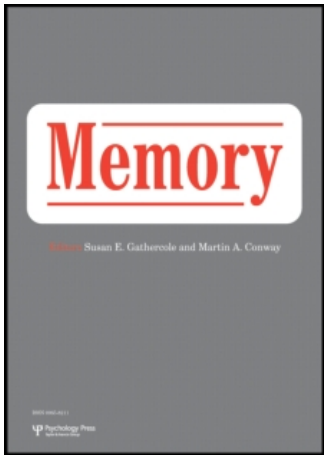

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Investigating the roles of phonological and semantic memory in sentence recall

Tracy Packiam Alloway
University of Durham, UK

The mechanisms underlying short-term sentence recall have been the subject of recent investigations. While both semantic and phonological information have been found to play a role in sentence recall, this has been established using different paradigms in previous research. As a result, it is not clear whether the contributions of semantic and phonological information are equivalent subject only to specific experimental conditions. The present study used a common paradigm with equally plausible lures to systematically compare the roles of semantic and phonological information in short-term sentence recall. The lure intrusion paradigm was used with three different lures that were all equally plausible in the context of the sentence: semantic, onset, and rhyme. Further, no contextual cues were provided in the sentence to bias the participant. The findings indicate that there were significantly more semantic and onset intrusions compared to rhyme intrusions. This is interpreted in light of models incorporating lexical information during sentence production.

It is well established that there is a recall advantage for sentences over unrelated words. Recent studies have increasingly focused on the different cognitive mechanisms underpinning verbatim recall of sentences in order to account for this advantage. It has been suggested that sentence recall is a task that involves the integration of semantic information with surface representations of a sentence such as phonological and lexical information. However, the contributions of semantic and phonological information have been assessed using different paradigms in previous research. As a result, it is not clear whether the contributions of semantic and phonological information are equivalent subject only to specific experimental conditions. Thus, the aim of the present study is to use a common paradigm to compare the roles of semantic and phonological information in short-term sentence recall using equally plausible lures and removing contextual information that may bias the participant.

The role of semantic information in sentence recall has been investigated using a lure intrusion paradigm (e.g., Potter & Lombardi, 1990). According to this paradigm, participants are presented with a sentence (*The knight rode around the palace searching for a place to enter*) followed by a list of words (*turtle, recipe, booth, castle, medal*). Next, a probe word (*medal*) is presented and participants have to determine whether the probe word appeared in the preceding word list. They then have to recall the sentence. Embedded in the word list is a semantic lure that is more contextually appropriate in the sentence than the target word. For example, in the above sentence, the lure *castle* would be more strongly associated

Address correspondence to: Dr Tracy Packiam Alloway, School of Education, University of Durham, Leazes Road, Durham DH11TA, UK. E-mail: t.p.alloway@durham.ac.uk

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than the target word *palace* with *knight* in the sentence. As the lure and the target words shared semantic structure, these words were likely to be exchanged during sentence recall, while the rest of the sentence was usually recalled verbatim. Potter and Lombardi (1990) suggested that this occurred because regenerating a sentence relies on recently activated lexical entries from conceptual information in long-term memory. Spontaneous intrusions of the lure word even when it did not appear in the word list (as in the control condition) lend support to this view. This high activation of semantic information is what preserves the meaning of the sentence thus supporting recall, a benefit that a word recall task does not have. It is worth noting that in these studies semantic lures always differed from the target in phonological features. This meant that the semantic effects were not weakened by potentially confounding phonological effects. In addition to the close association between the semantic lure in the word list and the target word in the sentence, Potter and Lombardi also constructed the sentences to provide ample semantic cues consistent with a particular schema. For example, knight was riding (a horse) to enter a castle/palace in the example provided above. These semantic cues could also have assisted the overall recall of the sentence.

While studies by Potter and Lombardi (1990) provide support for the role of semantic information in sentence recall, there is also emerging evidence for the contribution of phonological short-term memory. There are neuropsychological data establishing that impairments of phonological short-term memory are typically linked with poor recall of both word lists and sentences. Patients with phonological short-term memory deficits were more impaired on sentence recall compared to sentence comprehension (e.g., Hanten & Martin, 2000; McCarthy & Warrington, 1987), indicating that phonological short-term memory contributes to the recall but not comprehension of sentences.

Developmental studies have also indicated that phonological memory capacity is linked to marked differences in overall accuracy in sentence recall (e.g., Alloway & Gathercole, 2005a). For example, when comparing the number of words accurately recalled in a sentence between high and low phonological memory groups, the low phonological memory group achieved significantly lower scores. Furthermore, an error analysis revealed that the high phonological memory group retained the structural aspects of the sentence, such as word order, significantly better than the low phonological memory group, who were more likely to commit errors of omissions and insertions. One explanation is that phonological memory assists in the preservation of the structure of a sentence (see Caramazza, Basili, Koller, & Berndt, 1981). However, it is worth noting that other factors also play a role in sentence recall. Specifically, studies have found that sentence recall ability formed a separate cognitive construct from both verbal working memory and short-term memory tasks (Alloway, Gathercole, Willis, & Adams, 2004; Rohl & Pratt, 1995), and also has dissociable links from verbal working memory and short-term memory with learning (e.g., Alloway & Gathercole, 2005b).

The contribution of phonological short-term memory to sentence recall has also been established using the word length paradigm. Willis and Gathercole (2001) found that increasing the length and number of words in a sentence significantly affected sentence recall (see also Engelkamp & Rummer, 2002; Rummer, Engelkamp, & Konieczny, 2003). A different approach adopted by Rummer and Engelkamp (2001) was to vary both the retention period of the sentence by presenting the word list either before or after the sentence, and the modality of presentation (verbal or visual). The findings indicated that sentence recall was significantly better for verbally presented material when the word list preceded the sentence. This modality effect disappeared when the word list was presented after the sentence, an effect attributed to the decay of phonological codes in short-term recall.

One model able to account for both the semantic and phonological contributions to short-term sentence recall is the working memory model proposed by Baddeley (2000). Specifically, the recent addition to the original tripartite memory model, the episodic buffer, can explain the role of semantic information in sentence recall as its function is to integrate information from temporary memory subsystems such as the phonological loop to support the verbatim recall of individual words and their order, with semantic and syntactic information held in long-term memory.

The phonological loop component of the working memory model is responsible for the short-term store of verbal information, and comprises two parts: the phonological store and the articulatory control process. The phonological store is responsible for the retention of audio-based

information for a brief period. Information held in the store will decay within 2 seconds unless the individual actively maintains it via rehearsal. The articulatory control process is the rehearsal mechanism that refreshes a verbal trace to prevent decay and is also involved in translating visual information into a phonological code that can be rehearsed in the store. The word length effect in sentence recall (e.g., Willis & Gathercole, 2001) can be explained in light of the function of the articulatory control process. The longer the list of items or the longer the retention period, the harder it will be continue to refresh the items in the store, resulting in a decay of the relevant information.

An alternative account has been advanced by Martin, Lesch, and Bartha (1999; also Hanten & Martin, 2000). This view is based on specialised language processing mechanisms where, during word recall, knowledge structures in long-term memory that are closely linked with separate buffers supporting phonological, lexical, and semantic domains, are activated. Performance on sentence recall is constrained by a similar process involved in word production: information is encoded semantically first, then transformed into a lexical code to express this concept, and finally phonologically, before it can be articulated. In sentence comprehension, this sequence of activations occurs in reverse order, which may explain the dissociation in performance between sentence recall and comprehension (e.g., Hanten & Martin, 2000; Willis & Gathercole, 2001).

As sentence recall draws from different cognitive resources such as semantic and phonological information, it is important to establish whether one provides a better retrieval cue than the other when regenerating a sentence. So far, the research indicates that semantic intrusions occur significantly more than in non-lure conditions (e.g., Potter & Lombardi, 1990), and phonological information is critical when sentences are presented verbally and recall is immediate rather than delayed (e.g., Rummer & Engelkamp, 2003). To date there have been no studies comparing the effects of a semantic lure with a phonological one as equally plausible lures. Thus, the present study uses the intrusion paradigm as developed by Potter and Lombardi (1990) but introduces different types of lures that are equally plausible in the context of the sentence. This allows for a systematic comparison of the roles of semantic and phonological cues in sentence recall. Another feature of the present study that distinguishes it from previous studies is that the sentences were constructed to remove any information that could potentially bias the participant. This allowed for any intrusion effects to be associated with the lures rather than contextual cues.

A further aim of the present study is to discriminate between the different contributions of phonological memory by measuring phonological similarity effects. A well-established finding is that immediate serial recall is significantly impaired if items to be recalled are phonological similar to each other (Conrad & Hull, 1964; see Gathercole, 1998, for a review). One account for this impairment is that it is due to an overlap of features kept in the phonological store, one of two subcomponents of the phonological loop (e.g., Baddeley, 2003). This effect persists even when stimuli are presented visually, as visual information is recorded into a verbal code via the articulatory control process and then passed to the phonological store.

However, the manner in which phonological similarity is defined can mediate the effect. While some studies have used lists of rhyming words (e.g., Gathercole, Gardiner, & Gregg, 1982; Poirier & Saint-Aubin, 1996), others have used lists of single-syllable words with a common vowel and some overlap in the consonants (e.g., Coltheart, 1993; Watkins, Watkins, & Crowder, 1974). Fallon, Groves, and Tehan (1999; also Gathercole et al., 1982) found that although rhyming words impaired order recall, they actually enhanced item recall. Some researchers have suggested that this is because the vowel is the most highly activated phoneme and thus enhances recall of words that share the same vowel (Treiman & Danis, 1988). When comparing words that shared the onset (CV_) compared with those that had the same ending (_VC), Nimmo and Roodenrys (2004) found that recall was enhanced for words that shared the word endings (_VC words), but there was no advantage for words with the same onset structure (CV_ words). They explained this finding in light of psycholinguistic models of short-term memory based on language-processing mechanisms which suggest that words that share rhyme units are more stable than words that don't (e.g., Hartley & Houghton, 1996).

The present study included two types of phonologically similar lures: words with phonemic similarity at the end (rhyme) and words with phonemic similarity at the beginning (onset). Phonemic overlap was controlled for by altering only one phoneme in the words used in the rhyme

and onset lure conditions. This procedure allows us to directly compare different accounts of phonological similarity in sentence recall. According to the Baddeley working memory model, if the phonological store component plays a critical role in sentence recall, then we would expect both the rhyme and onset lures to produce a comparable amount of intrusions as would a semantic lure, and to produce significantly more intrusions than in the control condition. As this model explains the phonological similarity effect in terms of feature overlap, word strings such as "*man, mad, map, mat, can, cap, cad, cat*" (e.g., Baddeley & Hitch, 1974) are considered as phonological similar because words share either one or two features, regardless of whether the overlap is at the onset or at the end of the word.

However, if the same language production mechanisms that constrain phonological similarity effects in short-term recall (e.g., Hartley & Houghton, 1996; Martin et al., 1999; Nimmo & Roodenrys, 2004) are important in sentence recall, then we would expect onset lures to produce a comparable amount of intrusions as would a semantic lure. In contrast, as the rhyme unit is thought to be stable, we would not expect to see a significant amount of rhyme lure intrusions compared to the control condition. Consistent with previous studies, the stability of the rhyme unit could possibly enhance sentence recall as hearing a rhyme lure may activate fading memory traces (Nimmo & Roodenrys, 2004).

THE PRESENT STUDY

Participants

A total of 120 undergraduate students, all native English speakers, were recruited from the University of Durham. Of these, 40 were assigned to the pre-test condition, and the remainder to the experimental condition.

Materials

As materials, 51 sentences were constructed, each with a concrete noun as a target word. The target was embedded in the middle of the sentence, in line with materials used in Rummer and Engelkamp (2001) and Potter and Lombardi (1990). The sentences ranged from 14 to 21 words. As mentioned previously, in contrast to Potter and Lombardi's sentences where there was a salient relationship between the target and lures words (e.g., *knight*, *palace*, and *castle*), in the present study contextual cues that might encourage greater intrusions were removed from the sentence.

To accompany each sentence, a word list comprising five unrelated words was constructed. The lure word was always presented as the third word in the list. There were four different versions of the word list: semantic lure, rhyme lure, onset lure, and control. In the semantic lure condition, a word that was semantically similar to the target word in the sentence was the third word in the list. These were selected from the *Dictionary of English Synonyms and Antonyms (1986)*. In the rhyme lure condition, a word that shared the same phonemic ending as the target word was the third word in the list. In the onset lure condition, a word that shared the same phonemic beginning as the target word was the third word in the list. In the control condition, a noun that was neither semantically nor phonologically related to the target word was used in place of the lure word. Following each word list, the participant was presented with a probe word and had to identify whether it had occurred in the preceding word list. For half the sentences, the probe word was one of the words from the word list, but never one of the lure words. For the remaining sentences, the probe word was a new word that was not repeated in any of the lists in the study. After identifying whether the probe word was in the word list, participants then had to recall the sentence.

In the sentence "*Bill was excited, because after a long wait, he finally saw the CAKE for the first time*", CAKE was the target word. The list comprised the following words: *bowl*, *seed*, [lure/control word], *gown*, and *pea.* In the semantic lure condition, the lure was PIE, the rhyme lure was LAKE, the onset lure was CAVE, and the word in the control condition was MAN. In order to control for a phonemic similarity effect (see Fallon et al., 1999; Nimmo & Roodenrys, 2004), the amount of phonemic overlap between the target word and the rhyme and onset lures was equivalent. Apart from the lure words, the word lists were identical across conditions. None of the words included in the list, lure or otherwise, occurred more than once over the course of the experiment. Materials are provided in the Appendix.

Pre-test

Procedure. In order to select sentences in which the lures and target word would be equally plausible in the context of the sentence, each participant was presented with only the sentences. Neither the word lists nor the probe words were presented in the pre-test condition. One group ($n = 10$) heard the sentences as they would appear in the experimental condition with the target word (e.g., *Bill was excited, because after a long wait, he finally saw the CAKE for the first time*), another group ($n = 10$) heard the sentences with the semantic lure replacing the target word (e.g., *Bill was excited, because after a long wait, he finally saw the PIE for the first time*), a third group ($n = 10$) heard the sentences with the rhyme lure replacing the target word (e.g., *Bill was excited, because after a long wait, he finally saw the LAKE for the first time*), and a final group ($n = 10$) heard the sentences with the onset lure replacing the target word (e.g., *Bill was excited, because after a long wait, he finally saw the CAVE for the first time*). All 51 sentences were presented auditorily by a female speaker. Participants were asked to rate the plausibility and naturalness of each sentence on a scale of 1 to 5 (1 = implausible; 5 = plausible).

Results. The mean plausibility ratings for sentences with the target word, semantic, rhyme, and onset lures were calculated. The first step was to eliminate sentences that were rated low on the plausibility scale (ratings < 2 standard deviations from the mean rating). Next, independent t-tests were conducted between the pairs of plausibility ratings of the sentences with lures replacing the target word (e.g., with the semantic vs rhyme lure; semantic vs onset lure; and rhyme vs onset lure). In instances where there was a significant difference between items, sentences with low plausibility ratings were discarded.

The mean ratings for the remaining 25 sentences rated as highly plausible are shown in Table 1. The range and average of the plausibility ratings are similar across conditions. Paired sample t-tests confirmed no difference in the plausibility ratings between all pairs of ratings (alpha level adjusted to .008 for multiple comparisons): target and semantic, $t(24) = 1.74$, $p = .10$; target and rhyme, $t(24) < 1$; target and onset, $t(24) < 1$; semantic and rhyme, $t(24) = 2.30$, $p = .03$; semantic and onset, $t(24) = 2.24$, $p = .03$; and rhyme and onset, $t(24) < 1$.

As a further check for plausibility, the difference in ratings was calculated between all rating pairs. For example, the difference between ratings of the original sentence (with the target word) and sentences with the semantic lure, the rhyme lure, and the onset lure was calculated (see Table 1). The data indicate very small differences in the pairs of ratings. A repeated measures ANOVA on all the rating differences confirmed no difference between them, $F(5, 120) = 2.10$, $p = .13$.

The experiment

Procedure. Participants were individually tested and randomly assigned to one of four conditions: control ($n = 20$), semantic lure ($n = 20$), rhyme lure ($n = 20$), and onset lure ($n = 20$). Based on the item analysis of the plausibility ratings in the pre-test, 25 sentences were selected in which the semantic, rhyme, and onset lures were all highly and equally plausible substitutions for the target word in the context of the sentence. For the control condition, an unrelated word was

TABLE 1
Descriptive statistics of ratings of sentences in the pre-test condition

	Minimum	*Maximum*	*Mean*	*Standard Deviation*
Sentences with target word	2.70	4.70	3.84	.48
Sentences with onset lure	2.75	4.83	3.78	.50
Sentences with rhyme lure	3.00	5.00	3.79	.49
Sentences with semantic lure	3.10	5.00	4.02	.54
Difference between ratings				
Sentences with target versus onset lure	−1.20	.75	.06	.49
Sentences with target versus rhyme lure	−1.20	1.00	.06	.59
Sentences with target versus semantic lure	−1.20	.90	−.18	.52
Sentences with semantic versus onset lures	−.93	.85	.22	.52
Sentences with semantic versus rhyme lures	−.80	1.20	.22	.49
Sentences with rhyme versus onset lures	−1.13	1.15	.01	.59

included as the third word in the list in place of the lure. Apart from this substitution, the word lists were identical in the control and lure conditions.

All sentences, word lists, and probe words were read aloud with natural prosody by a female speaker. The audio files were recorded using a minidisk player and then digitised and edited on the GoldWave program (2004). The digitised recordings of sentences, word lists, and probes were presented using Microsoft PowerPoint while the individual faced a 21 cm by 28 cm ($8'' \times 11''$) screen of a laptop computer. Each sentence was presented auditorily followed by one of the four versions of word lists (*control*, *semantic*, *rhyme*, and *onset*). All participants were presented with the same set of 25 sentences, but depending on the assigned condition they heard different versions of the word lists. The word list consisting of five words was presented 500 milliseconds (ms) after the sentence, at a rate of 250 ms per word. A probe word was presented 250 ms after the end of the word list. Participants in all conditions were presented with the same set of probe words and had to decide whether the probe word was part of the word list by answering ''yes'' or ''no'' as quickly as possible. As soon as they responded, a beep was played. This was to cue the participants to recall the sentence aloud as accurately as possible. No feedback was given.

Performance was recorded as follows. First, the accuracy of recall was scored by calculating the percentage of correctly recalled words per sentence, excluding the target word. Next, the percentage of lure intrusions for the target word was calculated. Only words that replaced the target words in the sentence were counted as an intrusion. For the lure conditions (semantic, rhyme, and onset), we recorded if the participant recalled the sentence with the lure word in place of the target word. In the control condition, we recorded if the participants recalled the sentence with the control word in place of the target word. Finally, the accuracy of responses to the probe word (i.e., *yes* or *no*) was recorded.

Results

An item analysis of the 25 sentence–list combinations indicated that there was a significant difference in the amount of intrusions across conditions for one item (item 7). As a result, this item was excluded from the subsequent analyses.

Fewer words in the control condition were recalled correctly compared to the lure conditions, as shown in Table 2. A one-way ANOVA confirmed there was a significant difference in accuracy across the conditions, $F(3,\ 79) = 5.44$, $p = .002$. A post-hoc Scheffé's test established that there was a significant difference in accuracy only between the control condition and all lure conditions ($p < .05$): control and semantic; control and rhyme; and control and onset. There was no significant difference in accuracy between the lure conditions: rhyme and semantic; rhyme and onset; and semantic and onset. Also shown in Table 2 is the percentage of correctly recalled words for auditorily presented sentences in Potter and Lombardi (1990), and Rummer and Engelkamp (2001, 2003 delayed condition). The percentage of accuracy in the lure conditions in the present study is in line with these findings.

With respect to the probe judgements, there was a 92% accuracy rate in identifying whether a probe word occurred in the word list, suggesting that participants were attending to this information. Table 2 also summarises the percentage of lure intrusions for the target word across lure conditions. The mean number of lure intrusions in

TABLE 2
Percentage of correctly recalled words and percentage of intrusions as a function of lure condition

	Accuracy				*Intrusions*			
Condition	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*
Control	57	92	70.72	13.83	0	4	0.80	1.64
Semantic lure	55	97	82.47	11.19	0	20	5.20	5.04
Rhyme lure	63	94	83.02	9.64	0	8	2.00	2.43
Onset lure	65	92	82.77	7.37	0	8	4.20	3.04
Potter & Lombardi (1990)*	–	–	91	–	–	–	53	–
Rummer & Engelkamp (2001), Exp 1*	–	–	65	–	–	–	24	–
Rummer & Engelkamp (2001), Exp 2*	–	–	79	–	–	–	42	–

*Delayed condition, i.e., sentence then word list presentation, as in the present study.

the present study was lower than in previous studies as no contextual cues were provided in these sentences (see below for further discussion). The percentage of rhyme intrusions was lowest, while there were more semantic and onset intrusions. A one-way ANOVA confirmed that there was a significant effect of lure condition (*control*, *semantic*, *rhyme*, and *onset*) on the percentage of intrusions made, $F(3, 79) = 7.47$, $p < .001$. A post-hoc Scheffé's test established that there was a significant difference in intrusions between all of the following conditions ($p < .05$): control and semantic; control and rhyme; control and onset; rhyme and semantic; and rhyme and onset. There was no significant difference between the following two conditions: semantic and onset.

In order to assess the magnitude of the effect between lure conditions, effect size indices between conditions were calculated. The benefit of using this measure of standardised effect size is that unlike significance tests, these indices are independent of sample size. The effect size indices were calculated using the following formula: the difference between the means, $M_1 - M_2$, divided by the pooled standard deviation (see Cohen, 1988). The formula was: $d = M_1 - M_2 / \delta_{pooled}$, where the formula for $\delta_{pooled} = \delta[(\delta_1^2 + \delta_\delta^2)/2]$ (see Rosnow & Rosenthal, 1996). The effect size indices between the control condition and all three lure conditions were very high: control and semantic ($d = 1.37$); control and rhyme ($d = 0.93$); and control and onset ($d = 1.69$). Between the lure conditions, effect size indices were large in both the semantic and rhyme conditions and between the onset and rhyme conditions ($d = 0.81$ and $d = 0.80$, respectively). The effect size index was small between the semantic and onset conditions ($d < 0.25$).

Discussion

The data indicate that there were significantly more lure intrusions compared to the control condition. Analyses of effect size were consistent with the finding that semantic, rhyme, and onset lures exerted a moderate amount of influence on sentence recall above that evidenced in the control condition. The findings also indicate that there were more semantic and onset intrusions than rhyme intrusions in sentence recall, also confirmed by the effect size analyses. The finding that semantic information is crucial in sentence recall is important. While in other studies sentences were constructed to elicit the most semantically salient word in the sentential context, in the present study no contextual cues were provided. Rather, each of the lures had been judged as equally plausible substitutions for the target word in the sentence, eliminating any prior advantage for semantic information. Further, the persistence of semantic information in sentence recall despite verbal rather than visual presentation confirms that articulatory or phonological codes did not diminish the contribution of semantic knowledge.

However, it is possible that in equating lures for plausibility, contextual cues that would enhance intrusions were eliminated resulting in a lower percentage of intrusions in the present study (2% to 5%) compared to previous studies (24% to 53% in Potter & Lombardi, 1990; Rummer & Engelkamp, 2001). For example, in the sentence "*Bill was excited, because after a long wait, he finally saw the cake for the first time*", neither the target word "*cake*", nor the lure words (*lake*, *cave*, or *pie*) are immediately associated with the events in the sentence. In contrast, with materials used by Potter and Lombardi (1990), the sentences provided strong contextual cues, which would encourage greater intrusions. For example, in the sentence "*The knight rode around the palace searching for a place to enter*", there is a salient relationship between *knight*, *palace* (target word), and *castle* (lure word). This explanation for low intrusion rates is consistent with evidence that semantic coherence boosts recall (e.g., Baddeley & Levy, 1971; Poirier & Saint Aubin, 1995). Studies have also shown that recall is improved when participants were given cues about the overall theme of a passage, using a title or a picture (e.g., Bransford & Johnson, 1972; Dooling & Lachman, 1971). Additional factors not controlled for in the present study that could also account for the low intrusion rates include the imageability of the target and lure words (e.g., Bourassa & Besner, 1994), word frequency, and cloze frequency.

The data from the present study also indicate that phonological information is important in sentence recall. However, there is a degree of specificity regarding the type of phonological information, as there were significantly more onset intrusions, while the proportion of rhyme intrusions were similar to those found in the control condition. One possible explanation is that the onset intrusions involved more phonemic overlap with the target word than the rhyme

lures. In the present study, the rhyme and onset lures were equated for phonemic overlap, and thus it seems unlikely that this would account for the findings.

While there is some evidence that the rhyme unit is more tightly bound in short-term memory and thus enjoys greater activation through repeated reinforcement (Treiman & Danis, 1988), it is likely that this benefit is diminished as a result of delayed sentence recall in the present study. This is consistent with the view that the acoustic trace is brief and only immediate recall benefits from this, whereas in delayed recall only the semantic effects are retained (e.g., Baddeley & Ecob, 1970; Sachs, 1967). According to the redintegration model (Saint-Aubin & Poirier, 1999; Stuart & Hulme, 2000), semantic cues are used to reconstruct decaying phonological traces in short-term memory. Because individuals will use any cues available to them in order to retrieve information, it is possible that when semantic cues are unavailable, individuals rely on onset information instead.

A viable account for the high proportion of onset intrusions can be found from research in sentence production errors. Researchers have suggested that in sentence production, both semantic and lexical information of target words are activated, resulting in word substitutions (see Vigliocco & Hartsuiker, 2002, for a review). Common word substitutions involve errors of both semantic (meaning) and form (lexical) substitution (e.g., Garrett, 1976, 1993). With lexical substitutions, it is the onset rather than the ending of the target and substitution words that are similar (e.g., "*I went to open the darn boors*"; instead of "*barn doors*"; see Dell, 1988). This suggests that the initial part of the word is critical during sentence production and may be more susceptible to phonological similarity effects than the end of words as in rhymes. The higher percentage of onset intrusions compared to rhyme intrusions in the present study reinforces Potter and Lombardi's (1990; also Lee & Williams, 1997) proposal that during sentence presentation, lexical information is also activated resulting in competition between entries during recall. This high lexical activation results in more onset lure intrusions than in rhyme ones.

How do the findings from the present study that both semantic and lexical information are critical in short-term sentence recall fit with the accounts of the Baddeley (2000) and Martin (e.g., Hanten & Martin, 2000; Martin et al., 1999) models? First, the finding that semantic lures produce significantly more intrusions than both the control and rhyme conditions fits well with the role of the episodic buffer in the Baddeley model. The episodic buffer is responsible for integrating information from temporary and long-term memory systems and has access to semantic and lexical knowledge stores. However, the findings also indicated that the onset lures produce significantly more intrusions than the rhyme lures. While there is evidence from word recall tasks that permanent knowledge stores from long-term memory such as lexicality support word recall (e.g., Hulme Maughan, & Brown, 1991; Roodenrys, Hulme, & Brown, 1993), the present study indicates that the phonological short-term memory stores are not as important in supporting sentence recall compared to word recall. This also suggests that phonological similarity in the form of rhyme units is not as highly activated as semantic and lexical information. Emerging evidence from developmental studies supports the view that sentence recall involves more cognitive resources than phonological short-term memory (e.g., Alloway & Gathercole, 2005b; Alloway et al., 2004; Rohl & Pratt, 1995). It appears then that the contribution of phonological short-term memory to sentence recall is restricted to the articulatory loop component of the phonological loop responsible for the word length effect (e.g., Engelkamp & Rummer, 2002; Rummer et al., 2003; Willis & Gathercole; 2001). It is possible that this component is responsible for rehearsal of information while the episodic buffer component integrates semantic and lexical information from long-term memory during sentence recall.

The Martin model, which draws on language-processing mechanisms perhaps provides a better account for the present data. First, the finding that both semantic and lexical information play a role in sentence recall is consistent with the idea that both these representations are activated before phonological information. Second, the finding that rhyme units are not critical in sentence recall corresponds with a separate phonological buffer in the Martin model (see Martin, Shelton, & Yaffee, 1994) and is consistent with psycholinguistic interpretations of short-term memory that the rhyme unit is stable and thus will not impair recall or produce intrusions (e.g., Hartley & Houghton, 1996).

In summary, the present study extends previous research to establish the robustness of

semantic information in sentence recall even under conditions where there are no salient contextual cues. A new finding emerging from this study is that words that share similar onset cues as the target cause significantly more intrusions than rhyming words. This suggests that both semantic and lexical information are activated during sentence presentation and a comprehensive model of sentence recall needs to account not only for the role of semantic information, but also for lexical effects in the form of onset lure intrusions.

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APPENDIX

Sentence (Words in italics are the target words in the sentence)	Word List								
	1	*2*	*Control word*	*Rhyme lure*	*Onset lure*	*Semantic lure*	*4*	*5*	*Probe*
1. The day before yesterday, John noticed the *mat* in the corner of the living room.	Goat	Nail	Cane	Cat	Map	Rug	Fork	Zoo	Nail
2. Bill was excited, because after a long wait, he finally saw the *cake* for the first time.	Bowl	Seed	Man	Lake	Cave	Pie	Gown	Pea	Screw
3. Tom was angry when his little brother took away the *rock* he had carefully hidden.	Fig	Pin	Coat	Sock	Rope	Stone	Bag	Grape	Bag
4. The old man loved waking up at sunrise and going with his old *cap* out into the woods.	Tab	Bell	Toad	Map	Cat	Hat	Lawn	Stork	Tab
5. Josie thought it was very strange that she kept seeing the same *pan* in different shops.	Rose	Log	Cave	Man	Pad	Pot	Dog	Fight	Nut
6. Joe knew he drank too much when he kept seeing a *road* appearing suddenly next to his pint.	Hen	Pill	Grub	Toad	Roll	Street	Boot	Tin	Boot
7. Simon would usually give Betty a little *shrub* whenever she stopped by his house to say hello.	Key	Pig	Lake	Grub	Shrug	Bush	Moth	Hoe	Pig
8. Joe was going to quit when he finally found the *lamp* he had spent days looking for.	Shirt	Plant	Roll	Ramp	Land	Light	Chart	Egg	Chart
9. Bev wished she knew a bit more about the history of the use of the *horse* during her grandparents' era.	Gin	Bib	Rope	Morse	Horn	Pony	Broom	Scarf	Skirt
10. Tim was nervous and hoped his *wig* would help him to impress Mary at the party.	Dew	Worm	Pie	Jig	Wit	Hair	Top	Weed	Fish
11. Finally, the public was allowed to see the *seat*, which had been a carefully guarded secret.	Bird	Neck	Ramp	Wheat	Seal	Chair	Tree	Graph	Neck
12. Grandmother had promised Janey that she could see the *plane* that was always kept in the barn.	Wax	Soup	Bush	Crane	Plate	Jet	Bike	Tap	Hole
13. Cate loved staring at the colourful *bits* in the corner shop next to the bakery.	Pool	Clip	Light	Mits	Bins	Pieces	Son	Sand	Cot
14. Jillian was disappointed to see that her *boot* was wet from the rain last night.	Pub	Tux	Street	Flute	Book	Shoe	Hand	Glove	Pub
15. Steve had to sell the *house* to anyone who wanted it because it was just time to get rid of it.	Bath	Cart	Horn	Mouse	Hound	Flat	Phone	Knock	Rake
16. The boss wanted to keep the *wall* looking new, just like it was on the first day.	Pouch	Count	Jig	Ball	Ward	Fence	Car	Star	Pouch
17. Although his family thought it was odd, Donald loved *chips* more than anything else.	Toy	Male	Pony	Ships	Chicks	Fries	Pup	Train	Lane
18. Susie kept seeing funny coloured *clocks* in the shop windows on the high street.	Pond	Dart	Gate	Blocks	Cloths	Watches	Mug	Shin	Pond
19. A little piece of stone or something like a *foot* was found lying in the hotel lobby.	Sofa	Nose	Jet	Root	Food	Paw	Belt	Crib	Purse
20. The essay concerned the role of the *mark* in rural communities around the world.	Bed	Pork	Flute	Lark	Mart	Sign	Back	Salt	Quid
21. Sometime Kevin would imagine he was staring at a *game* in order to alleviate the boredom of lectures.	Tray	Rat	Chair	Dame	Gate	Match	Bead	Sheet	Tray
22. Only Nate was foolish enough to go near the *grave* despite the urban legend surrounding its history.	Silk	Bench	Food	Cave	Grail	Tomb	Bill	Knee	Mud
23. The toddlers loved playing with the brightly coloured *spoon* at the nursery next door.	Comb	Mint	Bin	Moon	Spool	Ladle	Truck	Ledge	Mint
24. Liam was interested in studying the use of the *braid* in primitive Eastern countries.	Child	Sink	Plate	Maid	Brain	Plait	Bone	Trim	Doll
25. The object that looked like a *lip* was the curator's favourite from his assortment of odd-shaped objects.	Cash	Park	Flat	Tip	Lid	Mouth	Duck	Steam	Duck