THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY
2006, 59 (3), 577–596

Psychology Press
Taylor & Francis Group

The influence of phoneme position overlap on the phonemic similarity effect in nonword recall

Lisa M. Nimmo and Steven Roodenrys
University of Wollongong, Wollongong, Australia

The current research examined the predictions that short-term memory models generate for the phonological similarity effect, when similarity was defined in different ways. Three serial recall experiments with consonant–vowel–consonant (CVC) nonwords are reported, where the position of the phonemes that list items shared was manipulated (i.e., shared vowel and final consonant [_VC; Experiment 1], initial consonant and vowel [CV_; Experiment 2], or the two consonants [C_C; Experiment 3]. The results show that the position of common phonemes in nonwords has differential effects on order and item information. The findings are discussed in relation to previous research into the effect of phonemic similarity on nonword recall, and modifications to current short-term memory models are proposed.

One of the most prominent and robust findings in the research literature on verbal short-term memory is the phonological similarity effect: the finding of poorer serial recall for words that sound similar to each other than for lists of phonemically dissimilar words. Numerous studies of this effect have led to the view that phonological similarity predominantly disrupts memory for the order rather than memory for the identity of words (e.g., Baddeley, Lewis, & Vallar, 1984; Coltheart, 1993; Conrad, Baddeley, & Hull, 1966; Conrad & Hull, 1964; Cowan, Saults, Winterowd, & Sherk, 1991; Laughery & Pinkus, 1966; Schweickert, Guentert, & Hersberger, 1990).

Given the robust nature of the phonological similarity effect, most short-term memory models incorporate mechanisms to account for it. However, the majority of short-term memory models do not provide an explanation for the effect of phonemic similarity on recall performance when the stimuli are nonwords (e.g., Brown, Preece, & Hulme, 2000; Burgess & Hitch, 1992, 1999; Henson, 1998; Page & Norris, 1998). This reluctance to model this effect may stem from the fact that although the similarity effect is a benchmark finding in the research literature for words, few studies have explored this effect with lists of nonwords (Besner & Davelaar, 1982; Drewnowski, 1980; Fallon, Mak, Tehan, & Daly, in press; Gathercole, Pickering, Hall, & Peaker, 2001; Lian & Karlsen, 2004; Lian, Karlsen, & Winsvold, 2001). Moreover, as compared to when the stimuli are words, the results of nonword studies are contradictory.

Correspondence should be addressed to Lisa Nimmo, School of Psychology, University of Western Australia, Crawley, W.A. 6009, Australia. Email: lisan@psy.uwa.edu.au

The authors are grateful to Stephan Lewandowsky, James Nairne, and two anonymous reviewers for comments on an earlier version of this manuscript. Preparation of this manuscript was partially supported by a Discovery Grant from the Australia Research Council to Stephan Lewandowsky.

http://www.psypress.com/qjep
DOI:10.1080/02724980443000845

The purpose of conducting the current study was twofold. The first aim was to clarify the nature of the phonological similarity effect on short-term memory for nonwords, and in doing so differentiate short-term memory models that predict an order memory impairment (Hartley & Houghton, 1996; Nairne, 1988, 1990, 2002) from those that do not (Brown et al., 2000; Burgess & Hitch, 1992, 1999; Henson, 1998; Page & Norris, 1998). For short-term memory models that do postulate an effect of similarity on nonword recall, a further aim of the present research was to critically examine the predictions generated by these models. The structure of this paper is as follows: After briefly reviewing the contradictory data from studies on the effect of phonological similarity on nonword recall, we describe a number of short-term memory models with a particular emphasis on the differential predictions that each generate for the effect of similarity on nonword recall. We then report three experiments where phonological similarity was manipulated. The first experiment was designed to verify that as with words, phonological similarity does indeed impair order memory when the stimuli are nonwords. By contrast, Experiments 2 and 3 were designed to critically examine the predictions generated by memory models that do provide an explanation for the effect of similarity on nonword recall.

The effect of nonword similarity on short-term memory

One study that has examined the effect of similarity on nonword memory was conducted by Lian et al. (2001). They compared memory for dissimilar, phonemically similar, and rhyming lists of nonwords that differed in associative value (i.e., nonwords rated high in associative value are more wordlike) and found that order memory was better for dissimilar nonword lists that were rated as being high in associative value. By contrast, when the stimuli were rated low in associative value, in one experiment (Experiment 1B) they found no effect of similarity for rhyming nonword lists and, in another experiment (Experiment 1A), an order memory advantage for phonemically similar lists.[1] Lian et al. (2001) suggest that nonwords that are high in associative value are more similar to real words than are those rated low in associative value. According to this view, the more wordlike an item is, the easier it is to access lexical representations held in long-term memory. These lexical representations can then be used to aid in the retrieval process. This idea is consistent with previous research suggesting that the more wordlike a nonword is rated, the more accurately the nonword is recalled (e.g., Gathercole, 1995; Gathercole & Martin, 1996; Gathercole, Willis, Emslie, & Baddeley, 1991; Metsala, 1999).

However, there is an alternative suggestion that may account for the inconsistencies observed across the Lian et al. (2001) study. When the recall task requires oral report, performance may be influenced by an individual's articulatory ability (see Gathercole, Service, Hitch, Adams, & Martin, 1999; Snowling & Hulme, 1989; Wells, 1995). For example, it may be that saying a list of either rhyming (e.g., wut, vut, zut, yut, chut) or phonemically similar (e.g., zut, fub, zun, zug, fup) nonwords is easier than saying a list of phonemically dissimilar nonwords (e.g., zut, yied, hig, chone, wabe). Moreover, as Wickelgren (1965) suggests, the correct-in-position measure of order memory (i.e., scored as correct if a participant recalls the correct item in the correct position) is influenced by the total number of items recalled irrespective of position. Hence, the findings obtained when performance is measured using the correct-in-position criterion may be influenced by other factors, such as articulatory ease (see Murray & Jones, 2002), which may act

[1] Please note, Lian et al. (2001, Exp. 1A) did not provide enough detail as to how the phonemically similar stimulus sets were constructed (i.e., all sharing a vowel, sharing initial or final consonants, or a mixture of phonemes in different positions). This is important in that Fallon, Groves, and Tehan (1999) suggest that differential results emerge in the literature depending on how similarity has been operationally defined.

to constrain the number of items an individual is able to recall.

To control for the effect that differences in the number of items recalled has on the measure of order memory obtained, Fallon et al. (in press; see also Lian & Karlsen, 2004) used a measure of order memory that takes into account individual differences in item recall ability (correct-in-position divided by the score obtained using the item recall measure—termed "order accuracy"). Consistent with the findings from a number of word studies (e.g., Fallon et al., 1999; Gathercole, Gardiner, & Gregg, 1982), Fallon et al. (in press) found an item recall advantage for rhyming lists of nonwords. Moreover, they found that correct-in-position recall was better for rhyming than for dissimilar lists. However, when performance was measured using the order accuracy criterion, Fallon et al. (in press) found that similarity impaired order memory. That is, after controlling for individual differences in item recall ability, order memory was better for dissimilar than for rhyming lists of nonwords. Hence, although there are some inconsistencies in the literature when the stimuli are nonwords, recent research suggests that comparable results can be found from studies of words and nonwords.

Explanations derived from short-term memory models to account for the effect of similarity on nonword recall

One core assumption that is proposed to account for the lexicality effect—the finding that memory is better for words than for nonwords (Hulme, Maughan, & Brown, 1991)—is that when the stimuli are words preexisting long-term memory representations aid in the recall of degraded short-term memory traces. Termed redintegration, this process is assumed to operate at the lexical level, and the effect of similarity on memory is assumed to be a product of this process (Brown et al., 2000; Burgess & Hitch, 1992, 1999). Taken literally, this implies that word recall benefits from stored long-term memory representations, whereas nonword recall does not. In consequence, some researchers have suggested that phonemic similarity should not influence nonword recall (e.g., Brown & Hulme, 1995). Although this view has recently been tempered with the suggestion that highly wordlike nonwords may also undergo a redintegration process (see Saint-Aubin & Poirier, 2000), clear evidence of a phonological similarity effect with nonwords would, in itself, need to be addressed by memory models that rely on a generic redintegration process in which to explain the lexicality effect.

By contrast, short-term memory models that do provide an explanation for the effect of phonemic similarity on memory for nonwords can be divided into two classes: psycholinguistic and nonlinguistic models. Psycholinguistic models of short-term memory were designed to account for linguistic research suggesting that subsyllabic structures influence the recall of nonwords (Ellis, 1980; Treiman & Danis, 1988), and in consequence they attribute the effect of phonological similarity on memory to linguistic constraints that operate at the subsyllabic level (e.g., Gupta & MacWhinney, 1997; Hartley & Houghton, 1996). By contrast, nonlinguistic memory models are based on general principles, without regard for stimulus type (e.g., pictures or spatial location). Nairne's (1988, 1990) feature model of immediate memory can be used as an exemplar of what is meant by a nonlinguistic short-term memory model. Although psycholinguistic, as well as a number of nonlinguistic, models maintain that phonological similarity differentially influences item and order memory, they differ in terms of the underlying mechanisms that they assume are responsible for this effect. Hence, we present a brief description of the two classes of models with an emphasis on critically examining the predictions that each class of model generates for the effect of similarity on both item and order memory.

Outline of Experiments 1–3 and the predictions generated by psycholinguistic and nonlinguistic models of short-term memory

Across experiments, lists of consonant–vowel–consonant (CVC) nonwords were constructed that shared the same amount of phonemic overlap, but differed with respect to the position of the shared phonemes. Experiment 1 compared item and order memory for lists of CVC nonwords where the stimuli in each list were phonemically dissimilar (i.e., each stimulus in each list did not share any phonemes with any other stimulus in the same list), were phonemically similar (i.e., each stimulus in each list shared two phonemes with at least one other stimulus in the same list), or rhymed (i.e., _VC condition). Experiments 2 and 3 also examined item and order memory for lists of phonemically similar and dissimilar nonwords; crucially, however, as compared to when the stimuli rhyme (Experiment 1), the comparison group in these experiments shared either the initial consonant and vowel (i.e., CV_condition; Experiment 2) or the two consonants (i.e., C_C condition; Experiment 3).

Nonlinguistic models of short-term memory

According to the feature model (e.g., Nairne, 2002; Neath, 1999) both short-term and long-term representations are formed during the experimental session, regardless of whether the stimuli are words or nonwords. In other words, the long-term (secondary memory) representations are context specific. At recall, although order of recall is determined by the retrieval of degraded traces from a short-term store, those traces are identified by comparison against traces in long-term memory. This comparison process leads to both item and order errors. For instance, Nairne (2002) suggests that phonemic similarity should facilitate item recall when list items share unique features that can be used as retrieval cues to limit the size of the "secondary memory search set" (e.g., when the words in each list rhyme). Hence, in the current context, the feature model would predict an item memory benefit for rhyming (Experiment 1), CV_(Experiment 2), and C_C (Experiment 3) lists of nonwords as compared to the phonemically similar conditions where the secondary memory search set in this case should comprise a larger number of items, which in turn should be better than when the stimuli are phonemically dissimilar, a situation where list retrieval cues are no longer effective at reducing the size of the search set (see Table 1).

In contrast to the predictions derived for the effect of phonological similarity on item memory, as with other nonlinguistic models of short-term memory (e.g., Brown et al., 2000), the feature model (Nairne, 1990) is based on the ratio rule or idea that the likelihood of recalling a presented list item is relative to the phonemic similarity of all the presented list items (Gillund & Shriffrin, 1984; Hintzman, 1986; Luce, 1959; Nosofsky, 1986).

Table 1. *Predictions generated by psycholinguistic and nonlinguistic models of short-term memory for the effect of similarity on nonword recall*

Experiment		*Psycholinguistic models*	*Non-linguistic models*
1 (Rhyme)	Item	_VC > similar > dissimilar	_VC > similar > dissimilar
	Order	Dissimilar > similar > _VC	Dissimilar > similar > _VC
2 (CV_)	Item*	Similar > CV_ > dissimilar	[CV_ > similar > dissimilar]
	Order	Dissimilar > similar > CV_	Dissimilar > similar > CV_
3 (C_C)	Item*	[Similar > C_C > dissimilar]	C_C > similar > dissimilar
	Order*	Dissimilar > C_C > similar	[Dissimilar > similar > C_C]
Cross-experiment comparison	Item*	[_VC > C_C = CV_]	[C_C = _VC = CV_]
	Order*	C_C > _VC = CV_	[C_C = _VC = CV_]

Note: The * denotes differences in the predictions generated by each class of model, whereas the brackets indicate where the data obtained in the current study deviate from what was predicted.

Accordingly, as phonological similarity increases order memory should decrease. Hence, the feature model predicts that order memory should be impaired to the greatest extent when the lists comprise items with the highest amount of net phonemic overlap (i.e., in the current experiments this equates to the_VC lists in Experiment 1, the CV_lists in Experiment 2, and the C_C lists in Experiment 3), as compared to the phonemically similar conditions (i.e., where the net phonemic overlap is lower), which should impair order memory to a greater extent than when the non-words are phonemically dissimilar (see Table 1).

It could be argued that this description of the feature model and the predictions derived from it is too simplistic, in that the feature model includes an attentional parameter, which may allow some information to be preferentially encoded into the memory traces. On this basis one could argue that the rhyme can be encoded more easily than the CV or C_C components and so produce larger effects on recall. However, this seems to require an appeal to something outside of the model, in fact to some psycholinguistic mechanism, to explain why participants might selectively attend to the VC component of lists when they all rhyme and ignore other list dimensions when they do not (e.g., when list items share the CV component).

Psycholinguistic models of short-term memory

In contrast to nonlinguistic models, the predictions generated by psycholinguistic models of short-term memory derive from the inclusion in these models of additional mechanisms by which to explain language-specific constraints on short-term memory performance: namely, syllable structure and sonority.

Linguistic research suggests that syllables have an internal structure comprising an onset and a rhyme (Fudge, 1969; Treiman, 1983, 1986; Treiman & Zukowski, 1990). The onset consists of the initial consonant or consonant cluster, whereas the rhyme includes the vowel and subsequent consonants. Moreover, the idea that two separate nodes are used to represent each syllable at the syllable group level can explain why, when recall errors occur, the_VC rather than the CV_or C_C phonemes are more likely to be retained as a pair in the response (Treiman & Danis, 1988). To model the effect of syllable structure on memory performance, Hartley and Houghton (1996) have incorporated a syllable group into their model, above the level of the phoneme nodes. At this level in the model, two separate nodes corresponding to the onset and rhyme are used to represent each syllable. Each phoneme stream that enters the model passes through the syllable group where the syllable nodes (i.e., onset then rhyme) are activated in turn, before activating one syllable node at the syllable layer. In consequence, because the same rhyme node is activated each time an item is presented to the model, this model predicts the item recall advantage observed when stimuli rhyme (e.g., Fallon et al., in press).

The second linguistic principle that Hartley and Houghton (1996) incorporate into their model is sonority. Sonority refers to the energy of a speech trace, and the sonority principle refers to the fact that the speech trace or the energy of a syllable increases to a peak at the vowel and then decreases. Hartley and Houghton (1996) set the activation level of vowels higher than that of consonants to reflect the idea that vowels are both longer in duration and more acoustically intense. Accordingly, order memory should be poorer when list items share the same vowel than when they do not.

In terms of the current research, priming of the same phoneme nodes in the phonemically similar conditions[2] (e.g., the repeated activation of the initial consonant) should facilitate the recall of item information, as compared to when the stimuli are phonemically dissimilar (see Table 1). Furthermore, when stimuli rhyme, repeated

[2] Please note that all of the items in the phonemically similar lists shared the same initial consonant (Experiment 1), the final consonant (Experiment 2), or the vowel (Experiment 3).

activation of the same rhyme node at the syllable level should lead to a further item recall advantage. For Experiment 1 this equates to an item recall benefit for rhyming as compared to phonemically similar nonword lists where all of the list items share the initial consonant, which should be better than when the stimuli are phonemically dissimilar.

In Experiments 2 and 3 item recall should be poorest in the phonemically dissimilar condition. Although the CV_(Experiment 2) and C_C (Experiment 3) conditions share the initial consonant within each list, which should prime the onset node, a different rhyme node will be activated for each list item. Moreover, as the vowel is the most strongly represented phoneme (i.e., most highly activated) the beneficial effect of repeating the onset may be quite small, and thus performance in these conditions may not be much better than that in the dissimilar condition. However, consider the phonemically similar conditions in these experiments. In both cases a number of items within each list will share the VC component and so activate the same rhyme node. This should result in improved item recall in these conditions relative to the dissimilar condition. If we assume that repetition of the rhyme unit is more helpful for recall than is repetition of the onset, then item recall in the similar conditions may actually be better than recall in the CV_and C_C conditions (see Table 1). This prediction must be more tentative as it would seem to depend on the contribution of the onset and rhyme nodes to recall relative to each other and relative to the individual phoneme nodes.

For order recall, any form of phonemic similarity should disrupt the recall of order information, as compared to when the stimuli are phonemically dissimilar (see Table 1). When list items share the vowel, however, order memory should be further impaired as compared to when list items share a consonant. Therefore, in Experiment 1 order memory should be best for the dissimilar condition and worst for the rhyme condition, which has the greatest overlap in phonemes and where each item shares the vowel with every other item. In Experiment 2 order memory should be worst for the CV_lists, better for the similar condition where fewer items share the vowel, and best for the dissimilar condition. In Experiment 3 order memory should be best for the dissimilar condition, worse in the C_C condition where all of the list items share the consonants, and even worse still in the similar condition where all of the list items share the same vowel, and each item shares some consonants with other items (see Table 1).

To reiterate, in a number of short-term memory models (e.g., Brown et al., 2000; Burgess & Hitch, 1992, 1999; Henson, 1999; Page & Norris, 1998) the phonological similarity effect arises during redintegration: a process that by definition occurs only for words. In consequence, some researchers have suggested that phonemic similarity should not influence nonword recall (e.g., Brown & Hulme, 1995). By contrast, short-term memory models that do predict an effect of nonword similarity on memory can be classified on the basis of whether they employ general (i.e., nonlinguistic) or psycholinguistic principles in which to explain memory over the short term. Moreover, although both classes of model predict that similarity will differentially influence item and order memory, crucially these predictions differ as a consequence of the mechanisms that each model assumes is responsible for the phonological similarity effect. Therefore, the aim of Experiment 1 was to elucidate whether the robust order memory impairment observed for rhyming word lists is also found when the stimuli are nonwords and, in doing so, to distinguish between short-term memory models that predict an order memory impairment (Hartley & Houghton, 1996; Nairne, 1990) from those that do not (Brown et al., 2000; Burgess & Hitch, 1992, 1999; Henson, 1998; Page & Norris, 1998), whereas Experiments 2 and 3 critically examine the predictions generated by nonlinguistic and psycholinguistic models of short-term memory to account for the effect of similarity on the recall of item information and memory for an item's position in a list.

EXPERIMENT 1

Experiment 1 employed the same experimental design as the one that we (Nimmo & Roodenrys, 2004) used in a recent word study. Hence, the same item pool was used to construct three sets of nonwords. For one set (rhyming condition), all of the nonwords in a list shared a common rhyme ending (i.e.,_VC). In the phonemically similar set, all of the items in a list shared the initial consonant, whereas in the phonemically dissimilar set, none of the stimuli in each list shared any phonemes with any other stimulus in the same list. Moreover, as the correct-in-position measure of performance is not independent of a participant's item recall ability (Fallon et al., 1999; Murdock, 1976; Poirier & Saint-Aubin, 1996; Wickelgren, 1965), a measure of order accuracy was obtained. This yields a measure of the proportion correct as a function of the number of items recalled.

Method

Participants

A total of 24 undergraduate psychology students from the University of Wollongong participant pool (5 males and 19 females), with an age range from 18 to 56 years ($M = 23.21$), participated in compliance with a course requirement. Only native Australian English speakers who indicated having no prior problems with hearing participated in the study.

Stimuli

The stimuli comprised 150 nonwords/nonsense words with a CVC phonemic structure (refer Table A1). The stimuli were used to create 30 rhyming, 30 phonemically similar, and 30 phonemically dissimilar five-item lists. Thus, each nonword was sampled three times, such that each appeared in one rhyming, one similar, and one dissimilar list. For the rhyming condition, all of the stimuli in a particular list shared the_VC component (e.g., Vame, Pame, Yame, Wame, Zame). For the similar condition, two constraints were placed on list construction. The first constraint was that no item in a list shared the_VC component. Also, each stimulus in each list shared two phonemes with at least one other stimulus in the same list (e.g., Pame, Pone, Pog, Pome, Pag). Therefore, all of the items in a similar list shared the same initial consonant. Finally, for the dissimilar condition, none of the stimuli in each list shared any phonemes with any other stimulus in that list (e.g., Pame, Lun, Teeb, Hoke, Vag).

Using an Arista Cardioid dynamic microphone (Model No. DM-904D), the stimuli were recorded onto a Sony Minidisc Deck (Model No. MDS-JE640) in a sound-attenuated booth by a female speaker with an Australian English accent. Each stimulus was transferred digitally to a Macintosh computer and normalized to control for possible amplitude effects on performance. Before testing began, 5 participants who did not take part in the experiment were asked to listen to and repeat each nonword in order to check their audibility. If more than one participant repeated the same nonword incorrectly, the nonword was re-recorded, and another 5 participants were asked to listen to and repeat each nonword. The criterion (i.e., no more than one participant repeated the same nonword incorrectly) for satisfactory audibility of the nonwords was met. Overall, participants correctly repeated 99.2% of the nonwords presented. The lists were presented in three blocks of 30 trials. The order of the blocks within the experimental session was counterbalanced across participants. The order of the lists in each block and the order in which the items occurred in each list were randomized for all participants.

Procedure

Across all conditions, two practice lists were given to each participant prior to the presentation of the first experimental list. Each participant heard five nonwords at a rate of one per second. Stimulus presentation rate was controlled using Hypercard (Version 2.4.1). One second after presentation of the last item in a list, participants heard a

200-ms, 500-Hz tone, which was used as a recall prompt. The participant's task was to orally recall the list items in order of presentation. Participants were told to say "pass" if they could not remember an item. Thus, strict serial recall instructions were employed. Presentation and recall attempts were recorded onto Minidisc to enable accurate scoring. The recordings from 3 randomly selected participants were transcribed and scored independently by a researcher who was familiar with the scoring rules used in the current study. Inter-rater reliability scores for the rhyming (item recall, 100%), similar (item recall, 97%) and dissimilar (item recall, 99%) conditions were obtained. The time taken for each participant to complete all three conditions was approximately 40 minutes.

Results

The scores obtained for item (i.e., scored as correct if a participant recalled an item presented in a given list, regardless of position) and order memory (i.e., correct-in-position divided by the score obtained using the item recall measure) were analysed using separate repeated measures analyses of variance (ANOVAs). Figure 1 summarizes performance for the dissimilar, similar, and rhyming lists of nonwords, for both performance measures. Unless otherwise specified, α was set at.05 (two-tailed).

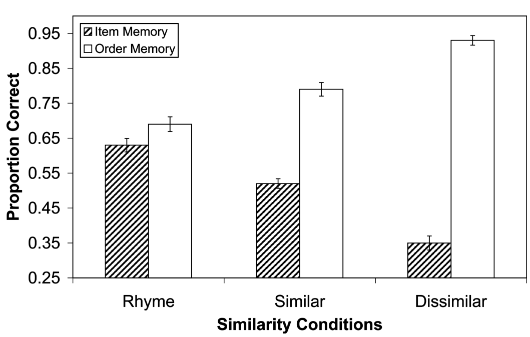

Figure 1. *Mean proportions correct ($\pm SE$) for the similar, dissimilar, and rhyming lists of nonwords for the two scoring procedures (Experiment 1).*

The item recall analysis revealed a main effect of phonological similarity, $F(2, 46) = 118.64$, $MSE = 89.09$. Post hoc repeated measures t tests with sequential Bonferroni adjustments revealed an item recall advantage for rhyming as compared to similar lists, $t(23) = 7.12$, which was better than when the nonwords were dissimilar, $t(23) = 9.05$. Further, the order accuracy analysis revealed the standard phonological similarity on order memory, $F(2, 46) = 85.94$, $MSE = .004$. Bonferroni adjusted, post hoc comparisons revealed that order memory for dissimilar lists was better than that for similar lists, $t(23) = 8.63$, which was better than that for lists where the nonwords rhymed, $t(23) = 5.25$.

Discussion

The finding of an item recall advantage for rhyming as compared to phonemically dissimilar lists is consistent with previous research, regardless of whether the stimuli are words (Fallon et al., 1999, Exp. 1; Gathercole et al., 1982; Nimmo & Roodenrys, 2004) or nonwords (Fallon et al., in press; Lian & Karlsen, 2004). Moreover, order memory for dissimilar lists was better than that for phonemically similar lists, which was better than that for lists where the nonwords rhymed. This finding of an order memory impairment for phonemically similar as compared to dissimilar nonwords is also consistent with the findings from other nonword studies (i.e., Fallon et al., in press) that have used the order accuracy criterion to examine the effect of similarity on order memory. Hence, as with words, when the stimuli are nonwords, although phonological similarity benefits the recall of item information, it has a detrimental effect on order memory.

The findings from the current study are also consistent with the predictions generated from both nonlinguistic (e.g., Nairne, 2002) and psycholinguistic (e.g., Hartley & Houghton, 1996) models of short-term memory. For example, according to nonlinguistic (Nairne, 2002) models, the item recall advantage observed for rhyming lists is due to the fact that these items share unique features that can be used to limit the size of the memory search set (i.e., common_VC phonemes) as compared to the phonemically similar lists, which in turn share some features (i.e., a common initial consonant) that can be used to limit the size of the memory search set in relation to the phonemically dissimilar nonword lists. For psycholinguistic models (e.g., Hartley & Houghton, 1996), rhyming lists of nonwords receive support not only from the repeated activation of the same vowel and final consonant nodes at the phoneme layer, but also from the repeated activation of the same rhyme node at the syllable layer. This can be compared with the phonemically similar condition where item recall only benefits from the repeated activation of the onset, and the phonemically dissimilar condition where each phoneme is only ever activated once in each list. Finally, the observed order memory impairment for phonemically similar nonwords is also consistent with the explanations generated from these classes of model. For example, nonlinguistic short-term memory models that are based on the ratio rule (e.g., Nairne, 2002) predict that as similarity increases order memory should decrease. Furthermore, the Hartley and Houghton (1996) model suggests that although any form of similarity should impair order memory (e.g., phonemically similar as compared to the dissimilar lists), when the overlapping phoneme is the vowel (i.e., in this case the _VC lists), order memory should be further impaired.

The finding of an order memory impairment for phonemically similar nonwords, however, has a larger implication. The majority of short-term memory models incorporate a generic redintegration process to account for the lexicality effect: the finding that short-term memory is better for words than for nonwords (Hulme et al., 1997). Significantly for the present research, in a number of models the phonological similarity effect is also assumed to arise during this process (e.g., Brown et al., 2000; Burgess & Hitch, 1992, 1999; Henson, 1999; Page & Norris, 1998): a process that by definition can only be completely effective for words. Although one could argue that nonword recall can benefit from the use of lexical representations held in long-term memory, the finding of an order memory impairment for phonemically similar nonwords emphasizes the need for these models to provide a more detailed description of this process.

To summarize, when stimuli rhyme, both the feature model (Nairne, 2002) and Hartley and Houghton's (1996) linguistically constrained model of short-term memory can provide plausible explanations for the effect of phonemic similarity on both the recall of item information and memory for an item's position in a list. Hence, two further experiments are reported, which were designed to distinguish between these two competing explanations.

EXPERIMENT 2

Experiment 2 differed from the first study in several ways: First, a different item pool was used to construct the three sets of nonwords. Second, as compared to the rhyming condition in Experiment 1, the important condition in Experiment 2 comprised nonword lists that shared the CV_component.

In the current context both nonlinguistic and psycholinguistic models of short-term memory make the same predictions with respect to the effect of phonemic similarity on order memory (i.e., order memory for CV_ should be worse than that for phonemically similar nonwords, which should be worse than that for phonemically dissimilar stimuli). Crucially, however, these models differ in their predictions for the recall of item information (see Table 1).

The feature model (Nairne, 1988, 1990) postulates that an item recall advantage should be observed whenever retrieval cues can be used to limit the size of the secondary memory search. Accordingly, this model predicts an item recall advantage for CV_ as compared to that for the phonemically similar condition (where each item in a list shares the final consonant), which should be better than when the nonwords are phonemically dissimilar. Psycholinguistic models also predict that fewer items will be recalled when the stimuli are phonemically dissimilar than for either of the similar conditions. In contrast to the predictions generated by nonlinguistic models, however, psycholinguistic models predict an item recall advantage for phonemically similar over the CV_ lists of nonwords. This is because in the phonemically similar condition, not only is the final consonant repeatedly activated at the phoneme level, but a number of list items share a common rhyme ending, thus repeatedly activating the same rhyme node. By contrast, in the CV_condition, although the initial consonant and vowel are repeatedly activated at the phoneme level, each list item activates a different rhyme node at the syllable level (see Table 1).

Method

Participants

A total of 24 undergraduate psychology students from the University of Wollongong participant pool (5 males and 19 females), with an age range from 16 to 49 years ($M = 21.54$), participated in compliance with a course requirement. The same inclusion criteria as those in Experiment 1 were placed on the selection of participants.

Stimuli

The stimuli comprised 150 nonwords with a CVC structure (refer to Table A2). The stimuli were used to create 30 same initial consonant and vowel (CV_), 30 phonemically similar, and 30 phonemically dissimilar five-item lists. List construction was the same as in Experiment 1, with two exceptions. The first exception was that for the CV_ condition, all of the stimuli in a particular list shared the CV_ component (e.g., Maib, Maip, Maig, Maif, Maich). Second, for the similar condition, no item in a list shared the CV_ component (e.g., Maib, Mab, Wab, Raib, Wieb). Hence, all of the items in a similar list shared the same final consonant.

Procedure

The same testing procedure as that used in Experiment 1 was used in Experiment 2. The criterion for satisfactory audibility of the nonwords was met with participants correctly repeating 99.5% of the nonwords presented. Inter-rater reliability scores for the CV_ (item recall, 100%), similar (item recall, 99%), and dissimilar (item recall, 96%) conditions were obtained.

Results

The scores obtained using the item and order memory measures were analysed using separate repeated measures ANOVAs. Figure 2 summarizes performance for the dissimilar, similar, and CV_ conditions, for the two performance measures.

The item recall analysis revealed a main effect of phonological similarity, $F(2, 46) = 83.75$, $MSE = 64.21$. Post hoc t tests with sequential Bonferroni adjustments revealed that item memory for similar lists was better than that for CV_ lists, $t(23) = 2.74$, which in turn was better than that for dissimilar lists, $t(23) = 9.79$. Furthermore, the order accuracy analysis revealed the standard order memory impairment for phonemically similar nonword lists, $F(2, 46) = 95.72$, $MSE = 0.007$. Bonferroni adjusted, post hoc comparisons revealed that order memory for dissimilar lists was better than that for similar lists, $t(23) = 5.48$, which was better than that for lists of CV_ nonwords, $t(23) = 8.77$.

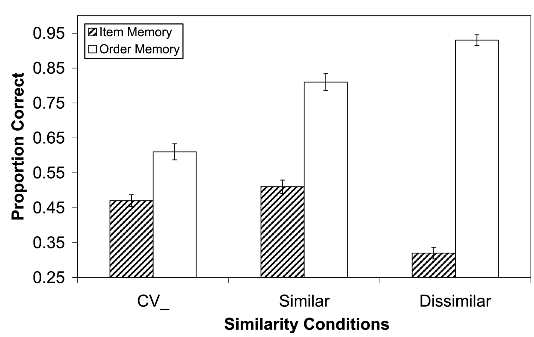

Figure 2. *Mean proportions correct (±SE) for the similar, dissimilar, and CV_ lists of nonwords for the two scoring procedures (Experiment 2).*

Discussion

Consistent with a recent word study that we (Nimmo & Roodenrys, 2004) conducted, order memory for the dissimilar lists was better than that for the similar lists, which was better than that for lists where nonwords shared the CV_ component. Moreover, this pattern of results-was predicted by both nonlinguistic and psycholinguistic models of short-term memory (see Table 1).

Although phonological similarity impairs a participant's ability to recall list items in the correct order, consistent with Experiment 1, and the predictions generated by nonlinguistic and psycholinguistic models, the data show an item recall advantage for phonemically similar (irrespective of the similarity condition) as compared to dissimilar nonword lists. Furthermore, more items were recalled when the stimuli were phonemically similar than for CV_ lists of nonwords (see Table 1). Although these data are consistent with a psycholinguistic (Hartley & Houghton, 1996) account for the effect of similarity on item memory, they are contrary to the predictions generated from the feature model (Nairne, 1988, 1990). For example, according to the feature model, phonemic similarity should facilitate the recall of item information to the extent that the size of the secondary memory search set can be limited to a smaller set of possible items (i.e., all items that share the CV_ component). In consequence, if the item recall advantage obtained in Experiment 1 for rhyming nonword lists was due to limiting the size of this search set, then an item recall advantage should also have been found for the CV_ condition in this study. One could argue that the rhyme unit is a more salient cue than other types of list cues. For example, the feature model (Nairne, 1988, 1990) includes an attentional parameter to reflect the idea that the recall of item information is influenced not only by the distinctiveness of list items in relation to the other presented list items, but also by the salience of the cues. To make a logical argument, however, this model would need to specify why this may be the case as compared to lists of CV_ nonwords.

In summary the findings from Experiment 2 are consistent with (a) the idea that, irrespective of whether the stimuli are words or nonwords, phonological similarity facilitates the recall of item information and has a detrimental effect on order memory, and (b) psycholinguistic models (Hartley & Houghton, 1996), and they are inconsistent with the predictions derived from nonlinguistic models of short-term memory (Nairne, 1988, 1990) that predict an item recall advantage whenever the list items share unique features (i.e., in this case, CV_ nonwords) that can be used to limit the size of the memory search set.

One final experiment further examined the predictions generated by psycholinguistic (Hartley & Houghton, 1996) and nonlinguistic (Nairne, 1988, 1990) memory models for the effect of similarity on item and order memory.

EXPERIMENT 3

Experiment 3 differed from the preceding experiments in several ways: First, a different item pool was again used to construct the three sets of nonwords. Second, as compared to lists of either _VC (Experiment 1) or CV_ (Experiment 2) nonwords, the important condition in Experiment 3 comprised nonword lists that shared the C_C component.

In the current study, psycholinguistic and nonlinguistic models of short-term memory predict an identical pattern of results with respect to the effect of similarity (irrespective of how similarity is operationally defined) on item and order memory when compared with lists of nonwords that are phonemically dissimilar (see Table 1). That is, when the nonwords are phonemically dissimilar, although participants are less likely to recall the presented list items (item memory), when they do, they are more likely to recall the items in the correct order (order memory). The predictions generated by these models for the effect of similarity when operationally defined in different ways do differ, however, as a consequence of the mechanisms that each model assumes is responsible for the effect of similarity on the recall of item information and memory for an item's position in a list.

According to nonlinguistic models (Nairne, 1988, 1990), a smaller number of items should be included in the secondary memory search set when all of the nonwords in a list share the C_C components than in the phonemically similar condition (i.e., where in this case, all of the items share a common vowel). In consequence, an item recall advantage should be observed in the C_C as compared to the phonemically similar condition (see Table 1). However, in comparison to the phonemically similar condition, as these types of list (i.e., C_C condition) comprise items with a higher amount of net phonemic overlap, order memory should be further impaired. By contrast, psycholinguistic models (Hartley & Houghton, 1996) make the opposite predictions. For example, these models predict an item recall advantage for the phonemically similar (i.e., not only is the vowel repeatedly activated at the phoneme level, but a number of list items share a common rhyme ending, thus repeatedly activating the same rhyme node) as compared to C_C (i.e., although the initial and final consonants are repeatedly activated at the phoneme level, in this condition each list item activates a different rhyme node at the syllable level) lists of nonwords (see Table 1). Furthermore, as all of the nonwords in the phonemically similar condition share the same vowel, order memory should be further impaired as compared to situations where each list item has a unique vowel (i.e., in this case C_C lists of nonwords).

Method

Participants

A total of 24 undergraduate psychology students from the University of Wollongong participant pool (2 males and 22 females), with an age range from 18 to 34 years ($M = 22.63$), participated in compliance with a course requirement. The same inclusion criteria were placed on the selection of participants as those for Experiment 1.

Stimuli

The stimuli comprised 150 nonwords with a CVC structure (refer to Table A3). The stimuli were used to create 30 same-consonant, 30 phonemically similar, and 30 phonemically dissimilar five-item lists. The same constraints were placed on the construction of the stimulus lists as for Experiment 1, with two minor modifications. The first modification was that for the C_C lists, all of the stimuli in a particular list shared the C_C component (e.g., Bech, Barch, Borch, Baich, Biech). Also, for the phonemically similar lists, no item in a list shared both consonants (e.g., Bech, Besh, Bedge, Teg, Cheg). Therefore, all of the items in a similar list shared the same vowel.

Procedure

The same testing procedure was used in the current experiment as in Experiment 1. The criterion for satisfactory audibility of the nonwords was met with participants correctly repeating 99.5% of the nonwords presented. Inter-rater reliability scores for the C_C (item recall, 98%), similar (item recall, 96%), and dissimilar (item recall, 99%) conditions were obtained.

Results

Measures of item and order memory were analysed using separate repeated measures ANOVAs. Figure 3 summarizes performance for the dissimilar, similar, and C_C conditions, for the two performance measures.

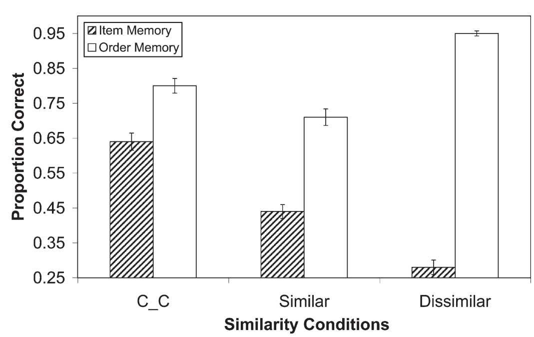

Figure 3. *Mean proportions correct (±SE) for the similar, dissimilar, and C_C lists of nonwords for the two scoring procedures (Experiment 3).*

The item recall analysis revealed a main effect of phonological similarity, $F(2, 46) = 179.99$, $MSE = 98.40$. Bonferroni adjusted comparisons revealed that item memory for C_C was better than that for similar lists, $t(23) = 11.09$, which was better than that for lists where the nonwords were phonemically dissimilar, $t(23) = 8.27$. Furthermore, the order accuracy analysis revealed the standard order memory impairment for phonemically similar nonword lists, $F(2, 46) = 55.88$, $MSE = .009$. Bonferroni adjusted, post hoc comparisons revealed that order memory for dissimilar lists was better than that for C_C lists, $t(23) = 8.33$, which was better than that for lists where the nonwords were phonemically similar, $t(23) = 3.31$.

To examine the effect of similarity on item and order memory in greater detail, the data for the similar conditions, where the position of the overlapping phonemes was varied, yet similarity remained constant (i.e., _VC, Experiment 1; CV_, Experiment 2; C_C, Experiment 3), were subjected to separate between-subjects ANOVAs. The item recall analysis revealed a significant difference in the number of items recalled across conditions, $F(2, 69) = 22.12$, $MSE = 229.52$. Bonferroni adjusted post hoc comparisons revealed that item memory for CV_ list (Experiment 2) was poorer than that for either C_C (Experiment 3), $t(46) = 5.95$, or rhyming (Experiment 1) lists, $t(46) = 5.55$, which did not differ, $t(46) = 0.39$, *ns*. Moreover, the order accuracy analysis revealed a significant difference in order memory across conditions, $F(2, 69) = 19.24$, $MSE = .01$. Bonferroni adjusted, post hoc comparisons revealed that order memory for C_C lists was better than that for either rhyming, $t(46) = 3.72$, or CV_ lists, $t(46) = 6.16$, which did not differ, $t(46) = 2.44$, *ns*.

Discussion

Consistent with the data obtained in the preceding experiments, and the predictions generated by psycholinguistic (Hartley & Houghton, 1996) as well as nonlinguistic (Nairne, 1988, 1990) models of short-term memory, irrespective of how similarity was operationally defined, a larger number of nonwords were recalled for phonemically similar stimuli than for the dissimilar nonword lists (see Table 1). Moreover, consistent with the predictions generated from the feature model (Nairne, 1988, 1990), more items were recalled in the C_C than in the phonemically similar condition. By contrast, this finding of an item recall advantage for lists of C_C as compared to phonemically similar nonwords is problematic for Hartley and Houghton's (1996) linguistically constrained model of short-term memory. For example, according to this model, in contrast to the C_C condition, where although the initial and final consonants are repeatedly activated at the phoneme level, each list item activates a different rhyme node at the syllable level, more items should be recalled in the phonemically similar condition where not only is the vowel repeatedly activated at the phoneme level, but a number of list items share a common rhyme ending, thus repeatedly activating the same rhyme node at the syllable level. Furthermore, although comparisons across experiments revealed an item recall advantage for rhyming as compared to CV_ lists (in support of the Hartley & Houghton, 1996, model), no differences in item recall levels were observed between the C_C and rhyming nonword lists (support for Nairne's, 2002, feature model).

However, a note of caution should be exercised in relation to the recall of item information. First, item recall performance across all three of the phonemically dissimilar conditions was extremely low. For instance, participants were recalling on average only 1 to 1.5 items out of 5. Thus, participants were only able to remember the first (or last) item in each list. This observation makes sense in that for phonemically dissimilar nonwords there is nothing to facilitate the recall of item information (e.g., a shared rhyme ending or repetition priming when the experimental stimuli are phonemically similar). Second, when there are high levels of item recall, as observed when the experimental stimuli are words (see Fallon et al., 1999; Nimmo & Roodenrys, 2004), item scores produce reliable, meaningful, and lawful results. Finally, factors other than short-term memory, such as ease of articulatory transition (Murray & Jones, 2002), may have also influenced the number of items that an individual was able to recall.

When the effect of similarity on order memory was examined with a measure that is independent of an individual's item recall ability (Poirier & Saint-Aubin, 1996; Wickelgren, 1965), however, the data show an order memory advantage for dissimilar as compared to C_C lists, which was better than when the nonwords were phonemically similar. This is an important finding in that nonlinguistic short-term memory models (Nairne, 1988, 1990) assume that as similarity increases order memory should decrease. However, in the current experiment, C_C lists shared a greater amount of phonemic overlap than did the phonemically similar nonword lists. In contrast, Hartley and Houghton's (1996) linguistically constrained short-term memory model suggests that, although any form of similarity should impair order memory, when the overlapping phoneme is the vowel (the phonemically similar condition in this experiment), order memory should be further impaired.

Finally, comparisons across conditions where similarity was held constant (e.g., VC, Experiment 1; CV, Experiment 2; C_C, Experiment 3) were conducted as a final test of the idea that sharing a vowel impairs order memory to a greater extent than does shared consonants. These analyses revealed an order memory advantage for C_C as compared to either rhyming or CV_ lists, which did not differ. Taken together, these findings are inconsistent with the predictions generated from nonlinguistic models (e.g., Brown et al., 2000; Burgess & Hitch, 1992, 1999; Nairne, 1988, 1990, 2002) and lend support to Hartley and Houghton's (1996) linguistically constrained model of short-term memory for nonwords, which predicts a further order memory impairment when list items share a vowel (i.e., _VC and CV_ lists) as compared to when they do not (i.e., C_C lists).

GENERAL DISCUSSION

The finding of clear evidence for a phonological similarity effect on nonword recall calls into question the explanations that short-term memory models (e.g., Brown et al., 2000; Burgess & Hitch, 1992, 1999; Henson, 1998; Page & Norris, 1998) generate for the similarity effect when they rely on a generic redintegration process to explain this effect. This is not to suggest that these models deny that lexical representations stored in long-term memory can aid the recall of nonwords. However, by definition, the redintegration process occurs only for words. Hence, the data obtained in the current research suggest that short-term memory models that rely on a generic redintegration process to explain both the lexicality and phonological similarity effects need to specify in greater detail the level at which this process is assumed to aid memory over the short term.

Short-term memory models that do predict a phonological similarity effect for nonwords were divided into two classes: psycholinguistic and nonlinguistic models. When item recall levels were examined the findings are inconclusive. For example, the finding of an item recall advantage for rhyming as compared to CV_ nonwords is consistent with psycholinguistic models and is inconsistent with the predictions derived from nonlinguistic models of short-term memory. By contrast, the finding that item recall levels were equivalent for rhyming and C_C lists of nonwords is consistent with nonlinguistic models and inconsistent with the prediction derived from psycholinguistic models of short-term memory. To date, however, little research has centred on the effect that oral report of nonwords has on short-term memory performance. For instance, other factors such as articulatory transition ease (Murray & Jones, 2002) have been found to influence the recall of words. Further, it may be that participants use different strategies when recalling lists of nonwords (e.g., focus on overlapping phonemes) as compared to words (e.g., use of similar-sounding items stored in long-term memory). Therefore, although the findings are promising, future research should aim to examine other factors that may influence the recall of item information when the experimental stimuli are nonwords.

By contrast, clear conclusions can be drawn from the data when order memory was examined. For example, the current study found an order memory advantage for C_C as compared to either rhyming or CV_ nonword lists. This is important in that the amount of shared phonemic overlap was held constant across all three of these phonemically similar conditions. At present, nonlinguistic short-term memory models (Nairne, 1988, 1990, 2002) assume that the locus of the similarity effect for order memory derives from the amount of shared phonemic overlap between list items. In consequence, these types of model predict that order memory should be impaired to the same extent for CV_, C_C, and _VC lists of nonwords: a prediction that is clearly at odds with the data obtained in the current research.

In comparison, this finding of an order memory advantage for C_C as compared to CV_ or rhyming nonword lists is consistent with the predictions generated by Hartley and Houghton's (1996) linguistically constrained model of short-term memory. According to this model, sharing any form of similarity with other list items should make it harder to recall the items in the correct order (i.e., phonemically dissimilar as compared to any of the similar conditions); however, when the overlapping phoneme is the vowel (i.e., CV_ and _VC, as compared to C_C lists), a further impairment in order memory should be observed. Hence, the findings from Experiments 1–3 are consonant with the idea that when the experimental lists are phonemically similar, order memory is influenced by both the amount of phonemic overlap between list items and whether the overlapping phoneme is the vowel.

In summary, although future research should focus on the influence that other factors have on the recall of item information when the stimuli are nonwords, in terms of order recall, Hartley and Houghton's (1996) linguistically constrained model of short-term memory is, at present, the only memory model that can adequately explain the current research findings. One criticism that could be directed at the previously drawn conclusion is that we have treated nonlinguistic models somewhat unfairly. For example, one could argue that it is not the case that these models deny the importance of linguistic constraints for memory over the short term. Moreover, one could also argue that slight modifications to any number of nonlinguistic models, such as increasing the salience of vowels as compared to consonants, may provide these models with plausible mechanisms in which to account for linguistic effects on memory. However, although simple modifications to nonlinguistic short-term memory models may provide these types of model with the mechanisms necessary to account for the present data, the strength of the current research is that it highlights the inadequacies of short-term memory models that are based on the distinctiveness assumption and in consequence illuminates an area of research (i.e., linguistics) that has been neglected by short-term memory modellers.

To reiterate, the major implications of the current findings are as follows. First, short-term memory models that rely on a generic redintegration process to account for the effect of phonological similarity on memory over the short term, for words, need to specify the level at which this process is also assumed to aid the recall of nonwords. Second, it is no longer sufficient to use a "phonemic overlap" or distinctiveness argument to account for the effect of phonemic similarity on order memory. Rather, the findings suggest that short-term memory performance is influenced by linguistic constraints, such as syllable structure and sonority, that are assumed to operate at the subsyllabic level. Hence, the current research points to a need for short-term memory modellers to incorporate the mechanisms necessary to deal with the psycholinguistic rules that constrain short-term memory performance at the subsyllabic as compared to the lexical level.

Original manuscript received 2 August 2004
Accepted revision received 12 December 2004
PrEview proof published online 25 July 2005

REFERENCES

Baddeley, A. D., Lewis, V., & Vallar, G. (1984). Exploring the articulatory loop. *Quarterly Journal of Experimental Psychology, 36A*, 233–252.

Besner, D., & Davelaar, E. (1982). Basic processes in reading: Two phonological codes. *Canadian Journal of Psychology, 36*, 701–711.

Brown, G. D. A., & Hulme, C. (1995). Modeling item length effects in memory span: No rehearsal needed? *Journal of Memory and Language, 34*, 594–621.

Brown, G. D. A., Preece, T., & Hulme, C. (2000). Oscillator-based memory for serial order. *Psychological Review, 107*(1), 127–181.

Burgess, N., & Hitch, G. J. (1992). Toward a network model of the articulatory loop. *Journal of Memory and Language, 31*, 429–460.

Burgess, N., & Hitch, G. J. (1999). Memory for serial order: A network model of the phonological loop and its timing. *Psychological Review, 106*, 551–581.

Coltheart, V. (1993). Effects of phonological similarity and concurrent irrelevant articulation on short-term memory recall of repeated and novel word lists. *Memory and Cognition, 21*, 539–545.

Conrad, R., Baddeley, A. D., & Hull, A. J. (1966). Rate of presentation and the acoustic similarity effect in short-term memory. *Psychonomic Science, 5*, 233–234.

Conrad, R., & Hull, A. J. (1964). Information, acoustic confusion and memory span. *British Journal of Psychology, 55*, 429–432.

Cowan, N., Saults, J. S., Winterowd, C., & Sherk, M. (1991). Enhancement of 4-year-old children's memory span for phonologically similar and dissimilar word lists. *Journal of Experimental Child Psychology, 51*, 30–52.

Drewnowski, A. (1980). Attributes and priorities in short-term recall: A new model of memory span. *Journal of Experimental Psychology: General, 109*, 208–250.

Ellis, A. W. (1980). Errors in speech and short-term memory: The effects of phonemic similarity and syllable position. *Journal of Verbal Learning and Verbal Behavior, 19*, 624–634.

Fallon, A. B., Groves, K., & Tehan, G. (1999). Phonological similarity and trace degradation in the serial recall task: When CAT helps RAT, but not MAN. *International Journal of Psychology, 34*, 301–307.

Fallon, A. B., Mak, E., Tehan, G., & Daly, C. (in press). Lexicality and phonological similarity in serial recall: A challenge for the retrieval-based model. *Memory.*

Fudge, E. C. (1969). Syllables. *Journal of Linguistics, 5*, 253–286.

Gathercole, S. E. (1995). Nonword repetition: More than just a phonological output task. *Cognitive Neuropsychology, 12*, 857–861.

Gathercole, S. E., Gardiner, J. M., & Gregg, V. H. (1982). Modality and phonological similarity effects in serial recall: Does one's own voice play a role? *Memory and Cognition, 10*, 176–180.

Gathercole, S. E., & Martin, A. J. (1996). Interactive processes in phonological memory. In S. E. Gathercole (Ed.), *Models of short-term memory* (pp. 73–100). Hove, UK: Psychology Press.

Gathercole, S. E., Pickering, S. J., Hall, M., & Peaker, S. M. (2001). Dissociable lexical and phonological influences on serial recognition and serial recall. *Quarterly Journal of Experimental Psychology, 54A*, 1–30.

Gathercole, S. E., Service, E., Hitch, G., Adams, A., & Martin, A. J. (1999). Phonological short-term memory and vocabulary development: Further evidence on the nature of the relationship. *Applied Cognitive Psychology, 13*, 65–77.

Gathercole, S. E., Willis, C., Emslie, H., & Baddeley, A. D. (1991). The influences of number of syllables and wordlikeness on children's repetition of nonwords. *Applied Psycholinguistics, 12*, 349–367.

Gillund, G., & Shriffrin, R. M. (1984). A retrieval model for both recognition and recall. *Psychological Review, 91*, 1–67.

Gupta, P., & MacWhinney, B. (1997). Vocabulary acquisition and verbal short-term memory: Computational and neural bases. *Brain and Language, 59*, 267–333.

Hartley, T., & Houghton, G. (1996). A linguistically constrained model of short-term memory for nonwords. *Journal of Memory and Language, 35*, 1–31.

Henson, R. N. A. (1998). Short-term memory for serial order: The start–end model. *Cognitive Psychology, 36*, 73–137.

Henson, R. N. A. (1999). Coding position in short-term memory. *International Journal of Psychology, 34*, 403–409.

Hintzman, D. L. (1986). "Schema abstraction" in a multiple-trace memory model. *Psychological Review, 93*, 411–428.

Hulme, C., Maughan, S., & Brown, G. D. (1991). Memory for familiar and unfamiliar words: Evidence for a long-term memory contribution to short-term memory span. *Journal of Memory, and Language, 30*(6), 685–701.

Hulme, C., Roodenrys, S., Schweickert, R., Brown, G. D. A., Martin, S., & Stuart, G. (1997).

Word-frequency effects on short-term memory tasks: Evidence for a redintegration process in immediate serial recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*, 1217–1232.

Laughery, K. R., & Pinkus, A. L. (1966). Short-term memory: Effects of acoustic similarity, presentation rate and presentation mode. *Psychonomic Science, 6*, 285–286.

Lian, A., & Karlsen, P. J. (2004). Advantages and disadvantages of phonological similarity in serial recall and serial recognition of nonwords. *Memory and Cognition, 32*, 223–234.

Lian, A., Karlsen, P. J., & Winsvold, B. (2001). A reevaluation of the phonological similarity effect in adults' short-term memory of words and nonwords. *Memory, 9*, 281–299.

Luce, R. D. (1959). *Individual choice behavior.* New York: Wiley.

Metsala, J. L. (1999). Young children's phonological awareness and nonword repetition as a function of vocabulary development. *Journal of Educational Psychology, 91*, 3–19.

Murdock, B. B. (1976). Item and order information in short-term serial memory. *Journal of Experimental Psychology: General, 105*, 191–216.

Murray, A., & Jones, D. M. (2002). Articulatory complexity at item boundaries in serial recall: The case of Welsh and English digit span. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*, 594–598.

Nairne, J. S. (1988). A framework for interpreting recency effects in immediate serial recall. *Memory and Cognition, 16*, 343–352.

Nairne, J. S. (1990). A feature model of immediate memory. *Memory and Cognition, 18*, 251–269.

Nairne, J. S. (2002). Remembering over the short-term: The case against the standard model. *Annual Review of Psychology, 53*, 53–81.

Neath, I. (1999). Modelling the disruptive effect of irrelevant speech on order information. *International Journal of Psychology, 34*, 416–424.

Nimmo, L. M., & Roodenrys, S. (2004). Investigating the phonological similarity effect: Syllable structure and the position of common phonemes. *Journal of Memory and Language, 50*, 245–258.

Nosofsky, R. M. (1986). Attention, similarity and the identification–categorization relationship. *Journal of Experimental Psychology: General, 115*, 39–57.

Page, M. P. A., & Norris, D. (1998). The primacy model: A new model of immediate serial recall. *Psychological Review, 105*, 761–781.

Poirier, M., & Saint-Aubin, J. (1996). Immediate serial recall, Word frequency, item identity and item position. *Canadian Journal of Experimental Psychology, 50*, 408–412.

Saint-Aubin, J., & Poirier, M. (2000). Immediate serial recall of words and nonwords: Tests of the retrieval-based hypothesis. *Psychonomic Bulletin and Review, 7*, 332–340.

Schweickert, R., Guentert, L., & Hersberger, L. (1990). Phonological similarity, pronunciation rate, and memory span. *Psychological Science, 1*, 74–77.

Snowling, C., & Hulme, C. (1989). A longitudinal case study of developmental phonological dyslexia. *Cognitive Neuropsychology, 6*, 379–401.

Treiman, R. (1983). The structure of spoken syllables: Evidence from novel word games. *Cognition, 15*, 49–74.

Treiman, R. (1986). The division between onsets and rhymes in English syllables. *Journal of Memory and Language, 25*, 476–491.

Treiman, R., & Danis, C. (1988). Short-term memory errors for spoken syllables are affected by the linguistic structure of the syllables. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 145–152.

Treiman, R., & Zukowski, A. (1990). Toward an understanding of English syllabification. *Journal of Memory and Language, 29*, 66–85.

Wells, B. (1995). Phonological considerations in repetition tests. *Cognitive Neuropsychology, 12*, 847–855.

Wickelgren, W. A. (1965). Short-term memory for phonologically similar lists. *American Journal of Psychology, 78*, 567–574.

Table A1. *Nonword lists and IPA codes for the stimuli used for Experiment 1*

Stimuli	*IPA codes*	*Stimuli*	*IPA codes*	*Stimuli*	*IPA codes*	*Stimuli*	*IPA codes*	*Stimuli*	*IPA codes*
pame	peɪm	vame	veɪm	yame	jeɪm	wame	weɪm	zame	zeɪm
hace	heɪs	zace	zeɪs	tace	teɪs	nace	neɪs	wace	weɪs
tait	teɪt	nait	neɪt	vait	veɪt	yait	jeɪt	zait	zeɪt
wayb	weɪb	hayb	heɪb	tayb	teɪb	fayb	feɪb	gayb	geɪb
zile	zaɪl	shile	ʃaɪl	yile	jaɪl	hile	haɪl	chile	tʃaɪl
shied	ʃaɪd	kied	kaɪd	mied	maɪd	zied	zaɪd	yied	yaɪd
zine	zaɪn	yine	jaɪn	hine	haɪn	gine	gaɪn	kine	kaɪn
boke	bəʊk	doke	dəʊk	goke	gəʊk	noke	nəʊk	hoke	həʊk
gome	gəʊm	wome	wəʊm	lome	ləʊm	pome	pəʊm	bome	bəʊm
yone	jəʊn	vone	vəʊn	pone	pəʊn	chone	tʃəʊn	wone	wəʊn
wole	wəʊl	chole	tʃəʊl	nole	nəʊl	lole	ləʊl	zole	zəʊl
pag	pæg	kag	kæg	vag	væg	chag	tʃæg	yag	jæg
kang	kæŋ	mang	mæŋ	nang	næŋ	dang	dæŋ	wang	wæŋ
bam	bæm	nam	næm	fam	fæm	cham	tʃæm	vam	væm
fap	fæp	vap	væp	wap	wæp	bap	bæp	dap	dæp
gin	gɪn	zin	zɪn	hin	hɪn	nin	nɪn	min	mɪn
bip	bɪp	gip	gɪp	mip	mɪp	fip	fɪp	vip	vɪp
hig	hɪg	chig	tʃɪg	nig	nɪg	vig	vɪg	yig	jɪg
ning	nɪŋ	hing	hɪŋ	ching	tʃɪŋ	ming	mɪŋ	fing	fɪŋ
geed	gɪːd	yeed	jɪːd	meed	mɪːd	zeed	zɪːd	veed	vɪːd
teep	tɪːp	veep	vɪːp	feep	fɪːp	zeep	zɪːp	yeep	jɪːp
deek	dɪːk	heek	hɪːk	neek	nɪːk	feek	fɪːk	yeek	jɪːk
leeb	lɪːb	teeb	tɪːb	heeb	hɪːb	geeb	gɪːb	deeb	dɪːb
mun	mʌn	yun	jʌn	vun	vʌn	zun	zʌn	lun	lʌn
wug	wʌg	zug	zʌg	vug	vʌg	shug	ʃʌg	kug	kʌg
lub	lʌb	fub	fʌb	gub	gʌb	shub	ʃʌb	mub	mʌb
wut	wʌt	vut	vʌt	zut	zʌt	yut	jʌt	chut	tʃʌt
zock	zɒk	yock	jɒk	gock	gɒk	fock	fɒk	vock	vɒk
shog	ʃɒg	pog	pɒg	chog	tʃɒg	yog	jɒg	mog	mɒg
chot	tʃɒt	zot	zɒt	mot	mɒt	fot	fɒt	vot	vɒt

Table A2. *Nonword lists and IPA codes for the stimuli used for Experiment 2*

Stimuli	*IPA codes*	*Stimuli*	*IPA codes*	*Stimuli*	*IPA codes*	*Stimuli*	*IPA codes*	*Stimuli*	*IPA codes*
mayp	meɪp	mayb	meɪb	mayg	meɪg	mayf	meɪf	maych	meɪtʃ
says	seɪs	sayp	seɪp	sayg	seɪg	sayng	seɪŋ	saych	seɪtʃ
waysh	weɪʃ	ways	weɪs	waych	weɪtʃ	waym	weɪm	wayb	weɪb
raych	reɪtʃ	rayb	reɪb	rayg	reɪg	rayng	reɪŋ	raym	reɪm
lieg	laɪg	lieng	laɪŋ	liech	laɪtʃ	liesh	laɪʃ	liedge	laɪdʒ
riech	raɪtʃ	riedge	raɪdʒ	riesh	raɪʃ	riev	raɪv	rieng	raɪŋ
tiech	taɪtʃ	ties	taɪs	tieng	taɪŋ	tieg	taɪg	tiev	taɪv
wieb	waɪb	wiesh	waɪʃ	wieng	waɪŋ	wies	waɪs	wiem	waɪm
birsh	bɜːʃ	birf	bɜːf	birng	bɜːŋ	birm	bɜːm	birb	bɜːb
pirsh	pɜːʃ	pirg	pɜːg	pirng	pɜːŋ	pirb	pɜːb	pirf	pɜːf
kav	kæv	kas	kæs	kaz	kæz	kang	kæŋ	kag	kæg
hab	hæb	han	hæn	haf	hæf	hadge	hædʒ	has	hæs
mab	mæb	maf	mæf	mav	mæv	maz	mæz	madge	mædʒ
wab	wæb	wan	wæn	wadge	wædʒ	wach	wætʃ	wav	wæv
lig	lɪg	lish	lɪʃ	lidge	lɪdʒ	lif	lɪf	lis	lɪs
pish	pɪʃ	piv	pɪv	pim	pɪm	pidge	pɪdʒ	pib	pɪb
bish	bɪʃ	bim	bɪm	biv	bɪv	bis	bɪs	bidge	bɪdʒ
seeb	sɪːb	seech	sɪːtʃ	seesh	sɪːʃ	seef	sɪːf	seeg	sɪːg
weesh	wɪːʃ	weech	wɪːtʃ	weef	wɪːf	weem	wɪːm	weeg	wɪːg
beev	bɪːv	beesh	bɪːʃ	bees	bɪːs	beeg	bɪːg	beeb	bɪːb
kudge	kʌdʒ	kung	kʌŋ	kuv	kʌv	kuch	kʌtʃ	kug	kʌg
hus	hʌs	huz	hʌz	hudge	hʌdʒ	hup	hʌp	huv	hʌv
mup	mʌp	muv	mʌv	mus	mʌs	muz	mʌz	mudge	mʌdʒ
ruch	rʌtʃ	rudge	rʌdʒ	rus	rʌs	ruv	rʌv	rup	rʌp
losh	lɒʃ	loch	lɒtʃ	lon	lɒn	lom	lɒm	lof	lɒf
kodge	lɒdʒ	kosh	lɒʃ	kom	lɒm	kov	lɒv	koch	lɒtʃ
sog	sɒg	som	sɒm	sodge	sɒdʒ	son	sɒn	sosh	sɒʃ
porv	pɔːv	porb	pɔːb	porg	pɔːg	porf	pɔːf	pors	pɔːs
worb	wɔːb	worg	wɔːg	worch	wɔːtʃ	worv	wɔːv	wors	wɔːs
harb	hɑːb	harn	hɑːn	hardge	hɑːdʒ	hars	hɑːs	harz	hɑːz

Table A3. *Nonword lists and IPA codes for the stimuli used for Experiment 3*

Stimuli	*IPA codes*	*Stimuli*	*IPA codes*	*Stimuli*	*IPA codes*	*Stimuli*	*IPA codes*	*Stimuli*	*IPA codes*
bech	bɛtʃ	barch	bɑːtʃ	borch	bɔːtʃ	baych	beɪtʃ	biech	baɪtʃ
bidge	bɪdʒ	bedge	bɛdʒ	beedge	bɪːdʒ	baydge	beɪdʒ	biedge	baɪdʒ
bish	bɪʃ	besh	bɛʃ	biesh	baɪʃ	barsh	bɑːʃ	baysh	beɪʃ
biv	bɪv	beev	bɪːv	barv	bɑːv	borv	bɔːv	bayv	beɪv
didge	dɪdʒ	dedge	dɛdʒ	dadge	dædʒ	deedge	dɪːdʒ	dardge	dɑːdʒ
div	dɪv	dav	dæv	dov	dɒv	darv	dɑːv	deev	dɪːv
diz	dɪz	dez	dɛz	daz	dæz	doz	dɒz	darz	dɑːz
has	hæs	hes	hɛs	hees	hɪːs	hays	heɪs	hies	haɪs
haf	hæf	heef	hɪːf	hirf	hɜːf	hayf	heɪf	hief	haɪf
han	hæn	hon	hɒn	hirn	hɜːn	hayn	heɪn	hien	haɪn
hom	hɒm	heem	hɪːm	hirm	hɜːm	haym	heɪm	hiem	haɪm
chaf	tʃæf	chof	tʃɒf	charf	tʃɑːf	chirf	tʃɜːf	chief	tʃaɪf
yeb	jɛb	yeeb	jɪːb	yob	jɒb	yarb	jɑːb	yieb	jaɪb
yeg	jɛg	yeeg	jɪːg	yog	jɒg	yarg	jɑːg	yieg	jaɪg
cheg	tʃɛg	chog	tʃɒg	charg	tʃɑːg	chirg	tʃɜːg	chieg	tʃaɪg
yek	jɛk	yeek	jɪːk	yock	jɒk	yark	jɑːk	yiek	jaɪk
yem	jɛm	yeem	jɪːm	yom	jɒm	yarm	jɑːm	yiem	jaɪm
larv	lɑːv	lev	lɛv	lorv	lɔːv	lav	læv	layv	leɪv
lef	lɛf	laf	læf	lorf	lɔːf	lirf	lɜːf	layf	leɪf
lidge	lɪdʒ	liedge	laɪdʒ	lordge	lɔːdʒ	ladge	lædʒ	laydge	leɪdʒ
lish	lɪʃ	lesh	lɛʃ	liesh	laɪʃ	lirsh	lɜːʃ	laysh	leɪʃ
res	rɛs	ras	ræs	rars	rɑːs	rors	rɔːs	rirs	rɜːs
rin	rɪn	reen	riːn	rarn	rɑːn	rorn	rɔːn	rirn	rɜːn
riz	rɪz	rez	rɛz	reez	rɪːz	rarz	rɑːz	rirz	rɜːz
tas	tæs	tus	tʌs	tors	tɔːs	tays	teɪs	ties	taɪs
teg	tɛg	targ	tɑːg	torg	tɔːg	tayg	teɪg	tieg	taɪg
tem	tɛm	tam	tæm	tum	tʌm	tarm	tɑːm	torm	tɔːm
wadge	wædʒ	wudge	wʌdʒ	weedge	wɪːdʒ	wardge	wɑːdʒ	wiedge	waɪdʒ
wem	wɛm	wum	wʌm	weem	wɪːm	warm	wɑːm	wiem	waɪm
wesh	wɛʃ	wash	wæʃ	wush	wʌʃ	waysh	weɪʃ	wiesh	waɪʃ