.20	2.08
W2	F2	T5	6.58	1.90

W1 = words, W2 = non-words, F1 = phonologically similar, F2 = phonologically dissimilar, T = trial.

TABLE 2

			Mean	*Standard deviation*
W1	F1	T1	2.33	1.61
W1	F1	T2	4.66	2.30
W1	F1	T3	6.41	1.67
W1	F1	T4	6.83	1.52
W1	F1	T5	7.25	1.28
W1	F2	T1	3.41	2.23
W1	F2	T2	5.50	2.61
W1	F2	T3	6.16	2.65
W1	F2	T4	6.83	2.12
W1	F2	T5	7.25	1.42
W2	F1	T1	0.58	1.16
W2	F1	T2	2.08	1.67
W2	F1	T3	3.16	2.12
W2	F1	T4	3.66	2.06
W2	F1	T5	4.41	2.64
W2	F2	T1	1.16	1.58
W2	F2	T2	3.33	2.18
W2	F2	T3	4.83	2.72
W2	F2	T4	5.91	2.35
W2	F2	T5	7.00	1.85

See Table 1.

TABLE 3

			Mean	*Standard deviation*
W1	L1	T1	2.58	1.50
W1	L1	T2	5.58	2.10
W1	L1	T3	6.00	2.08
W1	L1	T4	7.08	1.50
W1	L1	T5	7.33	1.15
W1	L2	T1	3.00	1.75
W1	L2	T2	5.16	1.94
W1	L2	T3	6.16	2.32
W1	L2	T4	7.16	1.40
W1	L2	T5	7.50	1.73
W2	L1	T1	0.83	1.03
W2	L1	T2	3.66	1.72
W2	L1	T3	5.00	1.80
W2	L1	T4	6.00	2.08
W2	L1	T5	6.41	1.88
W2	L2	T1	1.00	0.85
W2	L2	T2	2.16	1.33
W2	L2	T3	1.83	1.69
W2	L2	T4	3.25	1.86
W2	L2	T5	4.08	2.10

W1 = words, W2 = non-words, L1 = short, L2 = long, T = trial.