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Investigating the phonological similarity effect: Syllable structure and the position of common phonemes

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Abstract

The aim of the present research was to determine whether the effect that phonological similarity has on immediate serial recall is influenced by the consistency and position of phonemes within words. In comparison to phonologically dissimilar lists, when the stimulus lists rhyme there is a facilitative effect on the recall of item information and a detrimental effect on order memory (Experiment 1). When stimuli share the initial consonant and vowel (Experiment 2) or the same initial and final consonant (Experiment 3), there is no beneficial effect of similarity for item information, coupled with a detrimental effect on order memory. Contrary to the predictions made by non-linguistic models of STM, the influence that similarity has on both the recall of item information and memory for the position of items in a list is dependent on which components of the items are shared within a list.

One of the theoretically most influential findings in studies of verbal short-term memory (STM) is the phonological similarity effect (e.g., Baddeley, 1966; Conrad, Baddeley, & Hull, 1966; Conrad & Hull, 1964; Gathercole, Pickering, Hall, & Peaker, 2001; Laughery & Pinkus, 1966; Schweickert, Guentert, & Hersberger, 1990; Sperling & Speelman, 1970): The finding that immediate serial recall is worse if words sound similar to each other than if they do not.

It has been known for some time (e.g., Wickelgren, 1965) that effects on order memory, rather than item memory mediate the phonological similarity effect. The same numbers of words are recalled in similar and dissimilar lists, but items in similar lists are more likely to be recalled in the wrong order (see also Poirier & Saint-Aubin, 1996; Watkins, Watkins, & Crowder, 1974). This phonological similarity effect is so robust that any successful model of STM must be able to explain it.

Until recently little consideration has been given to what is meant by similarity and the possibility that different operational definitions may contribute to inconsistent findings in the literature. In some studies phonological similarity has been operationally defined as lists of rhyming words (e.g., Gathercole, Gardiner, & Gregg, 1982; Poirier & Saint-Aubin, 1996), while other studies have used lists of single syllable words with a common vowel and some overlap in the consonants (e.g., Coltheart, 1993; Watkins et al., 1974). Fallon, Groves, and Tehan (1999) directly compared the recall of lists of rhyming words, a phonemically similar condition in which items shared common phonemes but did not rhyme, and a dissimilar condition. They found that although both the rhyming and the phonemically similar condition showed impaired order memory compared to a dissimilar condition, the recall of item information was actually enhanced in the rhyming condition (see also Gathercole et al., 1982). That is, more items were recalled, albeit in the wrong order, when all of the items in a list rhymed than when the words in a list were phonologically dissimilar.

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It could be argued that a rhyming list of consonant–vowel–consonant (CVC) words is quantitatively more similar than a list of words with a common vowel plus some consonant overlap, because every word shares two phonemes (the _VC segment) with every other word in a list when they all rhyme. The finding that item recall is better in the rhyming condition (where there is more overlap) implies that the nature of the similarity effect may be determined by the amount of phonemic overlap. However, this raises the question of whether the position of the phonemic overlap within the words is important. Lists of CVC words where all items share two of the other phonemes (i.e., consonant–vowel, CV_, or consonant–consonant, C_C) can be regarded as having an equivalent degree of similarity as the rhyming (_VC) lists. However, there is evidence that the rime unit (_VC) is more tightly bound in STM as when a recall error occurs, it is the pairing most likely to remain intact when the stimuli are CVC nonwords (e.g., Treiman & Danis, 1988). This suggests that the VC may have a special role in STM and so the effects observed with rhyming lists may not be apparent with lists sharing the CV_ or the C_C.The aim of the following experiments was to evaluate if these conditions are functionally equivalent, and in doing so to evaluate the predictions of two different classes of STM models.

Models of short-term memory

Models of STM can be broken into two general classes. One class of models (e.g., Brown, Preece, & Hulme, 2000; Nairne, 1990) views STM as a specialised memory mechanism and explains performance in terms of processes and principles that are applicable to almost any type of information. That is, they could model recall of objects, spatial locations, pictures or verbal material with only relatively minor modifications. These models stem from a tradition of memory research going back over 100 years and have been a prominent approach to understanding STM in the psychological literature.

An alternative, psycholinguistic perspective views performance on verbal serial recall tasks as being based on language processes (e.g., Gupta & MacWhinney, 1997; Martin, Lesch, & Bartha, 1999). According to this view the processes underlying verbal serial recall are not simply general purpose mechanisms that exist to preserve a brief record of the immediate past, but instead reflect the operation of specialised language processing mechanisms whose primary purpose is to allow us to produce and comprehend spoken language. As such, performance may reflect constraints specific to verbal stimuli and use mechanisms that may be fundamentally different from those involved in remembering non-verbal material. What follows is a brief description of the two types of models, with some examples, and an explanation of the different predictions they make regarding the effect that phonemic similarity has on STM recall when it is defined as words sharing the CV_, the _VC or the C_C components.

Non-linguistic models of short-term memory

Many models of STM make few assumptions about the nature of the representations underlying serial recall performance. Items are often represented as a vector and the models are governed by general principles that pay no regard to any specific constraints related to the linguistic nature of the stimuli. As such, similarity in these models is a quantitative variable and without additional assumptions CVC items that share the _VC segment would be just as similar as items that share the CV_ or C_C.

A major concern of the non-linguistic models of STM has been to provide a mechanism to explain the retention of the order of list items as this appears to be one of the major differences between short- and long-term memory. In many of these models the likelihood of recalling an item in the correct position is a function of its distinctiveness from all other items in the list. This reliance on distinctiveness explains the detrimental effect of similarity on memory for order in several models (Brown et al., 2000; Burgess & Hitch, 1992, 1999; Nairne, 1988, 1990; Nairne & Kelley, 1999; Tehan & Fallon, 1999). For instance, according to the feature model (Nairne, 1988, 1990), the effect that similarity has on order memory arises from the interpretation or "deblurring" of memory traces at retrieval. It is assumed that confusion arises when a degraded trace from primary (short-term) memory is compared with a set of traces from secondary (long-term) memory. Nairne (1990) suggests that the selection of items from the 'secondary memory search set' is based on the ratio rule—the likelihood of recalling a presented item is a function of the relative similarity of the probe item to the similarity of all of the presented list items (Gillund & Shiffrin, 1984; Hintzman, 1986; Luce, 1959; Nosofsky, 1986). In most models, items are represented as vectors, and more similar items are represented by more similar vectors. Hence, STM models that are based on the distinctiveness assumption predict that as similarity increases, order accuracy should decrease, however, such models do not predict that the position of the phonemic overlap within the items should be important. Therefore, without the introduction of additional assumptions about the nature of item similarity, these models predict the same detrimental effect on order memory for lists that share the CV_, the _VC or the C_C components.

Most models of STM have been constructed to explain this detrimental effect of similarity on order memory but many seem unable to explain the facilitative effect of rhyme on item memory in the serial recall task reported by Fallon et al. (1999). A possible solution to this problem was offered by Nairne and Kelley (1999). They suggested that the representations of memory items are located in a multidimensional space in which stimuli are represented along a list dimension and a within-list dimension. Sharing phonemic features within a list, but not between lists, has a beneficial effect on item recall because it improves discrimination on the list dimension. Tehan and Fallon (1999) have proposed a similar suggestion to capture the idea that list cues can be used to facilitate the recall of item information. At the same time, the more similar list items are, the harder it should be to discriminate items on the within-list dimension. That is, to recover an individual item's position within a list. Therefore, according to these models similarity will only increase item recall when the detrimental effect of shared phonological features on the within-list dimension is compensated for by a beneficial effect of similarity on the list dimension (see also Watkins & Watkins, 1975). Nevertheless, such an approach predicts the same facilitative effect on item memory for lists that share the CV_, the _VC or the C_C components, as without additional assumptions each should provide for equally effective discrimination on the list dimension.[1]

To summarise, the non-linguistic models of STM predict that, in comparison to a phonologically dissimilar condition, lists in which any two phonemes are shared by all of the words (CV_, _VC or C_C) will show a detrimental effect on order memory and a facilitative effect on item memory.

Psycholinguistic models of short-term memory

Some models of verbal STM specifically acknowledge that verbal stimuli may place unique demands on memory and as such any mechanism underlying the recall of verbal material may be quite different from the memory system supporting the recall of other types of stimuli. Any model based on this position could be referred to as psycholinguistic. The strongest form of this argument would be those attempts to model verbal recall solely in terms of processes that have been posited to account for speech perception and production capabilities (e.g., Martin et al., 1999).

One psycholinguistic model of STM (Hartley & Houghton, 1996) that is pertinent to the current experiments has been developed to explain the findings from a small body of research on STM for nonwords. The majority of the research on verbal STM has used words and, as a consequence, most models of STM have focussed on the findings and challenges posed by this literature. However, research on the recall of nonwords poses different challenges for theories of verbal STM. Specifically, recall errors in these studies show a particular pattern that reveals effects of sub-syllabic structure on the recall of nonwords (e.g., Ellis, 1980; Treiman & Danis, 1988). Some researchers (e.g., Gupta & MacWhinney, 1997) have argued that these linguistic constraints must be incorporated into models of STM to provide a full account of performance.

Hartley and Houghton (1996) offer the most developed model of the linguistic constraints on STM that are relevant to understanding the effects of phonological similarity, and any effects of varying the position of the overlapping phonemes within words. This model incorporates two linguistic principles that are crucial to deriving predictions for the following experiments from a psycholinguistic perspective. The first of these is the sonority principle. Sonority refers to the amount of energy in the speech signal and the sonority principle refers to the fact that in syllables sonority increases to a peak in the vowel and then decreases. The strength of a speech trace will not be as strong for consonants as vowels because consonants are shorter in duration and are not as acoustically intense (Hartley & Houghton, 1996). To reflect this, Hartley and Houghton (1996) set the activation level for nodes representing vowels higher than for nodes representing consonants. Hence, this model predicts that any form of similarity will impair order memory, but the greatest impairment will be seen when the vowel is shared, as it is the most strongly represented phoneme in a word.

The second linguistic principle that Hartley and Houghton (1996) have incorporated is that syllables have an internal structure, comprising an onset and a rime. The onset consists of the initial consonant or consonant cluster, while the rime consists of the vowel and any following consonants. The rime is also divided into the peak (the vowel) and the coda (the following consonants). Hartley and Houghton (1996) suggest that syllables are represented by separate nodes corresponding to the onset and the rime. At the same time, individual phonemes are associated with slots in a syllable template that serves to maintain the structure of the syllable. Not all of the slots in the template are filled for each syllable, but each occupied slot is also linked to the onset and rime nodes. The syllable template preserves the structure of the syllable rather than the content, and is used to activate the onset and rime nodes appropriately, which in turn activate individual phonemes. These mechanisms explain why errors in the recall of CVC nonwords are more likely to preserve the VC than the CV or C_C pairings (e.g., Treiman & Danis, 1988), because these errors respect the onset-rime structure.

[1] A unique aspect of the feature model is the assumption that the utility of trace features for recall is not only influenced by the distinctiveness of the list items in relation to other list items, but also by the salience of the trace features. An attentional parameter was implemented into the original feature model to reflect the idea that cues can be used to increase the salience of list items to the extent that participants perceive the items as belonging to the same category.

Gupta and MacWhinney (1997) have proposed a conceptual hybrid model by describing how the Hartley and Houghton (1996) model can be incorporated into the Burgess and Hitch (1992) connectionist model of STM. The Burgess and Hitch (1992) model provides a mechanism that can serially order items and explain other recall phenomena, while the Hartley and Houghton (1996) model provides a linguistically constrained model of sub-syllabic processes.

In a hybrid model of this type, the sub-lexical linguistic mechanisms of Hartley and Houghton (1996) can be used to mediate the associations between phonemes and words. As in the Burgess and Hitch (1992, 1999) model, nodes corresponding to words can be associated to a context maintenance queue to maintain the temporal order of the words. If the onset and rime nodes are associated with the temporal order mechanism, even indirectly via word units, then this account can explain the facilitative effect of rhyme on item memory. Presentation of rhyming words results in the repeated activation of the same rime unit during both presentation and recall, increasing the likelihood of it being correctly recalled.

This psycholinguistic account also predicts that the position of the overlapping phonemes in a list will influence the nature of the phonemic similarity effect observed. If the words in a list share the CV or the C_C then a different rime unit will be activated by each word, just as would occur for a list of dissimilar words, so these lists will not benefit from the repeated activation of the same rime unit. Though lists of such items may show some benefit of the repetition of the initial consonant, this effect will be much smaller as the initial consonant is less strongly activated than the vowel (reflecting the sonority principle).

To summarise the psycholinguistic model predicts that, in comparison to lists of dissimilar words, order memory should be reduced for any list where all the items share two phonemes, but this effect will be larger when list items share a common vowel (i.e., _VC, CV_) than when they do not (i.e., C_C). This is because the vowel is the most highly activated phoneme and provides the best discrimination amongst the words. At the same time, item information will be better for lists that share the _VC because the same rime unit is repeatedly reinforced, while this is not true for lists that share the CV_ or C_C components.

The current experiments

The following experiments use the same pool of words (sampled without replacement) for all conditions in an experiment, but necessarily use different sets across experiments. The lists are constructed such that the conditions differ across experiments in terms of the position of the shared phonemes within words, yet are equated on phonological similarity. Therefore, in comparison to when the list items are phonemically dissimilar, Experiment 1 will attempt to replicate the item recall advantage that has been found with lists that share a rime ending (_VC; Fallon et al., 1999, Experiment 1; Gathercole et al., 1982). The stimulus lists for Experiment 2 will consist of words that share a common initial consonant and vowel (CV_) component, thus changing the position of the overlapping phonemes across experiments, yet keeping the amount of phonemic overlap (as measured by the degree of shared consonant and vowel information) constant. Finally, for Experiment 3 the stimulus lists will consist of words that share common initial and final consonants (C_C).

In each experiment three measures of recall performance will be examined. Correct-in-position refers to the number of items recalled in the position in which they were presented, whereas item recall refers to the number of items recalled regardless of the position in which they were recalled. As performance when scored using the correct-in-position and item recall measures is not independent (Fallon et al., 1999; Murdock, 1976; Poirier & Saint-Aubin, 1996; Wickelgren, 1965), a measure of order accuracy will also be obtained (i.e., correct-in-position divided by the item recall measure). This yields a measure of the proportion recalled in the correct order as a function of the number of items recalled. Therefore, the better a participant's memory for the order in which the list items were presented, the higher this proportion will be.

These measures provide a test of the predictions derived from the psycholinguistic and non-linguistic models of STM outlined above. To reiterate, non-linguistic models of STM predict that in comparison to phonemically dissimilar items, lists of CV_, _VC or C_C words will have a detrimental effect on order memory when measured using the order accuracy criterion and a facilitative effect on the recall of item information (using the item recall measure). In contrast, psycholinguistic models of STM predict that any form of similarity should impair order memory, but this effect will be largest when the items share a common vowel (i.e., _VC and CV_ lists) as compared to when they do not (i.e., C_C lists). Further, this model predicts an item recall advantage for rhyming lists of items that should be absent (or at least minimal) when list items do not rhyme (i.e., CV_ and C_C lists).

Experiment 1

Method

Participants

Twenty-four undergraduate psychology students from the University of Wollongong participant pool

(5 males and 19 females), with an age range from 19 to 46 years ($M = 23.38$), participated in compliance with a course requirement. Only native Australian English speakers who indicated having no prior problems with their hearing participated in the study.

Stimuli

The stimuli comprised 180 words with a consonant–vowel–consonant (CVC) phonemic structure (refer first table of the Appendix). The stimuli were used to create 30 rhyming, 30 phonemically similar, and 30 phonemically dissimilar six-word lists. Thus, each word 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 list shared the _VC component (e.g., *Came*, *Name*, *Maim*, *Lame*, *Dame*, and *Shame*). 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 had at least two phonemes in common with at least one other stimulus in the same list (e.g., *Came*, *Case*, *Cut*, *Kip*, *Cub*, and *Cap*). Therefore, all of the items in a similar list shared the same initial consonant. Finally, for the dissimilar condition, each stimulus in each list did not share any phonemes with any other word in that list (e.g., *Came*, *Sin*, *Rang*, *Leap*, *Hug*, and *What*).

Using an Arista Cardioid dynamic microphone (Model No. DM-904D), the stimuli were recorded using 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 onto a Macintosh computer and normalised to control for possible amplitude effects on performance. The lists were presented in three blocks of thirty trials. The order of the blocks within the experimental session was counterbalanced across participants. The order of the trials in each block and the order in which the items occurred in each list were randomised for all participants.

Procedure

For each condition, two practice lists were given to each participant prior to the presentation of the first experimental list. Each participant was auditorally presented with six words at a rate of one word per second. Stimulus presentation rate was controlled using Hypercard (version 2.4.1). One second after the presentation of the last item in a list, participants heard a 200 ms, 500 Hz tone that was used as a recall prompt. A participant's task was to verbally recall the list items in the order in which they were presented. 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 time taken for each participant to complete all three conditions was approximately 40 min.

Results

The data were analysed using a 3×6 (Phonological Similarity $\times$ Serial Position) repeated measures analysis of variance (ANOVA) for the correct-in-position measure of performance (i.e., scored as correct if a participant recalled the correct item in the correct position). In addition, item recall (i.e., scored as correct if a participant recalled a list item regardless of position) and order accuracy measures (i.e., correct-in-position divided by the score obtained using the item recall measure) were analysed using two separate repeated measures ANOVAs. Fig. 1 summarises performance when the stimulus lists were dissimilar, similar or rhyming, collapsed across serial position for each of the three measures. Unless otherwise specified, α was set at .05 (2-tailed). Also, the *Greenhouse–Geisser* statistic is reported instead of the standard F statistic where the assumption of sphericity was violated.

The correct-in-position analysis revealed a main effect of phonological similarity, $F(2, 46) = 20.032$, $MSE = 31.426$, $p < .001$. Post hoc paired samples t-tests were used to analyse the performance differences across the three conditions. α was set at .0167 (2-tailed) to control for the increased probability of committing a Type I error as a function of the number of comparisons performed, thus keeping the family-wise error rate at .05. The analyses revealed that dissimilar lists were recalled more accurately than either similar, $t(23) = 6.609$, $p < .0167$, or rhyming lists, $t(23) = 4.126$, $p < .0167$, which did not differ, $t(23) = 1.391$, *ns.* Although post hoc analyses were not performed on the main effect of position, *Greenhouse–Geisser* $(2.691, 61.892) = 181.488$, $MSE = 39.577$, $p < .001$, across all three conditions the standard serial position effect with better recall of the initial items and the last item in a list was observed. Phonological similarity was also found to interact with

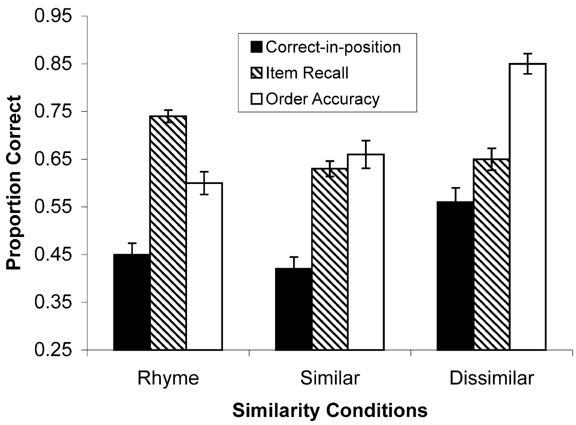

Fig. 1. Mean proportions correct ($\pm SE$) for the phonemically similar, phonemically dissimilar, and rhyming lists of stimuli, for the three scoring procedures (Experiment 1).

serial position, $F(10, 230) = 5.322$, $MSE = 6.986$, $p < .001$, such that differences between conditions increased across serial positions.

The item recall analysis revealed a main effect of phonological similarity, *Greenhouse–Geisser* (1.583, 36.399) = 28.424, $MSE = 123.542$, $p < .001$. Post hoc analyses revealed that item recall was higher for rhyming as compared to either similar, $t(23) = 8.626$, $p < .0167$, or dissimilar lists, $t(23) = 4.885$, $p < .0167$, which did not differ, $t(23) = 1.063$, *ns*. The order accuracy analysis revealed a main effect of phonological similarity, $F(2, 46) = 76.023$, $MSE = .0052$, $p < .001$. Post hoc analyses revealed that dissimilar lists were recalled more accurately than similar lists, $t(23) = 10.316$, $p < .0167$, which were more accurately recalled than rhyming lists, $t(23) = 2.622$, $p < .0167$.

Discussion

Consistent with previous research findings (e.g., Gathercole et al., 1982; Poirier & Saint-Aubin, 1996; Wickelgren, 1965), regardless of whether performance was scored using the correct-in-position or order accuracy measures, order memory was better for dissimilar as compared to either rhyming or similar lists. Although the correct-in-position criterion yielded no difference in order memory between rhyming and similar lists, when scored using the order accuracy measure, order memory was worse for rhyming as compared to similar lists. In other words, the current research found that order memory was impaired when lists consisted of words that shared a larger number of common phonemes (i.e., rhyming lists) as compared to either similar or dissimilar lists. This finding is consistent with the explanations generated from non-linguistic models of STM (Brown et al., 2000; Burgess & Hitch, 1992, 1999; Nairne, 1988, 1990; Nairne & Kelley, 1999; Tehan & Fallon, 1999). According to these models as similarity increases order memory should decrease.

Psycholinguistic models of STM can also account for these results. For instance, according to the Hartley and Houghton (1996) model, any form of similarity should impair order memory but the greatest detriment will be seen when the vowel is shared, as is the case for rhyming lists of words.

Consistent with previous research (i.e., Fallon et al., 1999, Experiment 1; Gathercole et al., 1982), the current study found an item recall advantage for rhyming as compared to either similar or dissimilar lists of words. In addition, the same numbers of words were recalled in the similar as compared to dissimilar condition. Therefore, the findings from the current study suggest that not only does the detrimental effect of similarity disappear when performance is measured for item information, but when the stimulus lists rhyme, similarity appears to facilitate the recall of item information whereas a less consistent form of similarity (i.e., similar condition) does not. The idea that the recall of item information is facilitated by retrieval cues is consistent with research that has found that taxonomic category membership can act as a retrieval cue (Huttenlocher & Newcombe, 1976; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1999). Further, this finding is not only consistent with non-linguistic models which suggest that the rime unit acts as a cue to aid in the retrieval of item information (Nairne, 1988, 1990, 2002; Nairne & Kelley, 1999; Tehan & Fallon, 1999), but also with the Hartley and Houghton (1996) model in which the rime unit serves as a prime to facilitate the recall of item information.

Experiment 2

Experiment 2 was designed to further examine the explanations generated by STM models for the effect that similarity has on both order and item memory. In one condition of Experiment 2 the stimulus lists consisted of words that shared a common CV_ component. Thus, in comparison to Experiment 1 (i.e., rhyming condition), although the positions of the overlapping phonemes differ, the amount of phonemic overlap has been held constant.

According to non-linguistic models of STM as similarity increases order memory should decrease. The Hartley and Houghton (1996) model also predicts that similarity will impair order memory, however, this effect should be greatest when all of the stimuli in a list share the vowel (i.e., CV_ lists). As such, the predictions generated from STM models to account for the effect that similarity has on order memory for CV_ lists of words are indistinguishable.

The linguistic and non-linguistic models do differ, however, in their predictions regarding the effect that similarity has on the recall of item information. For instance, Nairne and Kelley (1999; see also Nairne, 1988, 1990; Tehan & Fallon, 1999) suggest that lists that share features that make them easily discriminable along the list dimension should aid in identifying the correct list to recall. Hence, these models would predict an increase in the recall of item information when stimulus lists share the CV_ component.[2] Essentially these models predict that the findings from Experiment 2 should replicate those observed in Experiment 1, but with CV_

[2] While these predictions are correct for the most part, the feature model (Nairne, 1988, 1990) with the incorporation of an attentional parameter, suggests that it is the salience of the cues that is important for the recall of item information. Hence, it is possible to argue that the rime unit may be a more salient cue than other list cues. However, to make a coherent argument, this model would need to specify why this may be the case in comparison to CV_ and C_C lists.

in the place of _VC lists. In contrast, the Hartley and Houghton (1996) model suggests that syllable representations do not get the same degree of support as when the items rhyme because there is not a consistent rime unit activated by every item in the list. Hence, this model would predict that the item recall advantage observed when the stimuli rhyme (i.e., Experiment 1) should be absent (or at least minimal) when lists share the CV_ component.

Method

Participants

Twenty-four undergraduate psychology students from the University of Wollongong participant pool (4 males and 20 females), with an age range from 18 to 37 years ($M = 20.13$), participated in compliance with a course requirement. The same inclusion criteria were placed on the selection of participants for the current experiment, as in Experiment 1.

Stimuli

The stimuli comprised 180 words with a CVC structure (refer second table of the Appendix). The stimuli were used to create 30 six-word lists with a common CV_ component, 30 phonemically similar and 30 phonemically dissimilar lists. List construction was the same as in Experiment 1 except for a few minor modifications. The first modification was that for the CV_ condition all of the words in a particular list shared the CV_ component (e.g., *Time*, *Ties*, *Tight*, *Type*, *Tide*, and *Tile*). Also, for the similar condition no item in a list shared the CV_ component (e.g., *Time*, *Rum*, *Rhyme*, *Lime*, *Limb*, and *Dumb*). Hence, all of the items in a similar list shared the same final consonant.

Procedure

The same testing procedure was used in the current experiment as in Experiment 1.

Results

The data were analysed using a 3×6 (Phonological Similarity $\times$ Serial Position) repeated measures ANOVA for the correct-in-position measure. Also, the scores obtained using the item recall and order accuracy criteria were analysed using two separate repeated measures ANOVAs. Fig. 2 summarises performance when the stimulus lists were dissimilar, similar or shared the CV_ component, collapsed across serial position for each of the three scoring procedures.

The correct-in-position analysis revealed a main effect of phonological similarity, $F(2,46) = 34.996$, $MSE = 30.653$, $p < .001$. Post hoc analyses revealed that dissimilar lists were recalled more accurately than similar lists, $t(23) = 4.876$, $p < .0167$, which were more accurately recalled than CV_ lists, $t(23) = 4.278$, $p < .0167$. A main effect of position was observed, *Greenhouse–Geisser* (3.017, 69.397) = 238.865, $MSE = 28.210$, $p < .001$, and phonological similarity was found to interact with serial position, $F(10,230) = 4.192$, $MSE = 6.999$, $p < .001$, such that differences between conditions increased across serial positions.

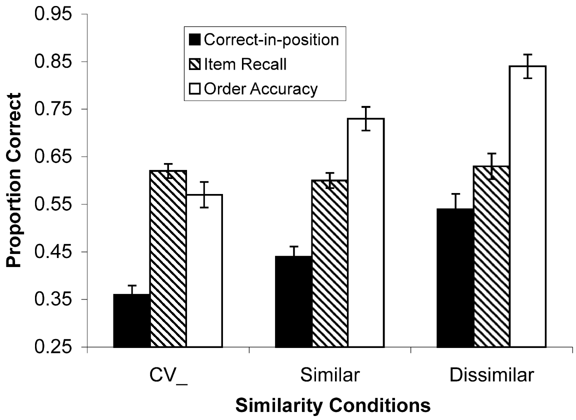

Fig. 2. Mean proportions correct ($\pm SE$) for the phonemically similar, phonemically dissimilar, and CV_ lists for the three scoring procedures (Experiment 2).

The item recall analysis revealed no phonological similarity effect, *Greenhouse–Geisser* (1.424, 32.745) = 2.517, $MSE = 138.734$, *ns*. The order accuracy analysis revealed a main effect of phonological similarity, $F(2,46) = 83.061$, $MSE = .0052$, $p < .001$. Post hoc analyses revealed that dissimilar lists were recalled more accurately than similar lists, $t(23) = 6.591$, $p < .0167$, which were more accurately recalled than CV_ lists, $t(23) = 6.659$, $p < .0167$.

Discussion

In terms of the recall of item information, although there was a trend toward a similarity effect, the current study found no differences in item recall levels across the three conditions. On closer inspection this trend was due to a decrease in item recall for the similar as compared to either the dissimilar or CV_ conditions, rather than to an increase in the recall of item information for the CV_ condition. This is important in that Nairne and Kelley (1999; see also Nairne, 1988, 1990; Tehan & Fallon, 1999) would predict an item recall advantage for stimulus lists that are easily discriminable along the list dimension (i.e., in this case CV_ lists). This prediction is clearly inconsistent with the current research findings. The current findings are, however, consistent with the predictions generated from Hartley and Houghton's (1996) linguistically constrained model of STM. According to this model, an item recall advantage should be observed when list items share a rime ending, as was found in Experiment 1. This is because the rime unit serves as a prime to reinforce syllable structure. When the phonemic overlap between items does not coincide with sub-syllabic structure (onset/rime), as is the case when words share the CV_ component (i.e., Experiment 2), they do not get this additional reinforcement. Hence, in comparison to rhyming lists, the speech traces for CV_ lists of items are less stable. This is consistent with the pattern of results observed in the current study.

In terms of the effect that similarity has on order memory, the predictions generated from both psycholinguistic and non-linguistic models of STM are consistent with the current research findings. For instance, according to non-linguistic models of STM that are based on the distinctiveness assumption (Brown et al., 2000; Burgess & Hitch, 1992, 1999; Nairne, 1988, 1990; Nairne & Kelley, 1999; Tehan & Fallon, 1999), as similarity increases order memory should decrease. Further, according to the Hartley and Houghton (1996) model any form of similarity should decrease order memory, however, when the vowel is the overlapping phoneme (i.e., in this case, CV_ lists), order memory should be further impaired. As such, these explanations are consistent with the current finding of an order memory impairment for CV_ as compared to similar lists, and for similar as compared to phonemically dissimilar lists.

Experiment 3

Experiment 3 was again designed to examine the explanations generated by STM models for the effect that phonological similarity has on both order and item memory. The critical stimulus lists for Experiment 3 consisted of words that shared the C_C component. STM models that are based on the distinctiveness argument predict an identical pattern of results to those observed across Experiments 1 and 2. Thus, as similarity increases these models predict a further order memory impairment. Also, STM models that suggest that list cues can be used to facilitate item recall (i.e., Nairne, 1988, 1990; Nairne & Kelley, 1999; Tehan & Fallon, 1999) predict an item recall advantage for stimulus lists that share the C_C component.

In contrast, although the Hartley and Houghton (1996) model predicts a decrease in order memory for C_C lists of words, because each item in a list has a unique vowel, order memory should not be influenced to the same extent as when the list items either rhyme (i.e., Experiment 1) or share the CV_ component (i.e., Experiment 2). In fact, in comparison to the C_C condition, in this experiment order memory should be poorer for the similar lists because the list items in this condition share a common vowel.

In terms of the recall of item information, the Hartley and Houghton (1996) model predicts an identical pattern of results as in Experiment 2. Thus, the syllable representations will not get the same type of support when list items do not share the rime unit. Hence, the item recall advantage observed when stimuli rhyme (i.e., Experiment 1) should be absent (or at least minimal) when the stimuli share the C_C component.

Method

Participants

Twenty-four undergraduate psychology students from the University of Wollongong participant pool (2 males and 22 females), with an age range from 18 to 32 years ($M = 20.33$), participated in compliance with a course requirement. The same inclusion criteria were placed on the selection of participants for the current experiment as for Experiment 1.

Stimuli

The stimuli comprised 180 words with a CVC structure (refer third table of the Appendix). The stimuli were used to create 30 same-consonant, 30 phonemically similar, and 30 phonemically dissimilar six-word 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 in the same consonant condition all of the stimuli in a particular list shared the C_C component (e.g., *Bought*, *Bet*, *Boot*, *But*, *Bat*, and *Bait*). Also, for the similar lists no item in a list shared both consonants (e.g., *Bought*, *Bored*, *Lawn*, *Wrought*, *Fort*, and *Fawn*). 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.

Results

The data were analysed using a 3×6 (Phonological Similarity × Serial Position) repeated measures ANOVA for correct-in-position. In addition, the scores obtained using the item recall and order accuracy measures were analysed using two separate repeated measures ANOVAs. Fig. 3 summarises performance when the stimulus lists were dissimilar, similar or shared the C_C component, collapsed across serial position for each of the three scoring procedures.

The correct-in-position analysis revealed a main effect of phonological similarity, $F(2,46) = 32.172$, $MSE = 31.741$, $p < .001$. Post hoc analyses revealed that dissimilar lists were recalled more accurately than C_C lists, $t(23) = 4.778$, $p < .0167$, which were more accurately recalled than similar lists, $t(23) = 3.384$, $p < .0167$. A main effect of position was observed, *Greenhouse–Geisser* $(2.974, 68.410) = 183.313$, $MSE = 29.320$,

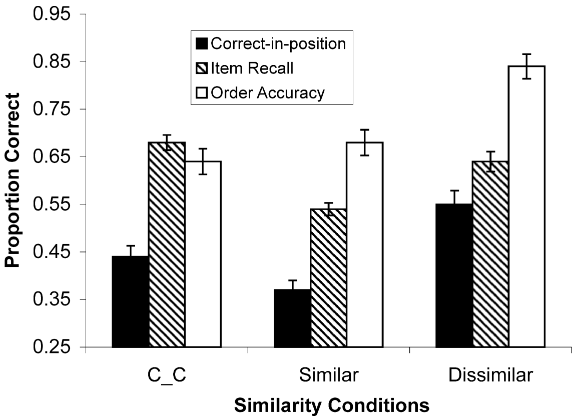

Fig. 3. Mean proportions correct (±*SE*) for phonemically similar, phonemically dissimilar, and C_C lists for the three scoring procedures (Experiment 3).

$p < .001$, and phonological similarity was found to interact with serial position, $F(10, 230) = 5.716$, $MSE = 5.603$, $p < .001$, such that differences between conditions increased across serial positions.

The item recall analysis revealed a main effect of phonological similarity, *Greenhouse–Geisser* (1.576, 36.250) = 37.316, $MSE = 141.030$, $p < .001$. Post hoc analyses revealed that in comparison to the phonemically similar condition, item recall was higher for C_C and dissimilar lists, ($t(23) = 11.662$, $p < .0167$; $t(23) = 5.757$, $p < .0167$; respectively). However, the recall of item information did not differ between the C_C and dissimilar lists, $t(23) = 2.043$, *ns*. Finally, the order accuracy analysis revealed a main effect of phonological similarity, $F(2, 46) = 48.578$, $MSE = .0055$, $p < .001$. Post hoc analyses revealed that order memory was better for dissimilar as compared to either C_C, $t(23) = 10.566$, $p < .0167$, or similar lists, $t(23) = 7.314$, $p < .0167$, which did not differ, $t(23) = 1.646$, *ns*.

Discussion

Regardless of whether the correct-in-position or order accuracy criterion was used to measure performance, order memory was better for the dissimilar as compared to either of the phonemically similar conditions (i.e., similar or C_C lists). Thus, the standard detrimental effect of similarity on order memory was observed (e.g., Baddeley, 1966; Baddeley, Lewis, & Vallar, 1984; Gathercole et al., 2001; Lian, Karlsen, & Winsvold, 2001; Watkins et al., 1974). Although no difference was observed between the C_C and similar conditions when scored using the order accuracy measure, the correct-in-position measure yielded an order memory impairment for similar as compared to C_C lists of words.

This finding of a decrease in order memory (as measured using the correct-in-position criterion) for similar in comparison to C_C lists is inconsistent with explanations generated by non-linguistic models of STM (Brown et al., 2000; Burgess & Hitch, 1992, 1999; Nairne, 1988, 1990; Nairne & Kelley, 1999; Tehan & Fallon, 1999). Furthermore, the finding of no difference in order memory between C_C and similar lists when measured using the order accuracy criterion is also problematic for these models. According to these models as similarity increases order memory should decrease. However, C_C lists share a larger number of overlapping phonemes than do similar lists. Thus, non-linguistic models of STM that suggest that it is the distinctiveness of items in relation to other list items that determines the effect that similarity has on order memory cannot deal with the current research findings.

The results are consistent with psycholinguistic models that suggest that the influence that similarity has on order memory is dependent on the phonemic make up of the experimental list items. For instance, according to the Hartley and Houghton (1996) model, order memory is influenced by both the phonemic similarity of the list items and the effect that sharing a common vowel has on order memory. Therefore, although C_C lists share a greater amount of phonemic overlap than do the phonemically similar lists, the greater weighting of the vowel in comparison to consonants means that order memory is more adversely affected in the similar condition, despite list items in this condition sharing fewer common phonemes.

The findings from the current study regarding the recall of item information are inconsistent with predictions generated from STM models which suggest that shared features that make lists easily discriminable along the list dimension (i.e., C_C lists) aid in the recall of item information (i.e., Nairne, 1988, 1990, 2002; Nairne & Kelley, 1999; Tehan & Fallon, 1999). If this were the case then the recall of item information for the C_C lists should significantly exceed what was observed for the dissimilar lists and it did not. In contrast, the Hartley and Houghton (1996) model suggests that in comparison to rhyming lists of items, the syllable representations do not get the same level of support when the items share the C_C component. As a consequence, the recall of item information for C_C lists should not benefit to the same extent as when the stimulus lists rhyme.

Although performance for the dissimilar conditions was almost identical across the three experiments, one finding that requires further exploration was the decrease in the recall of item information for the phonemically similar condition in Experiment 3 (i.e., $M = .54$) as compared to the similar conditions in the other two Experiments (i.e., Experiment 1, $M = .63$; Experiment 2, $M = .60$). One possibility is that the differences in item recall levels are due to differences in the prevalence of phoneme recombination errors across these conditions (e.g., the list *sat*, *bit*, *sap*, *map* is recalled as *bat*, *sit*, *sap*, *map*). Although recombination errors are rare when the experimental stimuli are familiar and phonemically dissimilar (Hartley & Houghton, 1996), using phonemically similar stimuli may increase the likelihood that participants will produce these types of errors.

To further examine this idea, the proportion of recombination errors that occurred across each of the phonemically similar conditions was collated. Across the phonemically similar conditions, recombination errors made up 7.5% of the errors in Experiment 1, 11.0% in Experiment 2, and 15.4% in Experiment 3. These data were subjected to a one-way ANOVA which revealed a significant difference in the proportion of recombination errors observed across the experiments, $F(2,71) = 12.914$, $MSE = .003$, $p < .001$. Post hoc independent samples *t*-tests revealed that fewer recombination errors occurred when the stimuli consisted of a mixture of C_C and CV_ items (i.e., Experiment 1) as compared to lists that consisted of a mixture of C_C and _VC items (i.e., Experiment 2), $t(46) = 2.696$, $p < .0167$, which in turn produced fewer recombination errors than when the lists consisted of a mixture of CV_ and _VC items (i.e., Experiment 3), $t(46) = 2.672$, $p < .0167$.

This pattern of results is consistent with findings from studies on the types of errors made in speech production and the serial recall of nonwords (Ellis, 1980; MacKay, 1970; Treiman & Danis, 1988) that show that recombination errors are not random. Rather, when a recombination error occurs, research suggests that the error is more likely to occur in the onset (initial phoneme) as compared to coda (final consonant) of a syllable (MacKay, 1970; Treiman & Danis, 1988). In addition, initial consonants tend to substitute for initial consonants and final consonants for final consonants, and vowels are less prone to substitutions than are consonants (Ellis, 1980). To summarise, these findings suggest that recombination errors are more likely to occur from initial phoneme movements and less likely to occur from the movement of vowels. This is consistent with the current research findings in that a lower proportion of recombination errors occurred in the similar condition when the onset was held constant across list items (i.e., Experiment 1) whereas a larger proportion occurred when the vowel was held constant (Experiment 3). Therefore, in comparison to the other phonemically similar conditions, although item recall was lower for the similar condition in Experiment 3, a larger proportion of the errors that occurred in this condition were recombination errors.

It should be noted that this pattern must also reflect the fact that not all recombination errors are detectable. For instance, movement of a phoneme in a list where that phoneme is always the same will result in what appears to be a correct recall. However, the movement of a phoneme that differs across list items may result in what appears to be an order error (e.g., when the initial phoneme in a rhyming list moves). Therefore, recombination errors are most likely to produce a word that was not presented in the list when the list consists of a mixture of CV_ and _VC items (i.e., the phonemically similar condition in Experiment 3).

General discussion

Despite the differences in how similarity was operationally defined across experiments, a number of results were consistently observed. For instance, regardless of the way in which order performance was measured (i.e., correct-in-position or order accuracy), order memory was better for dissimilar as compared to any of the similar conditions. This is consistent with earlier research findings of an order memory impairment for phonemically similar lists of stimuli, regardless of the type of stimuli employed, the presentation modality or the recall method used (e.g., Baddeley, 1966; Baddeley et al., 1984; Coltheart, 1993; Cowan, Saults, Winterowd, & Sherk, 1991; Li, Schweickert, & Gandour, 2000; Wickelgren, 1965). Further, a comparison across Experiments 1, 2, and 3 for the dissimilar conditions revealed similar levels of performance, regardless of whether performance was scored using the item recall (.65, .63, and .64, respectively) or order accuracy (.85, .84, and .84, respectively) measures. This consistency is important in that different stimulus sets were used for each experiment. Hence, if the findings from the current study hinged on stimuli differences, then disparities in the performance measures obtained across the dissimilar conditions would be evident. As such, this finding lends strong support to the suggestion that any differences in item and order memory observed across the current experiments between the dissimilar and similar conditions must be due to the way in which similarity has been operationally defined.

Although commonalities were found across the experiments, an interesting pattern of results emerged in terms of the recall of item information. The first is the finding that in comparison to the dissimilar condition, there was an item recall advantage for stimulus lists that rhymed (Experiment 1). Further, this item recall advantage was absent when the stimulus lists shared the CV_ (Experiment 2) or C_C (Experiment 3) components. Hence, these findings are inconsistent with STM models that suggest that an item recall advantage should be observed whenever lists share features that make them easily discriminable along the list dimension (e.g., Nairne, 1988, 1990, 2002; Nairne & Kelley, 1999; Tehan & Fallon, 1999). These findings are, however, consistent with the Hartley and Houghton (1996) model. For instance, according to this model the speech trace is more stable when list items share a rime ending as compared to when the words in a list do not share this structure (i.e., CV_ and C_C lists).

In terms of the predictions STM models generate for the effect that similarity has on order memory, non-linguistic models suggest that as similarity increases order memory should decrease (Brown et al., 2000; Burgess & Hitch, 1992, 1999; Nairne, 1990; Tehan & Fallon, 1999). It is clear that these models can explain the finding that order memory was better for phonemically similar as compared to either rhyming (Experiment 1) or CV_ lists (Experiment 2), as the overall phonemic overlap between list items is greatest in the latter two conditions. However, what is unclear is how these models could account for the finding that when measured using the correct-in-position criterion, order memory was lower for similar as compared to C_C lists (Experiment 3). In addition, when measured using the order accuracy criterion, no difference in order memory was found between the C_C and similar lists. Both of these findings are problematic for non-linguistic models of STM that assume that it is the distinctiveness of list items in relation to other list items that impairs order memory (Brown et al., 2000; Burgess & Hitch, 1992, 1999; Nairne, 1990; Tehan & Fallon, 1999). This is because the C_C lists shared a greater number of overlapping phonemes than did the similar lists (Experiment 3).

In contrast, the Hartley and Houghton (1996) model suggests that any form of similarity should impair order memory (i.e., C_C lists; Experiment 3). However, when the overlapping phoneme is the vowel, as is the case with rhyming (Experiment 1) or CV_ (Experiment 2) lists, this model predicts a further order memory impairment. Thus, the findings from the current study suggest that the influence that similarity has on order memory is dependent on the phonemic make up of the list items.

In summary, the current research findings suggest that phonological similarity influences both the recall of item information and memory for an item's position in a list. Also, the current findings rule out the possibility that the item recall advantage observed for rhyming lists of words is due to phonemic overlap. Rather, the results suggest that STM performance is influenced by linguistic mechanisms that operate at the sub-syllabic level. Further, these findings suggest that the influence that similarity has on order memory is dependent on the phonemic make up of the list items in that when similarity is held constant order memory is impaired to a greater extent when the vowel is the overlapping phoneme. Thus, to adequately explain the current research findings it is imperative that STM models incorporate mechanisms that can deal with the psycholinguistic rules that constrain speech production. Hence, the current study has identified an urgent need for STM researchers to integrate linguistic research, and models based on this research, into STM models.

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Appendix

Stimuli used for Experiment 1

name	maim	came	lame	dame	shame
wait	bait	mate	date	fate	rate
sail	mail	fail	pail	gail	tail
lace	face	mace	race	case	base
hide	ride	side	lied	tied	died
shine	mine	sign	line	wine	fine
bile	mile	tile	dial	rile	file
gnome	foam	roam	dome	comb	home
loan	bone	cone	phone	hone	sewn
coke	soak	choke	woke	poke	folk
goal	dole	bowl	foal	soul	pole
bag	wag	lag	rag	hag	tag
hang	rang	tang	gang	sang	pang
ram	sham	ham	lamb	mam	dam
cap	gap	rap	sap	chap	map
fin	win	sin	chin	pin	kin
whip	lip	kip	chip	tip	sip
dig	pig	big	wig	rig	fig
sing	ring	wing	ding	ting	ping
seize	tease	peas	knees	bees	cheese
bead	seed	heed	need	lead	weed
reap	seep	weep	sheep	beep	leap
sheik	meek	peek	cheek	teak	seek

Appendix (*continued*)

sun	ton	run	gun	shun	done
rug	bug	hug	tug	mug	dug
tub	sub	cub	rub	pub	hub
putt	cut	gut	hut	rut	mutt
mock	wok	hock	rock	sock	Knock
log	bog	cog	hog	dog	fog
lot	what	rot	not	pot	cot

Stimuli used for Experiment 2

mace	maim	main	mate	make	maze
sane	safe	sake	same	save	sail
wade	waif	whale	wain	wake	weighs
rail	rake	race	rain	rate	rave
live	life	light	lime	line	lice
rhyme	rice	rife	right	ripe	rise
ties	tight	time	type	tide	tile
while	white	wife	wise	wide	wine
bird	burn	burp	burg	burrs	birch
purred	pearl	perk	pert	purrs	perch
cab	can	cap	cat	cash	caff
hack	have	hash	hag	had	hang
man	mass	map	mate	mad	mag
sack	sad	sag	sang	sap	sat
lick	lid	limb	lip	lit	liv
pick	pig	pin	pit	pip	pill
bid	bill	bit	big	bin	bitch
seas	seal	seem	seek	seat	scene
wheeze	week	wean	wheel	weed	wheat
beak	bead	beam	beep	bees	beat
dung	dull	done	duck	duff	dumb
huff	hum	hush	hut	hub	hutch
mud	mull	mutt	muck	much	mush
rub	rum	rung	rush	rough	run
lob	lock	long	lop	loss	lot
cob	cod	con	cop	cot	cough
sob	sock	sod	song	sop	sot
poured	porch	pork	pawn	pause	port
ward	walk	wharf	warn	wart	wars
half	hard	harm	heart	halve	harsh

Stimuli used for Experiment 3

bide	beard	bod	bud	bored	bird
batch	birch	beach	bitch	botch	butch
bought	bet	boot	but	bat	bait
bile	bowl	bill	bull	bail	ball
choose	cheese	chose	chars	chores	cheers
fort	feet	fit	foot	fat	fate
fall	foul	feel	fool	full	fail
fees	fears	foes	furs	phase	fuzz
fawn	fern	phone	fun	fan	feign
guard	gored	guide	goad	geared	god
gut	got	get	git	goat	gate
ham	harm	home	him	whom	hum
hard	hide	heard	heed	hid	had
heart	hurt	heat	hut	hat	hoot
lurk	leak	look	lick	lake	lack
lawn	lane	line	learn	loan	lean
mess	mice	mace	mass	morse	moose

Appendix (*continued*)

mourn	main	mine	moon	men	man
porch	patch	perch	poach	pitch	peach
pars	pays	purrs	piers	pause	pies
pal	pearl	pole	peel	pool	pail
rook	ruck	rake	reek	rack	wreck
rhyme	roam	room	rum	ream	ram
roared	raid	ride	road	red	read
wrote	route	rut	rat	rate	wrought
soars	size	sues	sears	seas	sews
suck	sick	sock	soak	sake	sack
sap	soap	sip	seep	sop	soup
walk	work	woke	wick	week	wack
warn	wian	wine	win	wean	one

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