Transient Phonemic Codes and Immunity to Proactive Interference

Gerald Tehan

University of Southern Queensland

Michael S. Humphreys

University of Queensland

Mailing Address:
Gerry Tehan
Faculty of Sciences
University of Southern Queensland
Toowoomba. Q. 4350
AUSTRALIA.

e-mail: tehan@usq.edu.au

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Abstract

Empirical data indicate that when memory for sub-span lists of taxonomically related material is tested immediately after study, prior experience with lists involving the same material has no affect upon recall or recognition. Six experiments explore the possibility that immunity to Proactive Interference (PI) is related to discriminative information that is provided by transient phonemic codes. In these experiments the strength of, or the presence or absence of phonemic codes was manipulated. Immunity to PI was found only in those circumstances where it was presumed that a phonemic representation of target items existed, and that information provided discriminative information. In all other cases PI was observed. The finding that PI effects correspond in a principled fashion with the manipulation of phonemic information provides strong evidence for the role of phonemic codes in producing short-term PI effects.

Transient Phonemic Codes and Immunity to Proactive Interference

One of the universally accepted characteristics of short-term memory performance is that forgetting is extremely rapid. The basis for such an assertion traditionally rests on performance characteristics observed in the Brown-Peterson paradigm (Brown, 1958; Peterson & Peterson, 1959).On each trial in this task, subjects are presented with a small number of items for later recall. Subjects are then presented some distractor activity which is aimed at preventing rehearsal of the memory items for varying retention intervals prior to recall. When tested after very short retention intervals, memory for the list items is near perfect. However, as the retention interval increases, subjects rapidly forget the target items. When the probability of recalling the items is plotted against retention interval a negatively accelerating forgetting curve results, with performance asymptoting when the retention interval is around twenty seconds. There are, however, conditions in which this pattern of events does not occur. Keppel and Underwood (1962) demonstrated that on the very first Brown-Peterson trial there is little forgetting, irrespective of the retention interval involved. In fact, they showed that the traditional Brown-Peterson forgetting curve gradually emerged over four or five trials. The Keppel and Underwood data tended to rule out such explanations of short-term forgetting as trace decay (Peterson & Peterson, 1959) or retroactive interference (Waugh & Norman, 1965), while indicating the importance of proactive interference (PI).

The importance of PI in short-term retention is further emphasized in data derived from the release from PI paradigm in which the materials across a number of Brown-Peterson trials come from a single category (e.g. animals). In this situation performance generally deteriorates across trials, only to return to near original levels of performance when the materials change on any subsequent trial (e.g. flowers) (Wickens, Born & Allen, 1963).

The role of PI in the Brown-Peterson task seems to be so pervasive that Crowder (Crowder, 1982; 1989) has argued that "a theory of Brown-Peterson forgetting has to be a theory of how proactive inhibition works in this task" (Crowder, 1989; p 275.). The likelihood that such a theory will be developed is complicated by the fact that there are occasions when short-term memory performance appears to be immune to the effects of PI (Halford, Maybery & Bain, 1988; Humphreys & Tehan, 1992; Wickens, Moody & Dow, 1981). Consequently, a theory of PI will need to explain performance in those situations in which PI is observed, and in addition, those situations in which immunity is observed. The first aim of the current paper is to provide some experimental data which hopefully will illuminate our understanding of how PI works in short-term retention. The primary focus, however, is on the conditions that produce immunity to PI.

Immunity to PI

The exploration of immunity to PI starts with a study by Wickens, Moody and Dow (1981) who devised a task that combined the essential features of the release from PI paradigm and the Sternberg probe recognition task. The task involved presenting blocks of three trials, each block using material from a single taxonomic category. On each trial memory for a two or four item list was tested via a probe that was presented either after a two second unfilled retention interval (immediate test) or after a twelve second filled retention interval (delayed test). Wickens et al. found that on an immediate test, probe RT's were equivalent for probes on the first (low PI) trial and third (high PI) trial in each set, indicating that PI had no effect upon performance. However, on delayed tests, probe RT's were markedly slower than on the immediate tests, and the effects of PI became apparent in that RT's for the low PI tests were some 35 msec faster than the high PI tests. Halford, Maybery and Bain (1988) using the same paradigm, demonstrated that PI effects were related to subjects' memory spans. On an immediate test of sub-span lists, performance was immune to PI. However, on an immediate test of supra-span lists, PI affected performance. Humphreys and Tehan (1992) also found that serial recall of sub-span lists (five digits or five letters) was immune to the effects of PI when an immediate test was employed. However, PI emerged after a filled retention interval of approximately two seconds. Dempster and Cooney (1982) provide analogous information to the Halford et al (1988) data, using an immediate serial position recall task. When the list length was below span, PI had no effect. When the memory set was above span level, the effects of PI on performance were observed.

If we can generalize from these studies, it would appear that when memory for short lists of semantically related material is tested immediately after study, prior experience with similar lists has no affect upon recall or recognition. However, if span is exceeded or brief distractor periods are employed before test, prior experience with such material interferes with both the recognition and recall of more recent items.

The relationship between immunity to PI and span is probably not coincidental. That is, the short-term mechanisms involved in span may also be responsible for immunity to PI. In fact, Wickens et al. (1981) explain their results by suggesting that on an immediate test, the list items are in consciousness and hence are uninfluenced by similar items that are no longer in consciousness. On delayed trials, however, the items have to be retrieved from secondary memory, and this retrieval process is affected by PI. While the specific two-store version of Wickens et al.'s explanation has been found wanting (Brannelly, Tehan & Humphreys, 1989), it is still plausible that some of the processes that operate in immediate recall may be responsible for immunity to PI that is observed in the experiments described earlier.

<u>The Role of Short-term Phonemic Codes</u>

If we accept as a working hypothesis that some process or mechanism involved in span, is responsible also for producing immunity PI, the question remains as to what that process or mechanism might be. Whatever it is, the data indicate that it must be transient. One possibility is the presence of short-lasting phonemic codes. Baddeley

(1986) has convincingly demonstrated that phonemic codes and associated articulatory processes are responsible for many of the effects that are observed in span and immediate serial recall. Thus, the registration and maintenance of phonemic information is thought to underlie the effects that such variables as word length, phonemic similarity, suppression, modality of presentation, unattended speech have on immediate serial recall. In addition, Penney (1989) has provided evidence that short-term phonemic information is involved in quite a diverse range of other short-term retention tasks. More importantly, Craik and Levy (1976) have persuasively argued that, while there is evidence for the use of non-speech based codes in short-term retention, only the speech related codes are truly transient. The key empirical findings underlying these assertions are that in immediate serial recall, extra-list intrusions tend to sound like the forgotten item (Conrad, 1964) and that lists of phonemically similar words tend to be harder to recall than dissimilar sounding lists (Conrad, 1965; Baddeley, 1966). The transience of these codes is evident in that after filled retention intervals ranging from about two seconds to no more than ten seconds, both the phonemic intrusion effect (Conrad, 1967; Estes, 1973) and the phonemic similarity effect (Hall, et al., 1983; Tell, 1972) are eliminated.

With regard to the coding issue, we make the further assumption that phonemic codes serve as a supplement to other available information (Crowder, 1989). We assert that longer lasting central codes that provide information about the semantic nature of the items, category membership, etc., also play an essential role in short-term memory performance. The build-up and release from PI that occurs with the change in semantic categories is an obvious example of the role of these central codes in short-term memory. With this latter assumption in mind, the set of experiments to be reported here are concerned with the way in which phonemic and central code information influence the likelihood that the effects of PI will or will not be observed in short-term recall.

Logically, for PI to occur the representations of interfering and target items must be present at retrieval and there must be some problems with discrimination. At the present time we have no firm ideas concerning the discrimination process[1]. However, with regards to the issue of representation, we suggest that in instances where PI is possible, the central representations of the target and interfering items are present, be it in the short-term domain or the long-term domain. PI in the short-term domain is in one sense unique, in that it is possible for phonemic representations of the items to be also present. The data concerning phonemic codes indicate that phonemic representations are very susceptible to retroactive interference (Nairne, 1988; 1990). Consequently, the phonemic representation of a particular item will survive only for brief periods if other phonemic representations are generated by subsequent activity. In effect, we assume that phonemic information will be limited to the most recent three or four items studied. Our working assumption is that the presence of phonemic information is crucial in producing immunity to PI, in that the addition of phonemic information to available central information makes an item very distinctive and thus easily discriminable. By way of analogy, one can consider driving at dusk on a gloomy winter's night. In heavy approaching traffic, all the cars tend to seem alike until one car switches on its headlights. With the lights on, that car becomes very distinctive and easily discriminable from other cars with their lights off. We suggest that in most short-term memory situations, the combination of phonemic and central information will make an item more distinctive than if central information alone is present. In such situations, immunity to PI should be observed.

The analogy of cars with their headlights on is also useful for suggesting the conditions under which immunity to PI should not be observed. We have already suggested that if no cars have their headlights on, then discrimination is difficult. Consequently, if there is no phonemic representation of the target item, PI should be observed. Moreover, if all the cars have their lights on, discrimination will again be difficult. If a phonemic representation of an interfering item is generated and maintained in addition to the phonemic representation of a target item, PI would again be expected. Finally, take the instance where a single car has its headlights on at noon on a bright sunny summer's day. In this case, the light still provides the same information but because of background factors that information is not as distinctive. We believe that there are conditions where phonemic information for the target item alone is available, but it does not provide distinctive or discriminating information. In these situations PI should again be observed.

If our analysis is correct it follows that PI should be observed under three sets of conditions. If there is no phonemic information about the target items; if there is phonemic information, but that it does not discriminate between target and interfering items; and finally, if there is phonemic information for both interfering and target items. In fact, the only time that immunity to PI should be observed is if there is phonemic information for the target item alone and that information does discriminate between the target and interfering item.

The following experiments were conceived with these assumptions in mind. To foreshadow what emerges, it appears that immunity to PI in short-term recall, is only observed under conditions where it is plausible that discriminative phonemic information concerning the target item is present. In all other conditions, the effects of interfering items are present.

General Method

In the following experiments subjects studied a series of one block or two block trials in which each block contained four words. They were instructed that at all times they were to remember the most recent block. This meant that if the trial was a two-block trial, they were to forget the first block and concentrate on remembering the second block. Memory was tested either immediately or after a two second filled retention interval that involved the verbal shadowing of two four digit strings. PI was manipulated by the presence or absence of a similar item or items in block one to the target item or items in block two.

Subjects

In each of the six experiments, save for Experiment 5, twenty first-year psychology students from either the University of Southern Queensland or the University of Queensland participated for course credit. No student participated in more than one experiment. In Experiment 5, where retention interval was a between-subjects variable, 40 first-year students participated.

Materials

The materials for the experiments are derived primarily from rhyme (Nelson, personal communication) and taxonomic category norms (McEvoy & Nelson, 1982) generated by Nelson and his colleagues at the University of South Florida.

In Experiment 1, four instances were selected from each of 40 different rhyme categories. The construction of the forty four-word study trials commenced with a randomization of the 40 categories. The first twenty categories that emerged from the randomization process served as the pool for the phonemically similar lists. The items within each category were randomly assigned to the four serial positions. The 20 phonemically dissimilar lists were constructed by randomly assigning the items from the remaining 20 rhyme categories to different lists. This process was carried out for each subject.

In the remaining experiments, on each trial participants studied either one or two block trials. The one-block trials always served as filler trials to ensure that subjects attended to the first four words that they studied. The critical trials in all experiments were the two-block trials because it was on these trials that PI was manipulated. The second block always contained the target item or items. In the case where PI was introduced, a similar item or items also appeared in the first block. In the no interference conditions, the items in the first block were always unrelated to the target items in the second block.

Thus in experiment 2 in which serial recall was required, eight instances were selected from each of thirty different taxonomic categories (McEvoy & Nelson, 1982). PI was manipulated by presenting material from the same category in both blocks. An interference trial started with the presentation of the category label in upper case. Then followed a random selection of four of the eight instances from the category, presented in lower case. The second block started with the presentation of the category label followed by the remaining four instances from the category. A typical interference trial might have looked something like "PROFESSION nurse teacher doctor prostitute PROFESSION psychologist lawyer dentist engineer". The structure of the no-interference trials was identical to the interference trials, the only difference being that the materials on the first and second block were different. A typical no-interference trial might have looked something like "FLOWER rose petunia daisy lily PROFESSION psychologist lawyer dentist engineer". Half the lists in each condition were tested immediately and half were tested after a two second filled delay.

The remaining four experiments all required cued recall instead of serial recall. Following the presentation of the items, a category cue appeared in upper case, and subjects were requested to recall the item from the most recent block that was an instance of the specified category. On these trials, a single target item appeared in the second block amongst three unrelated filler items. On the interference trials, a second item from the same category as the target item appeared amongst three unrelated filler items in the first block. Thus, a typical interference trial might have looked like "READY meal pig engine road ! image sheep dock starch FARM ANIMAL". On the control trials, all four items in the first block were unrelated to the target item, e.g. "READY meal lip engine road ! image sheep dock starch 0157 8733 FARM ANIMAL".

In constructing these trials, separate word pools were generated for filler and target items. There was no overlap between the category membership of filler and target items.Thus, filler items were always unrelated to the critical items. For the critical items, two instances were sampled from each category. In order to maximize the chance of finding PI on an immediate test, the interfering foil in block-one was usually a high dominant instance of the category, and the block-two target was usually a relatively weak member of the category. On the interference trials, foil and target always appeared in the same serial position in their respective blocks[2]. To avoid possible primacy and recency effects, the target (and foil) appeared equally often in the second and third serial positions only.

The assignment of materials to condition was randomized for each subject, as was the order of the trials in each experiment. The latter ensured that subjects never knew in advance, whether the trial would be a one-block filler trial or a two-block interference or control trial.

Procedure

Each trial began with a READY sign displayed on the computer monitor for two seconds. The study items were then displayed individually at a rate of one word per second, and subjects were instructed to remain silent (unless otherwise instructed) throughout the presentation of the study items. On two block trials, a block separator, usually an exclamation mark (!), was presented for one second after the fourth word in the first block and before the first word in the second block. Recall instructions always appeared for two seconds in upper case. For serial recall the word RECALL was used, and in the case of the cued recall experiments the category cue was presented. On an immediate test the cue appeared immediately after the fourth item in the block. On the delayed trials, two four-digit strings appeared on the screen after the fourth word, at the rate of one string per second. Subjects were required to read the digits aloud as they appeared on the screen. The recall cue appeared after this two seconds of shadowing activity. With the appearance of the recall cue, subjects were requested to either verbally recall the items in their presentation order on serial recall trials, or on the cued recall trials, verbally recall the category instance from the most recent block. Subjects had five seconds to make a response before the next trial began. The experimenter recorded the subjects responses (correct recall, order errors, intrusion errors, omissions, etc) on a hard copy of the the subject's input file.

Experiment 1.

If our assumptions about the importance of phonemic codes in producing immunity to PI are correct, we would argue that PI should be observable after a filled retention interval of a duration sufficient to eliminate the phonemic codes. From the work reviewed earlier, it is clear that the effects attributed to the operation of phonemic codes have dissipated within 10 seconds (Conrad, 1967; Estes, 1973; Tell, 1972). However, we were interested in shorter intervals than this. Baddeley (1986) and Schweickert and Boruff (1986) emphasize a two second limitation on the availability of phonemic codes in immediate serial recall. Furthermore, the Humphreys and Tehan (1992) data demonstrated that with non-vocalized visual presentation, PI effects emerged after about two seconds of distractor activity. If phonemic codes are important in producing PI effects, this data would suggest that these codes are not available after two seconds of distractor activity. Consequently, our expectation was that phonemic similarity would have a deleterious effect upon immediate recall but would have no effect upon delayed recall.

Method

Subjects studied forty one-block trials for serial recall. For twenty trials, the four items in each list all rhymed, and in the remaining trials the items within each block were phonemically dissimilar. Half the trials in each condition were tested immediately and half tested after a two-second filled delay.

Results and Discussion

The outcomes of this experiment were as predicted. On an immediate test the probability of recalling the phonemically dissimilar items in position was .79, and the probability of recalling the similar items was .70. On the delayed test the probability of recall of the dissimilar and similar lists were .33 and .32, respectively.

Planned comparisons confirmed that these observations represent stable characteristics in the data. Phonemic similarity hurt performance on an immediate test,

$\underline{F}$ (1,19) = 24.10; MSe = .016, but did not influence recall after a filled delay, $\underline{F}$ (1,19) = .15; MSe = .035.

The lack of similarity effects on the delayed test do not appear to be due to floor effects. The serial position curves for the two conditions are almost identical in shape. The probability of recalling the dissimilar items in position was .52, .36, .24, and .21 for the first, second, third and fourth positions respectively. The equivalent figures for the phonemic similarity condition were .51, .32, .22, and .24. Thus, even if performance on the last two serial positions is on floor, the early serial positions are not. Floor effects are not responsible for the attenuation of the phonemic similarity effect on a delayed test.

The attenuation of the phonemic similarity effect after a brief filled retention interval suggests that we have established a set of task parameters with which we can confidently make inferences regarding the availability of phonemic information. These same task parameters should enable us to test our assumptions about the role of phonemic information in producing PI effects. Given our explanation for immunity to PI, we expected that on an immediate test the effects of PI would not be evident. However, after a two second filled retention interval, the effects of PI should be readily observable.

Experiment 2

Method

Subjects studied forty trials, which consisted of 20 one-block filler trials and 20 two-block trials on which PI was manipulated. Half the trials of both type were tested for immediate serial recall, the other half were tested by serial recall after a two second delay.

Results

Filler Trials

Obtaining interference effects in this and subsequent experiments depends upon subjects attending to the first block in the two-block trials. To ensure attention to the first block, one-block trials were presented. Performance on the block-one trials in this experiment and in all subsequent experiments indicated that subjects attended to that first block. In the current experiment the mean probability of recalling an item in position on an immediate test was .91, and across all other experiments averaged around the 80% level. Serial position effects were consistent with the known patterns associated with visual presentation. We are confident that subjects attended to the first block and thus block-one performance will not be reported in subsequent experiments.

Two-block Trials

The two-block data are summarized in Figure 1.

Insert Figure 1 about here

The critical interference data in this and following experiments were analyzed by planned comparisons, in which the interference and the no-interference conditions were compared firstly for immediate test and then for delayed tests. On immediate tests, when performance is collapsed across serial positions, there was no evidence of any effect of PI, F (1,19) = 0.79; MSe =.042. On the delayed tests, however, the effects of PI do emerge. Performance on the interference trials was reliably below that on the no-interference trials, F (1,19) = 6.83; MSe =.077.

Discussion

The absence of PI effects on an immediate test is consistent with prior research (Halford et al., 1988; Humphreys and Tehan, 1992; Wickens et al., 1981). Finding PI effects after a filled retention interval is also consistent with previous research. In the current experiment, the task parameters of Experiments 1 and 2 are equivalent. Subjects are required to remember four words at any given time and are tested either immediately or after two seconds of shadowing activity. The results of the two experiments suggest that immunity to PI is found under conditions where phonemic codes are present, but PI effects emerge at the same retention interval that phonemic similarity effects disappear. These results indicate that our contention that phonemic codes play a role in producing immunity to PI is plausible.

Experiment 3

The following experiments examine PI effects within the context of a short-term cued recall task. We have changed tasks primarily for two reasons. Firstly, other factors such as output interference also play an important role in the standard short-term tasks (Hadley, Healy & Murdock, 1992; Nairne, 1990), including the Brown-Peterson task (Lewandowsky & Murdock, 1989). As such, these factors add additional problems to the interpretation of results. The adoption of a short-term cued recall task in which a single list item is cued ensures that the effects of extraneous variables are kept to a minimum and it allows for the easy manipulation of cues. Secondly, it is important to establish the generality of immunity to PI on an immediate test across as many different short-term tasks as possible.

The current experiment is a straight forward replication of Experiment 2, the only change being that cued recall with a taxonomic cue is required rather than serial recall. The experimental outcomes are expected to be identical to those obtained in Experiment 2.

Method

There were 72 trials in the current experiment consisting of 24 filler trials and 48 two-block trial. Again half the 24 interference trials were tested immediately and half tested after a two second delay. The same was true of the 24 control trials.

Results

Subjects performance at recalling the critical item, given a category cue at retrieval, is summarized in Table 1.

Insert Table 1 about here

The first planned comparison confirmed that there was no evidence for PI having any affect upon cued recall on an immediate test , F (1,19) = .38; MSe = .007. The effects of PI on cued recall did, however, emerge on a delayed test, F (1,19) = 22.66; MSe = .007.

It is possible to make three types of error on the cued recall trials. Firstly, subjects may fail to produce any item (Omission). Secondly, they may generate an appropriate category member which did not appear anywhere in the list (Extra-List Intrusion), and thirdly they can produce the interfering word from the first block (List Intrusion). Table 2 presents the probability of making the different types of errors for each condition.

Insert Table 2 about here

The essential features of the recall data are replicated in the error data. In the delayed condition, omissions and extra-list intrusions seem to be quite similar across all conditions. PI effects are obvious in the large percentage of list intrusions in the interference condition.

Discussion

With regard to the major concerns of the study, the expected pattern of PI effects did emerge in the data. We have argued that the retrieval process generates central representations of two possible candidates for recall, and at the same time, generates a phonemic representation of the target item alone. On an immediate test, phonemic information is then combined with the central information to facilitate the discrimination of the target item from the interfering item. On a delayed test, PI emerges because while the central information is available, the phonemic information about the target has been interfered with by subsequent distractor activity. Consequently, there is a reduced ability to distinguish between a target and an interfering item.

Given this explanation of the differing effects of PI with changes in retention interval, it should be possible to observe PI on an immediate test in situations where the phonemic information is present but does not discriminate between a target and a distractor. One situation in which this might occur is where the target and the interfering item are both members of a rhyme category. That is, information about the phonemic characteristics of the target would discriminate between two dissimilar sounding members of a taxonomic category, but such information would not easily discriminate between two similar sounding members of a rhyme category.

Experiment 4

The current experiment replicates Experiment 3 in all important respects, the only differences being that ending cues are provided at recall, and the interfering and target items have the same ending rather than being from the same taxonomic category[3]. Given our explanation of PI, the predictions are straightforward. On an immediate test the central representations of two instances of the ending category should be produced, along with a phonemic representation of the the target item. However, since this phonemic representation does not strongly discriminate between the target and the interfering item, PI is expected. On a delayed test PI is expected for the same reasons that it has been in previous experiment. That is, phonemic information has been lost.

Method

Subjects again studied 48 two-block cued recall trials under immediate or delayed recall conditions. In addition, twenty filler trials were tested via serial recall, ten were block one trials that were tested immediately, and ten were two-block trials in which the second block was tested after a 2-second retention interval. The procedure in this experiment was identical to that used in Experiment 3. The only difference was that instead of a category cue being presented, an ending cue e.g. OVE was presented prior to recall.

Results

The data from the cued recall trials are summarized and presented in Table 1. The data indicate that ending cues produce somewhat different effects than taxonomic cues. When the target was tested immediately, the presence of an interfering item in the first block reliably suppressed recall of the target item compared to the no-interference condition, $\underline{F}$ (1,19) = 4.54; $\underline{MSe}$ = .009. Interference was also apparent when the target was tested after two seconds delay, $\underline{F}$ (1,19) = 15.83; $\underline{MSe}$ = .018.

The effects of interference are also seen in the number of block-one intrusions present on the interference trials, as is evident in Table 2. These intrusions represent a major source of error on both immediate and delayed tests for this condition.

Discussion

The pattern of PI effects in Experiment 3 emerged in accord with our expectations. Our explanation of why immediate test performance differs from the pattern of performance in Experiment 3 is simply in Experiment 3 the phonemic code strongly discriminates between the target item and the interfering distractor. In the current experiment, the phonemic code, although present, no longer strongly discriminates the target from the distractor. That is, the phonemic code may specify the interfering item as well as the target item. PI on delayed tests is observed in both experiments because the phonemic codes are no longer present.

Our explanations for the differences on immediate test performance between Experiments 3 and 4 are basically target similarity explanations. That is, the effects were explained in terms of the properties of elicited representations and not as a function of the different cues. A clear prediction that emerges from such a perspective, is that, irrespective of the retrieval cue used, PI should be present on an immediate test any time phonemic codes do not discriminate a target item. Consequently, we would also expect PI on an immediate test where taxonomic cues are used but both the target and interfering item rhyme, for example in the case where "cat" appears in block-one and "rat" is the target item in block-two and the cue is "ANIMAL". We argue that the phonemic information will not be unique to the target item and thus subjects will not be able to use this information to discriminate the target from the interfering foil.

Experiment 5

The materials in this experiment were derived from thirty taxonomic categories. From each category a target item and two interfering items, of equal strengths were selected. One of the interfering items rhymed with the target whereas the other did not[4]. The process for obtaining these categories was to go through the S. Florida Rhyme Norms, to find rhyming words that could conceivably be members of the same category. Thus "rake" and "stake" could both be subsumed by the cue GARDENING IMPLEMENT. Having established thirty taxonomic categories with rhyming instances, controlled association procedures identical to those used to generate the S. Florida norms, were used. Seventy nine subjects were given the category cue and were instructed to write down the first instance of that category that they thought of. Using this procedure it was possible to select a non-rhyming instance of the category that had the same associative strength as the item selected to be the rhyming interfering instance. It should be stated that because rhyming members of taxonomic categories were uncommon, the vast majority of target and interfering items used in this experiment were very weakly related to the category cue. The cues and instances are presented in Appendix A. The method for construction each subject's trials was identical to that used in earlier experiments.

The forty five trials in the experiment consisted of 30 two-block trials and 15 filler trials. The thirty two-block trials consisted of 10 no-interference trials, 10 interference trials in which the target and foil did not rhyme and 10 interference trials in which the target and foil did rhyme. Retention interval was a between-subjects variable in this experiment whereas it has been a within-subjects manipulation in the previous experiments. Difficulties in establishing an adequate pool of rhyming instances of taxonomic categories forced this variation in procedure.

Results

Performance on the cued recall trials is summarized in Table 1. On immediate trials, the comparison comparing the non-rhyming interference condition to the no-interference condition confirmed that there were no reliable differences between the means for these conditions, $\underline{F}$ (1, 19) = 1.16, $\underline{MSe}$ = .017. The comparison between the rhyming interference and no-interference conditions demonstrated that having a rhyming item in the first block did hurt performance $\underline{F}$ (1, 19) = 9.00, $\underline{MSe}$ = .017. Regarding performance on the delayed trials, is was predicted that there should be no difference between the two interference conditions. The comparison involving these conditions was not significant, $\underline{F}$ (1, 19) = 0.01, $\underline{MSe}$ = .026.

The pattern of block-one intrusions, presented in Table 2, complements correct recall performance. Of those subjects who were given immediate tests, three subjects did not make any block-one intrusions. Of the seventeen remaining subjects who did produce at least one block-one intrusion, sixteen subjects made more rhyme interference intrusions than non-rhyme intrusions and one subject produced a tied score. Nobody made more non-rhyme intrusions than rhyme intrusions. On the delayed test, eight subjects produced more rhyme intrusions than non-rhyme intrusions, eight subjects produced more non-rhyme than rhyme, and there were four ties. Clearly the nature of the interfering item was having a strong effect upon an immediate test but little effect upon a delayed test.

Discussion

Most of the expected patterns of performance emerged in the data. Interference was present on an immediate test when the two instances on the list were rhyming members of a taxonomic category. When the instances did not rhyme, no effects of the interfering item were observed on target recall. Considering the results of this experiment and those of Experiment 3, it would appear that the presence or absence of PI on an immediate test can be best understood in terms of target similarity effects. That is, if the recall process produces representations of two items that have similar sound characteristics, it is less likely that the target item will be produced than if the two items have dissimilar sound characteristics.

In the current experiment, performance on the delayed test was not as clean as we would have liked. If one looks at the correct recall measure, it would appear that there are no interference effects. However, if one looks at block-one intrusions, it is clear that the block-one items are having a substantial effect upon performance. The deleterious performance in the control condition is probably due to the nature of the categories used and to extremely weak associations that generally existed between the cues and the instances. However, for present purposes the critical factor was that the two interference conditions did not differ, as they did on the immediate test. This was the case whether correct recall or block-one intrusions were used as the dependent measure.

Experiment 6

The previous experiments have focused on the phonemic attributes of the target items and have assumed that a phonemic representation of the interfering item has not been present. Logically it follows that if a phonemic representation of the interfering item could be generated we should observe PI on an immediate test. The final experiment to be reported here, attempted to ensure that at test, a phonemic representation of the interfering item would also be present.

Most current explanations of short-term recall (Baddeley, 1986; Nairne, 1990; Penney, 1989) argue that auditory presentation produces stronger or more distinctive short-term information than does visual presentation. Furthermore, it appears that this auditorially generated short-term information is not interfered with if subjects are instructed to group items (Ryan, 1969). Grouping items in such a way produces striking within group recency effects with auditory presentation and their absence with visual presentation (Frankish, 1985).

These within-list modality effects are important for present purposes because it would appear that they are related to phonemic information. Frick (1989) and Greene

(1989) have both carried out grouping studies in which phonemically similar lists have been employed. In both data sets, not only is the end of list recency effect depressed but also within group recency is almost non-existent. Furthermore, the Greene (1989) data has demonstrated that in grouped lists, reading the items aloud in one block tended to suppress the recall of silently read items in a second block.

On the basis of this literature, it might be possible to maintain a phonemic representation of the interfering item, if subjects read the first block items aloud, but read the second block items silently. If our guess is correct, at recall there may be a phonemic representation of the interfering item as well as the target item. If such is the case PI should be observed. In the case where subjects read the block-one items silently and the block-two items aloud, there should be strong phonemic information available for the target item alone. Under these conditions, we would expect to find immunity to PI.

Method

Twenty interference trials and twenty no interference trials were created in the same fashion as in the other experiments. Ten one-block cued recall trials were also presented.

Procedure

The procedure adopted in this experiment is very similar to that employed in previous experiments. The only difference in this experiment is that instructions concerning presentation conditions, preceded each block. Prior to the presentation of each block, the word ALOUD or SILENT appeared for one second. If the instruction was ALOUD, subjects were instructed to read the items aloud as they appeared on the screen. If the cue was SILENT, subjects were instructed to remain silent throughout the presentation of four items. The instructions came in two orders, if the first block was read aloud, the second block was read silently, or if the first block was was read silently, the second block was said aloud. All trials utilized an immediate test.

Results and Discussion

Performance on the cued recall trials is summarized in Table 1. When the first block was read silently and the second block was read aloud, the interference condition did not reliably differ from the no-interference condition, F (1, 19) = 1.63, MSe = .019. However, when the first block was read aloud and the second block read silently, PI was observed in that performance on the no-interference trials was reliably better than performance on the interference trials, F (1, 19) = 5.94, MSe = .019.

The error data on the two-block trials is presented in Table 2. The pattern of block-one intrusions again complements correct recall performance. Two subjects did not make any block-one intrusions. Of the eighteen remaining subjects who did produce at least one block-one intrusion, seventeen subjects made more block-one intrusions in the aloud-silent conditions than in the silent-aloud conditions. One subject made one block-one intrusion in the silent-aloud condition and none in the aloud-silent condition.

The study conditions were varied in the current experiment in an attempt to alter the strength of phonemic codes by requiring subjects to read items aloud. The pattern of PI effects appears to confirm the success of such a manipulation, in that the emergence of PI on an immediate test in the aloud-silent condition suggests that we have produced and maintained a phonemic representation of the interfering foil. With the presence of phonemic information for both the target and interfering item, there are problems in discriminating the target item from the interfering item.

General Discussion

Three basic performance characteristics have emerged from the current set of experiments that require explanation. Firstly, PI effects are time dependent. That is, they generally only emerge after a brief retention interval. Secondly, this time dependency of PI is modified by a materials variable. PI does occur on an immediate test if the to-be-remembered word and the interfering word rhyme. This occurs for both ending cues and taxonomic cues. Thirdly, PI effects appear to be sensitive to manipulations that either interfere with or strengthen phonemic codes.

This pattern of performance is consistent with an explanation of PI that is based upon an assertion that phonemic information can provide supplementary discriminative information when combined with central information. The relationship between PI effects and phonemic information is indicated in the first two experiments where phonemic similarity and PI effects were explored using the same task parameters. Immunity to PI was observed under the same task conditions that produced strong phonemic similarity effects. However, under task conditions in which phonemic similarity effects were attenuated, PI effects also became apparent. In the remaining experiments, attempts were made to manipulate the strength of or the presence or absence of phonemic codes. The finding that PI effects corresponded in a principled fashion to the manipulation of phonemic information provides strong converging evidence for the role of phonemic codes in producing PI effects. While the empirical evidence strongly indicates the influence of phonemic codes in short-term PI , we have ignored the possibility that other explanations of the data are possible. We now turn to this issue.

There are at least two factors involved in our experimental design that may be having an unwarranted impact upon performance[5]. In Experiments 3, 4, and 6 the interfering word was always a high dominant instance of the category and the target item was always a low dominant instance. If subjects became aware of this fact it is possible that they could use this information to restrict their answers to the low dominant member. The second methodological issue involves the use of only the second and third serial positions. Again if participants became aware of this constraint they could limit their responses accordingly. The adoption of these strategies should make the task much easier. That is, block two in effect becomes a one or two item list instead of a four item list. If this is happening, the current findings are all the more surprising and may well underestimate the effects of the variables being manipulated. Furthermore, these strategic explanations explain why immunity to PI might be observed on an immediate test, but they do not explain why modality and rhyming variables should produce differential effects, nor why PI emerges after such a brief retention interval when presumably the same strategies could be employed.

In turning to more theoretical alternatives to our explanations, it is possible to attempt alternative explanations for immunity to PI on the basis of different memory structures. Wickens, Moody and Dow (1981), for example, argue that the differences can be explained in terms of what is in consciousness and what is not. To account for the current data from this perspective, one would have to argue why rhyming items are lost from consciousness more rapidly than non-rhyming items. We can think of no plausible reasons why this should be the case. Furthermore, one would have to specify how modality of presentation affects consciousness. Again, we can think of no reasonable explanation for the modality effect in terms of items being active in consciousness. The pattern of PI effects do not appear to be conducive to explanations that involve items being resident in consciousness or in some type of short-term buffer.

Another frequently proposed alternative involves temporal distinctiveness. A number of researchers have suggested that many of the recency effects which pervade memory tasks can be explained by assuming that recent items are more temporally distinctive than early items (Baddeley & Hitch, 1974; Crowder & Neath, 1991; Glenberg & Swanson, 1986). A perceptual metaphor is usually employed to highlight the essential characteristics of temporal distinctiveness. The metaphor involves an observer looking at a line of telephone poles. The last pole in the line is more easily discriminated from earlier ones if the observer is standing near the last pole in the line than if the observer is standing a long distance from the last pole. To explain performance in Experiment 3 it would be argued that the target item in the second block is more temporally distinctive on an immediate test than it is on a delayed test, with the result that discrimination is easier on an immediate test than on a delayed test. In short, from this viewpoint immunity to PI is an emergent feature of increased temporal distinctiveness. However, we think that appeals to temporal distinctiveness cannot account for the effect that rhyming targets have. We cannot see how rhyming words are less temporally distinctive than non-rhyming words, an assumption that would have to be made to explain the rhyming effects. In terms of the telephone pole metaphor, we cannot think of any attributes of telephone poles that make them equally distinctive at short and long distances.

An alternative way to evaluate our explanation of short-term PI effects is to examine the necessity for the assumptions that have been proposed to explain the current findings. We would like to argue that a complete explanation of PI would have to include an assumption involving a distinction between speech based and central memory codes.

With respect to the involvement of phonemic codes, it is clear that target similarity effects are present in the data. These target similarity effects are observed in materials that are both orthographically similar and phonemically similar. In opting for a phonemic similarity account and rejecting orthographic similarity as the crucial variable, we are relying primarily upon the demonstrated involvement of phonemic codes in immediate serial recall, their role over short retention intervals in the Brown-Peterson task (Conrad, 1967; Estes, 1973; Tell, 1972), and their role in other short-term retention tasks (see Penney, 1989). In contrast to the strong support for the role of phonemic codes, Penney (1989) has presented a substantial amount of evidence which indicates that visual codes are unlikely to be used or even generated under the immediate test conditions employed in the current experiments. The finding that PI effects are sensitive to manipulations that are generally accepted to alter the strength or availability of phonemic information, provides converging evidence for the role of phonemic codes.

Given the strong evidence for the role of phonemic codes in other tasks, we think it is reasonable to assume that they are also operating in the current short-term cued recall task. Such an assumption has the benefit of explaining the pattern of short-term PI effects as an emergent feature of the operation of other, well documented short-term characteristics. From such a perspective, these results are continuous with much of the traditional short-term memory literature.

In concluding we would like to return to the issues that prompted this paper. We argue that immunity to PI and the interaction of PI with target similarity and presentation modality must be addressed in any account of PI. Our approach to this problem is to argue for the joint combination of central and phonemic codes. At the present time we have not specified exactly how this occurs. Solutions to this problem would probably differ, depending upon assumptions about the architecture of memory. However, providing a solution to the problem would not only go a long way towards providing a complete account of PI, it would go a long way towards providing a complete explanation for short-term memory as well.

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Author Notes

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Footnotes

1. By using the term discrimination, all we want to convey is the generic notion that some process is involved in being able to choose the target item and reject an interfering item. The most common way that discrimination has been addressed in the PI literature is in terms of trace discrimination. In these studies, PI is seen simply as the inability of the subject to discriminate the most recent memory trace from earlier similar traces (Bennet, 1975; Crowder, 1982; Gorfein, 1987). We think it ill advised to adopt this position for two reasons. Firstly, there are data to suggest that this is an overly simplistic response (Dillon & Thomas, 1975; data from the current experiments). Secondly, the idea of suppressing non-target responses and selecting target response is a feature of some connectionist models that assume distributed rather than localized representations (Chappell & Humphreys, in press). It is plausible that this type of memory model may provide a better fit of the PI data than the trace discrimination models.

2. Pilot work indicated that the position of the interfering item in the first block had no effect upon the interference effects found.

3. While we have chosen to explore phonemic codes within rhyme categories, our predictions would not change if the items that had similar beginnings and were cued with a stem. e.g. wreck, wrench WRE. Our choice of ending cues rather than stem cues were based solely on the fact that the norms we had for ending categories were more extensive than for stem categories.

4. As one reviewer pointed out, we have made one error in selecting one of the thirty sets of materials. Selecting slime and grit as rhyming and non-rhyming distractors for grime, fails to control for the fact that grit and grime also share some phonemic characteristics. Although the vowel characteristics differ, the presence of some overlap means that grit is less likely to be an appropriate control than other selected items.

5.These factors were suggested by an anonymous reviewer of an earlier version of this paper.

Table 1

Mean Probability Correct for Recalling the Block-2 Target as a Function of Type of Test, Interference Condition and Retention Interval .

	Retention Interval	
	Immediate	Delayed
Experiment 3 (pig sheep FARM ANIMAL)		
No Interference	.87	.79
Interference	.85	.58
Experiment 4 (wrench bench ENCH)		
No Interference	.92	.79
Interference	.85	.62
Experiment 5 (cat rat ANIMAL)		
No Interference	.87	.57
Interference - Non-rhyme	.82	.55
Interference - Rhyme	.74	.54
Experiment 6 (pig sheep FARM ANIMAL)		
Silent - Aloud		
No Interference	.88	-
Interference	.83	-
Aloud-Silent		
No Interference	.71	-
Interference	.60	-

Table 2

Probability (Conditional Probability) of Making Various Errors on Block-2 Target Recall as a Function of Interference Condition and Retention Interval.

	Type of Error		
		Extra-List	List
Experiment 3	Omissions	Intrusions	Intrusions
Immediate Test			
No Interference	.09 (.72)	.04 (.28)	-
Interference	.06 (.40)	.02 (.11)	.07 (.49)
Delayed Test			
No Interference	.22 (.77)	.06 (.23)	-
Interference	.17 (.39)	.04 (.11)	.21 (.50)
Experiment 4			
Immediate Test			
No Interference	.03 (.40)	.05 (.60)	-
Interference	.03 (.17)	.03 (.17)	.09 (.66)
Delayed Test			
No Interference	.06 (.25)	.15 (.75)	-
Interference	.06 (.17)	.09 (.24)	.23 (.59)
Experiment 5			
Immediate Test			
No Interference	.09 (.67)	.03 (.33)	-
Interference - Non-rhyme	.08 (.43)	.08 (.43)	.03 (.14)
Interference - Rhyme	.05 (.19)	.04 (.13)	.17 (.65)
Delayed Test			
No Interference	.31 (.71)	.13 (.29)	-

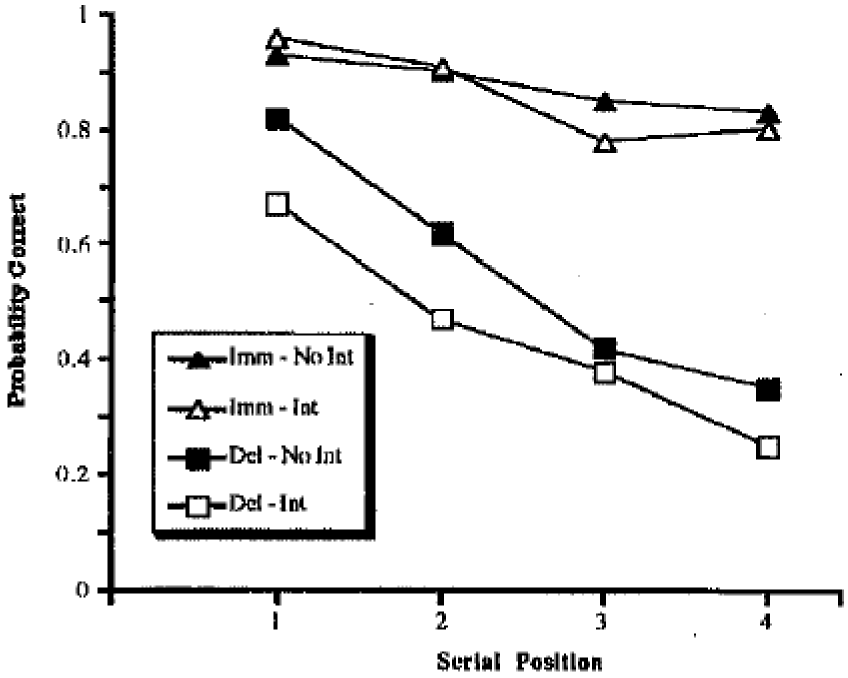
Interference - Non-rhyme	.19 (.42)	.09 (.20)	.18 (.38)
Interference - Rhyme	.18 (.38)	.10 (.22)	.18 (.39)
Experiment 6			
Silent - Aloud			
No Interference	.10 (.79)	.03 (.21)	-
Interference	.09 (.49)	.03 (.17)	.06 (.34)
Aloud-Silent			
No Interference	.22 (.75)	.08 (.25)	-
Interference	.09 (.21)	.04 (.09)	.28 (.70)

Note: The probability of making a particular type of error given that an error was made, is presented in brackets.

Figure Caption.

Serial Position Curves for Correct Recall of Immediate and Delayed, Interference and No-interference Trials in Experiment 2

Fig 1.


Probability Correct
1
0.8
0.6
0.4
0.2
0
1
2
3
4
Serial Position
Imm - No Int
Imm - Int
Del - No Int
Del - Int

Appendix A

Materials Used in Experiment 5

		Interfering Instance	
Cue	**Target**	**Rhyme**	**Non-Rhyme**
TYPE OF DIRT	grime	slime	grit
TYPE OF SOUND	ping	sing	music
TYPE OF NOISE	clang	bang	hum
AMUSEMENT PARK ITEM	slide	ride	swing
TYPE OF FOOD	wheat	meat	bread
RELATED TO THE HAND	wrist	fist	arm
ANIMAL	goose	moose	duck
TOY	trike	bike	plane
SYNONYM OF UNCOUTH	crude	rude	vulgar
COOKING PROCEDURE	broil	boil	fry
SMALL WOUND	nick	prick	gash
TYPE OF ACCIDENT	smash	crash	plane
NOISE FROM MOUTH	squeak	speak	cough
PART OF A BODY	loin	groin	breast
FARM ANIMAL	hog	dog	horse
MUSICAL INSTRUMENT	lute	flute	sax
BODY MOVEMENT	flick	kick	sway
FISHING EQUIPMENT	creel	reel	bait
TYPE OF PEST	lice	mice	flea
PART OF A HOUSE	wall	hall	lounge
HITTING MOVEMENT	whack	smack	thump
FOUR-LEGGED ANIMAL	rat	cat	cow

PART OF A BUILDING	floor	door	room
COOKING ITEM	rice	spice	ladle
TYPE OF BIRD	hen	wren	owl
GARDENING IMPLEMENT	stake	rake	fork
ARTICLE OF CLOTHING	smock	sock	jeans
TYPE OF PLANT	reed	weed	ivy
MICROSCOPIC ITEMS	sperm	germ	cell
DAILY MEAL	brunch	lunch	dinner