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The effects of rime on auditory recency and the suffix effect

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Two experiments are reported that consider the role of rime as the content of Precategorical Acoustic Storage (PAS). It was hypothesised that with auditory presentation of lists the rime component of the final item (the final vowel and, optionally, terminal consonant cluster of a word) was preserved in PAS and this served as a recall cue to identify the final item. Experiment 1 compared recall performance when the terminal or penultimate words rhymed with an irrelevant stimulus suffix. A suffix that shared a rime with the terminal word was found to attenuate the suffix effect, in line with Carr and Miles (1997) and consistent with the use of PAS as a positional code. However, contrary to the hypothesis that PAS information is automatically used to reconstruct the final item, the suffix effect was no greater when the suffix rhymed with the penultimate item than when no relationship existed between the suffix and the final item. Experiment 2 demonstrated that when the terminal and penultimate words shared a rime there was a drop in recall performance for the final item but a corresponding increase in correct recall of the penultimate item. No such changes were observed when the rime was shared between terminal and antepenultimate items. It is suggested that adjacency of identical rimes allows improved reconstruction of item information at the expense of order information.

Immediate serial recall of auditory lists is characterised by greatly improved performance on recall of the terminal item, a phenomenon

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referred to as the auditory recency effect. This level of recall performance is selectively disrupted by the presence of an irrelevant stimulus suffix (Morton, Crowder, & Prussin, 1971). Explanations of the effect have variously been based upon differential storage of the final item (e.g., Crowder & Morton, 1969), or upon the distinctiveness of the final item relative to the rest of the list (Nairne, 1988, 1990; Surprenant & Neath, 1996). In both cases this extra information available at the end of the list is assumed to be overwritten by the presence of a post-list suffix.

The exact relationship between the representation of the stimulus suffix and the to-be-recalled list, especially the final item, is a subject of some controversy. The classical Precategorical Acoustic Storage (PAS) account of Crowder and Morton (1969) claims that a PAS representation of the final item is obliterated by the presentation of the suffix. Categorical, or lexical, representations of the final item existing elsewhere in the cognitive system are largely unaffected by the presence of the suffix, as are representations of earlier list items which do not exist in PAS form (see Morton, 1976 for a full account). Implementations of this form of the theory are to be found in recent PDP simulation models by Burgess and Hitch (1999), Lewandowsky and Murdock (1989), Page and Norris (1998).

Since the PAS account was first proposed, data have been produced that highlight deficiencies in PAS as a complete account of auditory recency and suffix effects. Lip-reading (or "speech-reading") for example, produces similar, albeit smaller, recency effects to heard speech that are susceptible to suffix interference (Campbell & Dodd, 1980; de Gelder & Vroomen, 1994; Spoehr & Corin, 1978). This can be simply accommodated in the PAS model by assuming that heard and seen speech are perceptually organised as the same "kind" of entity (e.g., Barnard, 1998; Crowder, 1983), a proposal that has some independent support (Calvert et al., 1997). As the same kind of entity they will naturally have access to the same representational resources, including PAS. Thus, all the rest of the PAS explanation remains the same. The only difference is that the level of coding at which the phenomena occur is different. Speech-read material produces smaller effects than heard speech, according to this argument, because it drives the speech system less efficiently. Certain other, non-speech, stimuli also show small recency and suffix effects, for example environmental sounds (de Gelder & Vroomen, 1997) and American Sign Language (Shand & Klima, 1981), which may perhaps be produced by PAS-type mechanisms in non-speech domains (Nairne, 1990). The pattern of recency and suffix interference in these cases is not as well established as in heard and seen speech, however (Beaman & Morton, 2000). There is evidence that non-speech recency and suffix effects are restricted to their own domains of operation, so, for example,

environmental sound suffixes disrupt environmental sound recency but not auditory-verbal recency (de Gelder & Vroomen, 1997) and vice versa (Rowe & Rowe, 1976). Thus it seems likely that the actual mechanisms involved in producing recency and suffix effects in these domains are distinct from those used with auditory-verbal material, even though the processes involved may be similar.

In many cases, however, speech-reading does produce a suffix effect on auditory-verbal lists (Gardiner, Gathercole, & Gregg, 1983; Spoehr & Corin, 1978) and is itself disrupted by the presence of an auditory-verbal stimulus suffix (Campbell & Dodd, 1982; de Gelder & Vroomen, 1992; Gathercole, 1987; Greene & Crowder, 1984). Thus the term "Precategorical *Acoustic* Store" may be something of a misnomer, since the same mechanism is implicated in speech and speech-read recency and suffix effects. However, even with speech-read material it is clear from work on auditory-visual speech perception that different speech information may be conveyed by the different sensory modalities. The well-known McGurk illusion, for example, is not symmetrical in operation: When the visual information conveyed is "gah" and the auditory information is "bah", the resulting percept is "dah" (McGurk & MacDonald, 1976). If the auditory information is "gah", and the visual "bah", the "dah" illusion does not occur (see Summerfield, 1987 for a full discussion). Consequently, in this study we concentrate on investigating the auditory-verbal domain, using the PAS-derived idea that there exists a final representational resource available to the final list item, unless it is displaced by a post-list suffix. The term "PAS" will be used despite its deficiencies as a short-hand to refer to a mechanism for maintaining final-item speech information. In these experiments such speech information will always be presented auditorily.

Alternative formulations to PAS exist that assume a common level of representation for all items including the suffix item (e.g., Frick, 1988; Nairne, 1990). Such explanations vary in their ability to account for the existing data. These data include several series of experiments examining the types of stimuli that elicit strong auditory recency effects. For example, a series of experiments reported by Crowder (1971) show that accurate serial recall of the final item of a list of consonant-vowel (CV) stimuli is diminished if the lists share a common vowel sound but not if the lists share a common onset. Thus, lists constructed of the stimuli "ba", "da", "ga" do not show the levels of final item recency expected from an auditorily presented list, although lists constructed from the stimuli "ba", "be", "bu" do show such recency. Crowder attributed these differences to a selective retention of vowels in PAS.

Additionally, using lists in which the discriminability of the consonants was greater (the stimuli used were "ash", "am", "ag", and "sha", "ma",

"ga" for the VC and CV lists respectively, Darwin and Baddeley (1974) were able to show the same effect as Crowder (1971) with the drop in recall performance being more clearly restricted to the final serial position. The lists in which the initial consonant was varied in the Darwin and Baddeley (1974) study produce much-reduced auditory recency. The lack of such auditory recency for consonant-varied lists supported Crowder's (1971) suggestion that vowels rather than consonants are maintained by PAS.

There are, however, a number of difficulties with the suggestion that privileged retention of vowel sounds occurs with serial recall of auditorily presented material. First, there is the objection that in both the Crowder (1971) and Darwin and Baddeley (1974) studies the within-list phonological similarity was increased. Phonological similarity is known to disrupt the serial recall of even visually presented lists and therefore the loss of auditory recency might reflect confusion of a phonological code rather than anything specific to auditory presentation (Baddeley, 1968). However, if phonological similarity is measured by the number of phonemes in common then in the Darwin and Baddeley study the phonological similarity is identical for both CV and VC lists, yet the CV lists produced less auditory recency than the VC lists.

The second objection to the retention of vowel sounds with auditory presentation is the observation from the same data that, where the consonant was varied, CV lists produced less auditory recency than VC lists (see also de Gelder & Vroomen, 1994). If auditory presentation simply favours the retention of vowel sounds over consonants there should be no difference between these two conditions. The existence of such a difference suggests the possibility that the positioning of the consonant sound is also of importance. Since the early studies by Crowder (1971) and Darwin and Baddeley (1974) there have been a number of attempts to determine what stimuli are effective in producing auditory recency. The results of these studies are summarised in Table 1.

Reviewing the data from previous studies leads to the suggestion that rather than distinctive variation in the vowel sounds determining the levels of auditory recency, the location of the variation within the word is also important. Verbal stimuli can be broken down into the onset (in CVC stimuli, for example, this will be the initial consonant) and the rime (the vowel plus the rest). A possibility that arises from reviewing the data in Table 1 is that variation in the rime of the word, which is often determined by the vowel sound in CVC stimuli, rather than variation in the vowel sound *per se* is important. Variation in the onset of the word does not affect the appearance of the auditory recency effect.

For example, recent research along these lines carried out by Surprenant and Neath (1996) complicates the simple idea that stimulus variation

TABLE 1
Nonsense syllables tabulated according to whether they give reliable recency and suffix effects

Stimuli	*Recency?*	*Suffix?*	*Source*
be, bu, ba	Yes	Yes	Crowder (1971)
ba, da, ga	No	No	Crowder (1971)
aʃ, am, ag	Yes	Yes	Darwin & Baddeley (1974)
ʃa, ma, ga	No	No	Darwin & Baddeley (1974)
bi, ba, bo	Yes	?	De Gelder & Vroomen (1994)
ba, da, va	No	?	De Gelder & Vroomen (1994)
bæb, bib, bIb, bEb, bob, bΛb	Yes	?	Surprenant & Neath (1996)
bæb, dæb, gæb, kæb, pæb, tæb	No	?	Surprenant & Neath (1996)

in a particular location (onset versus rime) governs the appearance of auditory recency. Consistent with Crowder's (1971) suggestions, Surprenant and Neath found the CVC items that had the same initial and ending consonant but varied in vowel sound (e.g., "bab", "beab", "bib", "beb", "bob", and "bub") were more accurately recalled than CVC items which had the same vowel and terminal consonant but varied the initial stop consonant (e.g., /bab/, /dab/, /gab/, /kab/, /pab/, and /tab/). Closer examination of Experiment 1 of Surprenant and Neath reveals that the majority of the advantage for the vowel-varied stimuli over the consonant-varied stimuli appears in the recency portion of the curve. Specifically, when initial consonant-varied stimuli were employed there was no sign of the usual high levels of auditory recency. One possibility is that in Surprenant and Neath's study the onsets are all stop-consonants and therefore confusable, however the results are also consistent with the idea that the onset (the initial consonant) plays no part in determining the appearance of auditory recency, but the rime (here determined by the final VC) is crucial to the appearance of the effect.

The conclusion that "rimes enjoy a privileged status within acoustic memory in comparison to the onset component" was also reached by Carr and Miles (1997, p. 525) on the basis of a different line of evidence. Carr and Miles contrasted the effects of rhyming and alliterative suffixes (suffixes that shared an onset and vowel with the final item) on the appearance of auditory recency. For example, if the final item was "hut", the control (unrelated) suffix was "log", the alliterative suffix was "hum", and the rhyming suffix was "nut". In all cases an alliterative suffix shared onset and vowel with the final item, and a rhyming suffix shared the vowel and the final consonant. The results obtained by Carr and Miles (1997) demonstrated that a rhyming suffix produced an attenuated suffix

effect but that an alliterative suffix produced a full suffix effect. Carr and Miles argued from this data that the rime of the stimulus suffix was still active in auditory memory, a conclusion that converges with the earlier speculations that variations within the rime affect the appearance of auditory recency. Given that the stimulus suffix effect and auditory recency are generally assumed to be dependent upon the same system, the next question is to consider how that system might operate in practice.

One possibility is that the information in auditory memory regarding the nature of the final item is used as a guide to reconstructing what that item was at the time of recall. Since by definition the rhyming suffix shared a rime with the final item, therefore in Carr and Miles' experiment the attenuated suffix effect occurred as a result of retention of the rime of the suffix in auditory memory and its use as a guide to recall of the final item. In the case of alliterative or unrelated suffixes the information preserved in auditory memory is not consistent with the identity of the final item and so actively impedes attempts to reconstruct and then recall the final item. A logical corollary to this is that if auditory memory retains the rime of a preterminal item then even greater confusion would occur since, during recall, the information available in auditory memory is consistent with the identity of one of the list items, but not the final item. If use of the information available in auditory memory is obligatory during recall attempts we would therefore expect an increase in the number of mistaken recalls of the item that shared a rime with the suffix in the final serial position.

In quasi-connectionist terms one can imagine that with auditory presentation there would be residual activation of the rime of the final word in a layer of nodes representing PAS or acoustic memory. The term "speech trace" is used here for want of an alternative neutral term for a mechanism that might retain speech information but not orthographic visual-verbal information. The representation of the final word might also be active in a layer of nodes coding for phonological or lexical representations. This would also be associated with the representation at the "speech trace" layer since presumably both the phonological and lexical analyses of the word are derived from its early sensory representation. Thus, when recall of the final item is required the speech trace representation supplements the information available at the phonological/lexical level.

If an unrelated suffix were presented then the appearance of the suffix at the acoustic level of representation would interfere with the representation of list items at the phonological/lexical level because of cross-talk between the two incompatible representations (situation 1). However, if the suffix shared a rime with the final item then the situation would be much the same as if no suffix were presented. The speech trace represen-

tation would be automatically reactivated on recall, but in this case the speech trace representation (the rime of the suffix) is consistent with that of the final item and so the suffix effect would be attenuated (situation 2). What would happen in a condition in which speech trace representation was consistent with the representation of the penultimate item across the nodes coding the phonological/lexical level representation, that is the condition in which the suffix shared a rime with the penultimate item (situation 3)? There would not only be cross-talk but also, because the speech trace representation would activate those nodes at the phonological/lexical level with which it was consistent, the penultimate item would receive extra activation from the speech trace representation. Thus, there should be an increase in the number of penultimate items mistakenly recalled in the final serial position. A graphical depiction of the state of the system is given in Figure 1.

EXPERIMENT 1

Experiment 1 was designed to test the hypothesis that rime is preserved with auditory presentation and is automatically used as a cue to reconstruct the identity of the final item in a list. This assumes that the extra memory information available with auditory presentation is marked as being the final item before recall commences. This assumption is necessary for the simulation studies by Lewandowsky and Murdock (1989), Page and Norris (1998), as well as the original Crowder and Morton theory (1969) and other positions which rely on an additional final-item only memory representation. We expect to replicate the finding that if the suffix shares a rime with the final item then the suffix effect will be attenuated. In addition, the hypothesis under investigation predicts that if a suffix shares a rime with the penultimate item, it produces a greater suffix effect. As in earlier studies by Morton and colleagues the suffix effect is defined as a decrease in absolute recall of the final item relative to a no-suffix control (e.g., Morton, 1976; Morton et al., 1971). Order information pertaining to which item appeared in the end of list position can be inferred from the identity of the item retained by PAS. This is true regardless of whether precategorical acoustic storage acts to increase the activation level of the final item representation at the decision-making (output) stage (as in the account of Burgess & Hitch, 1999), or whether PAS is regarded as a separate "last-item only" buffer (Lewandowsky & Murdock, 1989; Page & Norris, 1998).

The logic of the experiment is as follows: The condition in which the suffix rhymes with the final item gives rise to an attenuated suffix effect because the rime of the suffix—the speech trace or PAS representation—

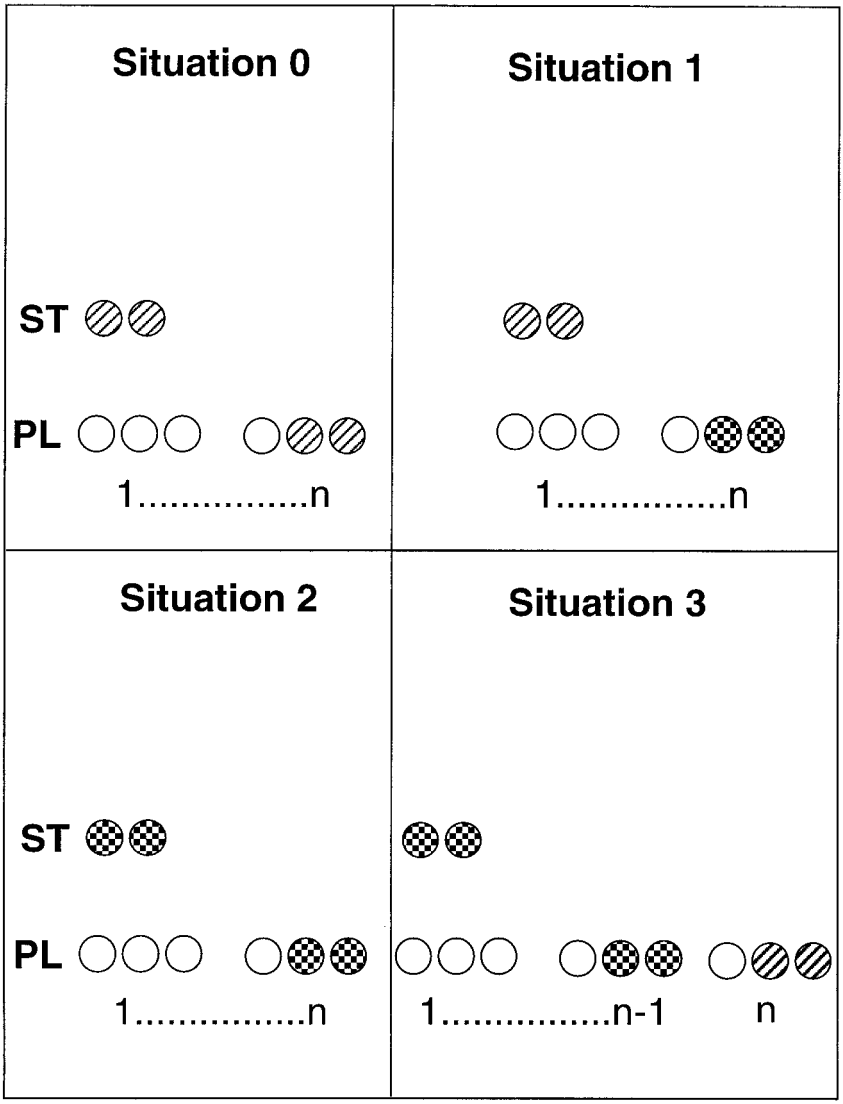

Figure 1. Individual stimulus items are represented here as comprising three elements, equivalent to a CVC structure. Recall of the final item (n) is assumed to occur by reconstructing its identity using information represented by a residual speech trace (ST) and at the phonolexical (PL) levels. In situation 0 (no suffix) and situation 2 (rhyming suffix) this has no consequences because ST and PL information is consistent. In situation 1 (unrelated suffix) a suffix effect occurs because ST and PL information is inconsistent, and in situation 3 (penultimate rhyming suffix) the effect is greater because the ST representation is consistent with the wrong PL representation.

is used as a cue to reconstruct the identity of the final item. However, if the rime of the suffix is shared with the penultimate item then it will mistakenly cue recall of the penultimate item to appear in the final position. The confusion occurs because the PAS representation (however it is construed) is consistent with the penultimate item and, by virtue of being represented in PAS, is marked as being the end of the list. In other words the system is predisposed to recall as the final item the item consistent with the PAS, or speech trace, information. Thus the predictions are two-fold. A suffix that rhymes with the penultimate item will produce a greater suffix effect than an unrelated suffix, and this will occur because there will be an increase in the number of times the penultimate item is erroneously recalled in the final position.

Method

Participants. Sixteen undergraduates were paid a small honorarium to participate. All were native English speakers and reported normal hearing.

Materials and design. All the stimuli used were disyllabic, frequency-matched words taken from the Kuçera and Francis (1967) database. The stress pattern for each word was strong–weak, thus the words were effectively P-centred (Morton, Marcus, & Frankish, 1976). Sixteen pairs of whole-word rhymes were selected. Each pair was assigned to a list of five other words. None of these "filler" words shared a rhyme with the rhyming pairs. One of the words of each rhyming pair was assigned to the suffix position; in half the cases the other word was assigned to the final list position, in the other half the word was assigned to the penultimate list position. A further 88 words were used to construct the control (non-rhyming) lists. Half of these lists included an unrelated stimulus suffix. There were no repetitions of any of the words within an experimental trial. All the lists were recorded in a male voice using SoundEdit software at a sampling rate of 22 KHz with 8-bit resolution. Each word was edited to last approximately 600 ms. Between the presentation of each word there was a 400 ms pause. A 600 ms sine-wave tone was played 400 ms after the end of the final word in each list and 400 ms before the stimulus suffix, if any. A list from each condition was designated as a practice list. The lists were played to participants in random order over Sony MDR-CD470 stereo headphones.

Procedure. Participants were tested individually in a sound-attenuated room. They were told that they would hear lists of words over the headphones, followed by a tone as a cue to recall at the end of each list. They

were informed that sometimes another word would be presented after the tone, but were asked to try to ignore this word. As soon as they heard the tone they were to write down all the words they could remember in the order in which they had been presented on the sheet provided. If they did not know a word they were encouraged to guess, but if they felt they could not guess they were to draw a line and proceed to the next word. Returning and correcting any earlier mistakes was not allowed.

Results

A repeated measures analysis of variance (ANOVA) was carried out on the results. A significant main effect of suffix condition was found, $F(3, 45) = 17.6$, $MSE = 1.64$, $p < .0002$, which interacted significantly with serial position, $F(12, 180) = 7.82$, $MSE = 1.03$, $p < .0002$. For reasons of clarity a condition in which the terminal item shared a rime with the suffix will henceforth be termed a "terminal rhyming suffix" condition. Likewise the condition in which the rime was shared between the suffix and the penultimate item will be referred to as the "penultimate rhyming suffix" condition. Means comparisons showed no significant difference between recall performance in the penultimate rhyming suffix and the unrelated suffix conditions ($F < 1$); however, significant differences were found between the terminal rhyming suffix and the unrelated suffix conditions, $F(1, 15) = 27.34$, $p < .0002$, and between the terminal rhyming suffix and the no-suffix conditions, $F(1, 15) = 8.78$, $p < .004$. The form taken by these interactions is shown in Figure 2.

These results show no sign of the predicted confusion between the penultimate item and the final item in the penultimate rhyming suffix condition even though the attenuated suffix effect in the terminal rhyming suffix condition has been replicated. One possibility is that the errors at the final position caused by incorrect recall of the penultimate item as the final item were masked by errors of other types in Figure 2. However, although Figure 3 demonstrates that recalled position of the penultimate item was slightly more likely to be at the final serial position in the penultimate rhyming suffix condition than in the unrelated suffix, this type of error did not appear anything like as often as would be predicted from the hypothesis under test.

Discussion

The results of Experiment 1 force us to reject the idea that information retained in acoustic memory is automatically used as a guide to the identity of the final item. If there is no confusion between a suffix that was constructed specifically to deceive the system into misrecalling an

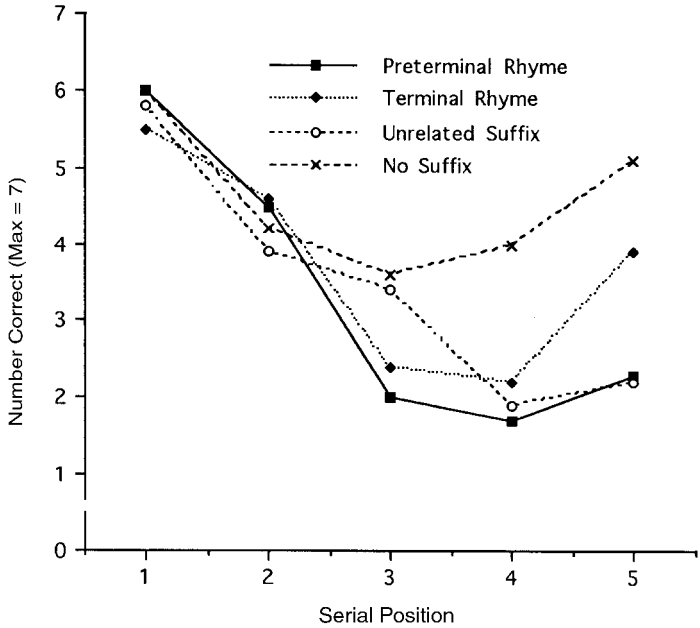

Figure 2. The effects of unrelated suffixes and suffixes rhyming with the final and penultimate list items on immediate serial recall.

earlier item as the final item then, the evidence suggests, the extra representation of the final item is not automatically used to reconstructing the identity of the final item. The replication of the attenuated suffix effect with a terminal rhyming confirms the reality of this phenomenon but the experiment failed to find support for the suggested explanation of the effect.

A further possibility is that the information retained by the speech trace can be voluntarily employed to reconstruct the identity of the final item given the right circumstances. Ordinarily in a suffix experiment the contents of the speech trace are rendered useless for recall purposes by the presence of a stimulus suffix and are consequently discarded. It is, however, possible that if there is a relationship between the suffix and the final item that can be immediately apprehended and retained on a single presentation then the speech trace representation of the suffix can be used to reconstruct the identity of the final item. Thus, by this hypothesis, the terminal rhyming suffix effect reflects an attentional process which registers the appearance of a rhyming pair, and uses the rime of the second item of the pair (which is preserved in the speech trace) to reconstruct the identity of the first item of the pair. Note that this is a different explana-

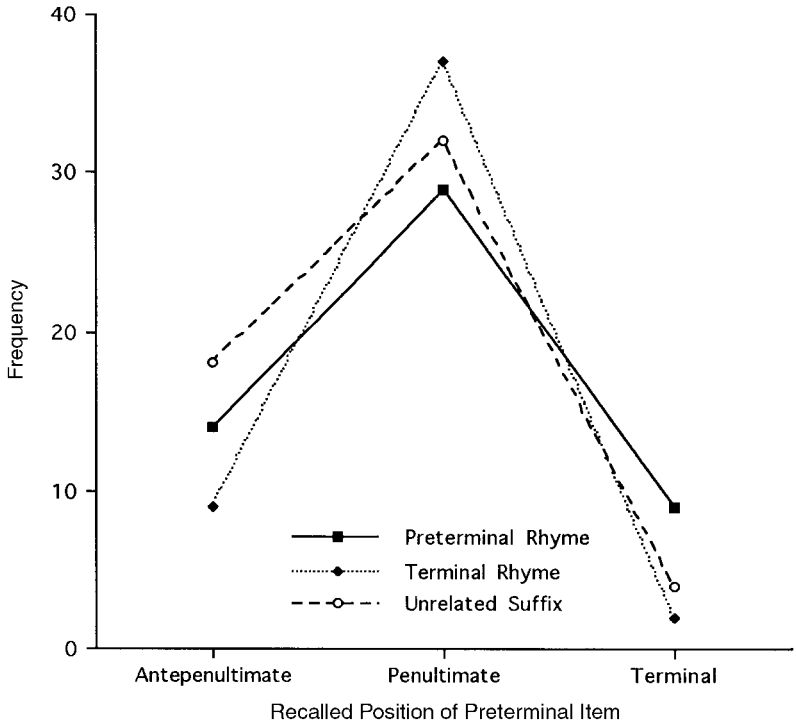

Figure 3. The frequency with which the penultimate item is recalled at the correct position and in earlier and later positions in suffix conditions in which the suffix rhymes with the penultimate item, the terminal item or is unrelated to either item.

tion from that given by Carr and Miles (1997), who argue that the rime component of a word is more durable than the onset within the whole of short-term acoustic memory (p. 525) but give no account of how this might be brought about. The explanation given here is arguably more parsimonious and also immediately gives rise to a number of predictions.

The first prediction can be tested by re-examination of the data from Experiment 1. The prediction is simply that if the suffix rhymes with the final item and is hence used to reconstruct the identity of the final item there must be occasions on which the speech trace or PAS information regarding the suffix (i.e., the rime of the suffix) is insufficient to correctly reconstruct the identity of the final item. On these occasions one would expect to see an item with an identical rime to the suffix misrecalled as the final item. This might be the suffix or another word that shares a rime with both suffix and final item. In fact, when the suffix shared a

rime with the terminal item 37.5% of all errors on the final item were mistaken reports of the suffix. The large number of such errors is consistent with the hypothesis that use of final-item specific PAS information to reconstruct the final item occurs when the final item and the suffix share a rime.

The second prediction is that a similar situation should also occur when there is no suffix and when the final two items share a rime. If the last two items share a rime then, as in the case where the suffix and the final item share a rime, the rime will be preserved as PAS information but for purposes of recall of the final two items it will not suffice to distinguish between them. Thus, there should be an increase in positional confusions between the final two items. Phonological similarity has long been known to detrimentally affect serial recall of list of items (e.g., Baddeley, 1968), so to ascertain that an attentional component is involved which registers the position of adjacent rimes when employing PAS, or speech trace, information an extra control condition is required.

Since pairs which share a rime but are separated from each other by a single item (the penultimate rhyming suffix condition) do not show an attenuation of the suffix effect there is a clear prediction that separating the rimes by a single item will prevent the shared rime registering. Even when the shared rime is included in the to-be-recalled list there should therefore be less positional confusion between rhyming pairs in a condition in which the rhyming pairs are not adjacent than in the condition where the rhyming pairs are adjacent.

EXPERIMENT 2

Experiment 2 was conducted as a further test of the hypothesis that rhyming pairs are immediately apprehended and used to guide recall under conditions where the pair are presented in adjacent serial positions and the rime of one of the pair is accurately and reliably stored. As a secondary issue, note that some models of serial recall (e.g., Lewandowsky & Murdock, 1989; Nairne, 1990) assume that recall involves the simultaneous comparison of a degraded memory trace of an item to undegraded representations of all the list items. These models must therefore predict that increasing the similarity—by allowing a shared rime—between the final item and any of the preterminal list items, whether adjacent or otherwise, will increase the number of positional confusions between those items. The prediction from these models is contrary to that derived from the results of Experiment 1. Phonological confusion is also used as an explanatory mechanism in the "phonological loop" component of the working memory model (Baddeley, 1986), however, reconstruction

of order information in that model is insufficiently well specified to derive an unambiguous prediction.

Method

Participants. Thirteen undergraduates were paid a small honorarium to take part. All were native English speakers who reported normal hearing. None had participated in Experiment 1.

Materials and design. The stimuli from Experiment 1 were used as experimental stimuli but the lists were rearranged such that the tone sounded after the presentation of the final list word in all cases. The terminal rhyming suffix lists from Experiment 1 thus became lists in which the final two items shared a rime (penultimate rhyming lists), the penultimate rhyming suffix lists became lists in which the final item and the antepenultimate item shared a rime (antepenultimate rhyming lists), and the unrelated suffix lists became an unrelated control list. The no-suffix control lists from Experiment 1 were excluded from the stimuli for Experiment 2. The equipment used to present the stimuli was the same as in Experiment 1.

Procedure. Participants were tested individually in a sound-attenuated room. They were told that they would hear lists of words over the headphones, followed by a tone as a cue to recall at the end of each list. The serial recall instructions were identical to those given in Experiment 1.

Results

The results of the experiment were analysed using a repeated measures analysis of variance (ANOVA). No main effect of rime was found, $F(2, 24) = 1.91$, $MSE = 1.75$, $p > 1$; however, there was a significant interaction between rime and serial position, $F(10, 120) = 3.55$, $MSE = .90$, $p < .0005$. Means comparisons of recall performance at the antepenultimate position between antepenultimate rhymes and control show no significant results, $F(1, 12) = 2.46$, $p > .05$, although means comparisons between penultimate rhymes and control at the penultimate position do show a significant difference, $F(1, 12) = 5.2$, $p < .03$. Importantly, a significant difference was also found at the final position between penultimate rhymes and controls, $F(1, 12) = 11.0$, $p < .002$, but no difference was detectable between antepenultimate rhymes and control at this position ($F < 1$). This pattern of results is displayed in Figure 4.

A post hoc analysis was also carried out on the effects of the rhyme on the first five serial positions. This analysis revealed a significant effect of

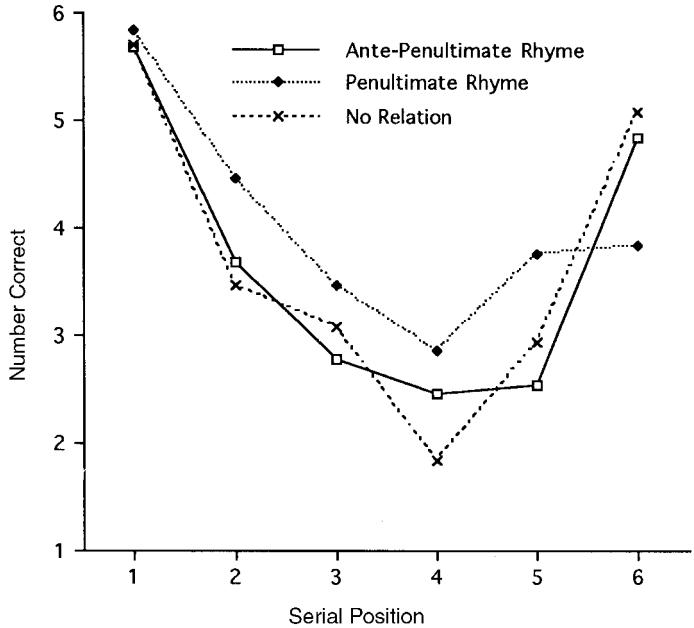

Figure 4. The effects on immediate serial recall of rhymes between the antepenultimate item and the final item (antepenultimate rhyme), and the penultimate item and the final item (penultimate rhyme).

rhyme early in the list, $F(2, 24) = 8.70$, $MSE = 1.82$, $p < .002$. As expected, there was also a significant main effect of serial position, $F(5, 60) = 18.98$, $MSE = 3.10$, $p < .0002$, although no significant interaction, $F(8, 96) = 1.92$, $MSE = 1.01$, $p > .05$. This general pattern confirms the impression given by Figure 3 that poorer performance on the final item in the penultimate rhyme condition was accompanied by improved recall earlier in the list.

Discussion

The outcome of Experiment 2 seems reasonably clear. If the terminal and penultimate items share a rime then confusion arises such that recall of the final item suffers, even though recall across the rest of the serial position curve is a little higher than in the control condition. Clearly, having a common rime for the last two items is effectively abolishing the auditory recency advantage because the extra representation of the final rime is no longer sufficient to distinguish between the final and the penultimate item. Unexpectedly, the existence of a common rime at the last

two serial positions also aided recall earlier along the serial position curve, presumably by reducing the functional size of the to-be-recalled list. We assume that the common rime is noted as occurring across the final two serial positions and this then limits the number of serial positions at which earlier items could be recalled as well as preventing either of the final two items from being recalled earlier than the penultimate position. This predicts that there will be no transposition errors between the last two serial positions and the earlier serial positions. Re-examination of the data confirms that this occurred only once throughout the entirety of the experiment.

No such argument applies in the case of the antepenultimate rhyme condition, which showed no significant differences from the control condition. When the rime of the final item was shared by an item that was not adjacent there was no confusion about the identity of the final item and no resultant improvement in recall at earlier serial positions occurred. This is contrary to the predictions from the TODAM model of Lewandowsky and Murdock (1989) and the feature model of Nairne (1990), both of which assume that recall of each item in a list occurs by finding the best fit to the degraded item representation from a pool including representations of the entire list.[1] It is, however, entirely consistent with the prediction from Experiment 1. If the antepenultimate item has not been registered as sharing a rime with the final item then the existence of the rime in PAS will ensure the usual high levels of auditory recency but will have no effect on the earlier list item(s).

GENERAL DISCUSSION

The experiments reported in this paper go some way towards demonstrating how the extra auditory information underlying the auditory recency effect can be used in a strategic manner. Note that although we have used the concept of the rime being retained by PAS, or by a residual speech trace, as the "extra" recency information, specific use of any form of representation supporting enhanced final-item recall could, in

[1]In fact, both experiments in this study create problems for Nairne's (1990) model, since the method of interference between items in that model is through overwriting of items by subsequent items. Overwriting occurs on the basis of similarity—the more similar a new item is to a previous one the greater the overwriting. Thus, a suffix that shares a rime with the final item should produce a greater suffix effect, not an attenuated effect (Experiment 1), and two adjacent items that share a rime should also produce lower levels of recall for the first item of the adjacent pair for exactly the same reason. See Neath and Nairne (1995) and Neath (in press) for further details about the nature of overwriting.

principle, be applied in the same way. The actual content of PAS (or some other hypothetical device for maintaining recency for e.g., auditory non-speech; de Gelder & Vroomen, 1997) is relatively unimportant compared to the way in which that representation is used to enhance recall. The current study investigated the view that use of information specific to the final item was obligatory when immediate serial recall was attempted. Such information is useful in deciding the ordering of the last few items; however, when the information is incorrect, as in the penultimate rhyming condition of Experiment 1, it will hinder accurate serial recall (see Figure 1).

The idea that PAS information can be used as positional information, or that the presentation of a stimulus suffix produces positional uncertainty is not a new one (Greene, Elliott, & Smith, 1988; Parkinson, 1978), although exactly how such a system might operate has not previously been elaborated in any detail. In their Primacy model of immediate serial recall Page and Norris (1998) point out that a representation of the identity of the final item can have an effect on memory for order by reducing the number of possible competitors for recall at the end of the list. This was clearly demonstrated in Experiment 2. We would, however, disagree with the statement made by Page and Norris (1998, p. 774) that "a memory for the last item heard involves no memory for order, merely memory for a single item". In fact the memory must involve some order information since to be of any use whatsoever it must be recognisably a memory of the *last* item. This was, in fact, a hidden assumption in Page and Norris' (1998) simulation. Since the rime of the final item is represented as PAS information, it is bound to the final serial position and it is this information that allows accurate reconstruction of the identity of the final item. When the PAS representation points to both of the final two items it cannot be used to decide between them. Both these items are, then, eligible for recall in the final position and therefore the final item advantage is reduced. It does not disappear entirely, however, and a corresponding advantage appears for the penultimate item. This is because, although the PAS information is insufficient to distinguish between these two items, it *is* sufficient to distinguish both of these items from the rest of the list. In effect, the final two items form a sub-group and performance elsewhere in the list increases as a result. In combination with a pattern detection mechanism that responds to adjacent rimes this forms a system capable of neatly explaining the current set of results.

In Experiment 1 there was attenuation of the suffix effect by the use of a terminal rhyming suffix because the pattern detection mechanism responded to the presence of a rhyming pair presented in adjacent serial positions. Since the rime of the latter member of the pair (the suffix) was also registered by PAS this information could be used to attenuate the

suffix effect. However, when the rime preserved by PAS was consistent with that of the penultimate item the pattern detection mechanism did not register the rhyming pair and so the suffix effect operated in the normal fashion. Henson (1998) found that the Ranschburg effect (poor recall of repeated items) occurred when the repetitions were separated by one or more unrelated items but that improved levels of recall occurred for the repeated items if the repetitions were adjacent. Thus, it seems likely that the same pattern detection mechanism is in operation in Henson's experiment and in ours and that this mechanism is limited to registering similarities between adjacent items.

The assumption that only adjacent rimes are registered also neatly explains the outcome of Experiment 2. The decrease in order information evident when the final two items cannot be distinguished by use of PAS (rime) information is only a decrease in order information between those two items. For the rest of the list it serves as an *increase* in order information. Since PAS information is yoked to the final serial position and the pattern recognition mechanism ensures that two items are associated with this final position the system decreases the level of positional uncertainty for all other list items. They can now no longer be confused with either the final or the penultimate item. Therefore, levels of recall elsewhere in the list improve. The data could possibly be related to the phonological similarity effect in serial recall, which forms a part of the working memory model (Baddeley, 1986) amongst others. However, the verbal account of working memory is insufficiently constrained to be directly applied to the current data. Working memory, in its current verbal form, does not address suffix effects (Experiment 1) and has been formally applied only to within-list similarity in situations where similarity across the list has been considered (Experiment 2). These data serve to constrain the form that more detailed accounts of similarity might take. Overall, therefore, these two experiments demonstrate how different sources of information serve to constrain the options available, even in so simple a task as serial recall, and highlight the need for short-term memory theorists to allow room in their models for the operation of monitoring devices.

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