The Quarterly Journal of Experimental Psychology

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t716100704

Lexical and semantic influences on item and order memory in immediate serial recognition: Evidence from a novel task

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Online Publication Date: 01 May 2006
To cite this Article: Jefferies, Elizabeth, Frankish, Clive and Ralph, Matthew A. Lambon (2006) 'Lexical and semantic influences on item and order memory in immediate serial recognition: Evidence from a novel task', The Quarterly Journal of Experimental Psychology, 59:5, 949 - 964
To link to this article: DOI: 10.1080/02724980543000141
URL: http://dx.doi.org/10.1080/02724980543000141

THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY
2006, 59 (5), 949–964

Psychology Press
Taylor & Francis Group

Lexical and semantic influences on item and order memory in immediate serial recognition: Evidence from a novel task

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Previous studies have reported that, in contrast to the effect on immediate serial recall, lexical/semantic factors have little effect on immediate serial recognition. This has been taken as evidence that linguistic knowledge contributes to verbal short-term memory in a redintegrative process at recall. Contrary to this view, we found that lexicality, frequency, and imageability all influenced matching span. The standard matching span task, requiring changes in item order to be detected, was less susceptible to lexical/semantic factors than was a novel task involving the detection of phoneme order and hence item identity changes. Therefore, in both immediate recognition and immediate serial recall, lexical/semantic knowledge makes a greater contribution to item identity than to item order memory. Task sensitivity, and not the absence of overt recall, may have underpinned previous failures to show effects of these variables in immediate recognition. We also compared matching span for pure and unpredictable mixed lists of words and nonwords. Lexicality had a larger impact on immediate recognition for pure than for mixed lists, in line with findings for immediate serial recall. List composition affected the detection of phoneme but not item order changes in matching span; similarly, in recall, mixed lists produce more frequent word phoneme migrations but not migrations of entire items. These results point to strong similarities between immediate serial recall and recognition. Lexical/semantic knowledge may contribute to phonological stability in both tasks.

This study examined the influence of lexical and semantic factors on matching span: a serial recognition task in which two successive lists of items are judged to be the same or different. Although it is clear that lexical/semantic factors make a major contribution to immediate serial recall

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The first author was supported in part by an ESRC studentship. The work was also supported by a grant from the NIMH (MH64445).

http://www.psypress.com/qjep
DOI:10.1080/02724980543000141

(e.g., Bourassa & Besner, 1994; Hulme, Maughan, & Brown, 1991; Hulme et al., 1997; Martin & Saffran, 1997; Poirier & Saint-Aubin, 1995; Walker & Hulme, 1999), several previous studies have failed to find effects of lexical/semantic factors in matching span. Gathercole, Pickering, Hall, and Peaker (2001) found that the effect of lexicality was markedly reduced (but still significant, especially for longer lists) in serial recognition compared with serial recall. In a similar vein, Thorn and colleagues (Thorn & Gathercole, 1999; Thorn, Gathercole, & Frankish, 2002) found a first-language advantage for bilinguals in immediate serial recall (ISR) but not in matching span. Walker and Hulme (1999) found no effects of concreteness in matching span performance, despite finding significant effects of this variable in ISR. Finally, Knott, Patterson, and Hodges (2000) found equivalent matching span performance for relatively well-known and poorly comprehended words in a patient with semantic dementia, despite finding a recall advantage for the better known words.

It has been argued on the basis of these findings that lexical/semantic effects in verbal short-term memory (STM) arise during a redintegrative process at recall. This view postulates a rapidly decaying phonological store, which is unaffected by lexical and semantic factors, together with a later process of redintegration (Baddeley, Gathercole, & Papagno, 1998; Hulme et al., 1991; Hulme et al., 1997; Schweickert, 1993). It is proposed that during recall, incomplete phonological traces are compared with separate long-term representations of the sounds of familiar words in order to reinstate the correct phonology of words. Although this reconstructive process was originally proposed to be underpinned by phonological–lexical representations (Hulme et al., 1991), the model might account for semantic effects in ISR by assuming that semantic activation contributes to the selection of lexical candidates for reconstruction (Poirier & Saint-Aubin, 1995). In line with this perspective, several computational models of ISR suggest (or if extended, would suggest) that lexical-level representations restore the appropriate phonological activation for individual words at an output stage, after order and partial item information have been recovered (Brown, Preece, & Hulme, 2000; Burgess & Hitch, 1999; Henson, 1998; Page & Norris, 1998). Proponents of the redintegration theory have suggested that lexical/semantic effects may be lessened or eliminated in matching span if this task largely bypasses the redintegration process at recall (e.g., Gathercole et al., 2001).

An alternative theoretical perspective suggests that verbal STM is temporary activation of long-term phonological and semantic representations within the language system (e.g., MacDonald & Christiansen, 2002; Martin & Saffran, 1997; Patterson, Graham, & Hodges, 1994). Interactivity between semantic and phonological nodes might help to overcome phonological decay (Martin & Saffran, 1997). In addition, word meaning might contribute to phonological coherence in STM (Patterson et al.'s 1994, semantic binding hypothesis). Patterson et al. noted that patients with semantic dementia make frequent phoneme migration errors when recalling lists of poorly comprehended words. In errors of this type, phonemes from one list item recombine with those from another item, altering word identity: for example, "pen, rug, mint"→"pen, mug, rint". Normal participants also make more of these errors for nonwords than for words (Jefferies, Frankish, & Lambon Ralph, 2004; Treiman & Danis, 1988). These findings suggest that semantic representations might help to constrain the sequence of phonemes in STM: Phonemes belonging to a familiar word are bound more tightly together. This theoretical standpoint anticipates parallel effects of lexical/semantic variables in recall and recognition.

Although the failure to find lexical/semantic effects in recognition has been interpreted as suggesting that these effects occur at a late stage by proponents of the redintegration account, an alternative possibility is that the matching span task was not sensitive to the impact of lexical/semantic factors. Critically, in every study, the task involved detecting transpositions in the order of items (e.g., ABCD became ACBD). In contrast, lexical/semantic factors appear to contribute to memory for item identity but not item order (Gathercole et al., 2001; Hulme et al., 1997; Poirier & Saint-Aubin, 1995, 1996; Saint-Aubin & Poirier, 1999, 2000; Walker & Hulme, 1999). Previous studies, therefore, may have failed to observe an effect of lexical/semantic variables in matching span for two distinct reasons: (a) because—as argued by these previous studies—the matching span task bypassed a redintegration process operating specifically at recall or (b) because the task was minimally sensitive to lexical/semantic effects as it did not require the maintenance of item information in STM. It is important to disambiguate this issue especially given that evidence from event-related brain potential (ERP) studies appears to contradict the conclusions drawn from matching span studies. Span tasks involving words and nonwords are associated with different patterns of ERP activity not only during recall but also in item presentation and retention phases. This suggests that stable lexical representations play a role throughout ISR tasks (Ruchkin et al., 1999).

In order to explore this possibility, a novel matching span task was devised, which tapped the ability to detect changes in phoneme order that altered item identity. Participants were presented with a list of items like "bag, rock, sun, hall", followed by a second list like "bag, *s*ock, *r*un, hall", in which a pair of phonemes had been exchanged between two items. The influence of lexical and semantic variables in this task was compared with the effect of these factors in a traditional matching span task, in which item order was changed (e.g., "bag, rock, sun, hall"→"bag, sun, rock, hall"). If lexical/semantic factors make a particular contribution to phonological coherence, as proposed by Patterson et al. (1994), these variables may impact on the recognition of phoneme order changes that affect item identity more strongly than item order changes. In pilot work, we examined the ability of three patients with semantic dementia to perform these two matching span tasks for words that were still relatively well understood and more semantically degraded, according to performance on naming, verbal definition, and synonym judgement tests (Jefferies, 2004). The patients' semantic impairments particularly affected their detection of phoneme order changes, in line with the view that semantic memory makes a contribution to phonological coherence in both immediate recall and recognition.

In the current study, we examined the impact of lexicality, frequency, and imageability on the ability of normal participants to detect (a) changes in item order and (b) changes in phoneme order that altered item identity (Experiment 1). We also compared matching span for pure and unpredictable mixed lists of words and nonwords (Experiment 2). The mixed lists contained words and nonwords in variable serial positions. This manipulation has a profound effect on the phonological stability of words in ISR. Healthy participants make more frequent phoneme migrations for words in mixed lists, mimicking the pattern observed for semantic dementia patients (Jefferies et al., 2004). If lexical/semantic knowledge contributes to phonological coherence in both immediate recall and recognition, the use of mixed as opposed to pure lists might disrupt the detection of phoneme more than item order changes because of the sensitivity of this task to a loss of item coherence.

EXPERIMENT 1: MATCHING SPAN FOR PURE LISTS OF WORDS AND NONWORDS

Method

Participants

The 48 participants were a mixture of undergraduates who took part for course credit and paid volunteers. They were aged between 18 and 45 years, spoke English as a first language and had normal hearing. They were tested individually or in groups of two or three.

Design and materials

Two 5-item lists were presented auditorily, and participants decided whether the lists had been identical or different. The lists could differ in one of two ways. First, the order of items, but not the items themselves, could vary. Second, the order of the phonemes could be altered, changing the identity of the items. These two types of change (item order vs. phoneme order) were made on the same lists and were compared as a between-subjects factor.

Each list contained five words or five nonwords. All of the stimuli had a consonant–vowel–consonant (CVC) structure. The nonwords were constructed from the words by recombining the initial consonants, vowels, and final consonants to form new items. Phoneme order changes did not affect the lexical status of the list items. Phoneme exchanges between two words resulted in two new words being produced ("rock, sun" to "sock, run"), and exchanges between two nonwords produced two new nonwords ("leb, hidge" to "heb, lidge"). The word lists also varied word frequency and imageability. Four groups of words were selected by crossing these two variables. The words in each list were taken from a single frequency and imageability group. Estimates of written word frequency and imageability were taken from the Celex database (Baayen, Piepenbrock, & van Rijn, 1993) and the MRC psycholinguistic database (Coltheart, 1981). Phoneme order changes resulted in new words of a similar frequency and imageability whenever possible. The stimuli are provided in Appendix A.

Each participant was tested on 80 lists, divided equally between words and nonwords, which were presented in separate blocks. The order of the blocks was counterbalanced. Within each block, the order of trials was rerandomized for each participant. There were 10 lists in each of the frequency by imageability conditions and equal numbers of change and no-change trials in each condition. There were two versions of the experiment. In the first version, changes occurred on one set of lists (A) and not on a second set of lists (B). In the second version, the B lists changed, and the A lists did not. Half the participants were tested on each version. Lists were assembled so that vowels were not repeated within a list. Although it was not possible to eliminate all repetitions of consonants, these were kept to a minimum (fewer than three repetitions per list). Items were not repeated over the course of the experiment.

Procedure

The items were recorded individually in a flat intonation by a female speaker and were digitized using a computer. Sound-editing software (Cool Edit, Syntrillium) was used to position the items in the lists so that they occurred at a rate of one item per second, with a silent interval of two seconds between the two lists to be compared. Presentation of the lists was controlled using SuperLab software (Cedrus). A red exclamation mark appeared on the computer screen just prior to the start of each trial and remained until the lists had finished playing. It was then replaced by a blue question mark that prompted participants to indicate whether the lists had been the same or different. They pressed "S" on the keyboard if they had detected no change and "D" to indicate that the lists had been different. The computer recorded their responses. Participants were given four practice trials at the start of each block of words/nonwords. Feedback was given on the practice trials but not during the remainder of the experiment. The items were presented over headphones.

Results

Table 1 shows accuracy for change and no-change lists in each condition. There were significant within-subjects main effects of lexicality, $F(1, 46) = 50.47$, $p < .0001$, frequency, $F(1, 46) = 12.09$, $p < .01$, and imageability, $F(1, 46) = 6.04$, $p < .05$, and a significant between-subjects main effect of change type (i.e., phoneme or item order changes). Participants were better at detecting changes in item than phoneme order, $F(1, 46) = 5.04$, $p < .05$. This difference may have resulted from the fact that in the former case, three phonemes, including a vowel, were repositioned in the list. In contrast, the phoneme order change

Table 1. *Matching span for pure lists of words and nonwords (Experiment 1)*

		Phoneme order changes				*Item order changes*			
		Word–word		*Nonword–nonword*		*Word–word*		*Nonword–nonword*	
Word type	*List type*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Overall	Same	86.9	10.3	70.4	16.4	88.1	10.8	80.4	14.5
	Different	83.8	18.0	70.8	18.5	88.3	11.3	80.8	16.0
	M	85.4		70.6		88.2		80.6	
High frequency, high imageability	Same	90.8	13.2			92.5	12.9		
	Different	88.3	18.6			96.7	7.6		
	M	89.6				94.6			
High frequency, low imageability	Same	90.8	13.2			88.3	11.7		
	Different	83.3	25.5			86.7	21.0		
	M	87.1				87.5			
Low frequency, high imageability	Same	85.0	13.5			87.5	16.5		
	Different	84.2	17.7			81.7	20.4		
	M	84.6				84.6			
Low frequency, low imageability	Same	80.8	20.8			84.2	22.1		
	Different	79.2	22.4			88.3	14.3		
	M	80.0				86.3			
High frequency	*M*	88.4				91.1			
Low frequency	*M*	82.3				85.5			
High imageability	*M*	87.1				87.9			
Low imageability	*M*	83.6				86.9			

Note: Figures denote % trials correct. 50% = chance level.

task involved the transposition of a single consonant.

There was a lexicality by change type interaction, $F(1, 46) = 5.10$, $p < .05$ (see left half of Figure 1). Bonferroni t tests indicated that accuracy was higher for words than for nonwords in both versions of the task: item order change detection, $t(23) = 3.16$, $p < .01$; phoneme order change detection, $t(23) = 7.29$, $p < .0001$, although the size of the lexicality effect was larger for the phoneme order change task. The traditional matching span task, requiring changes in item order to be detected, was therefore less sensitive to the effects of lexicality than our novel task involving the detection of phoneme order and hence item identity changes.

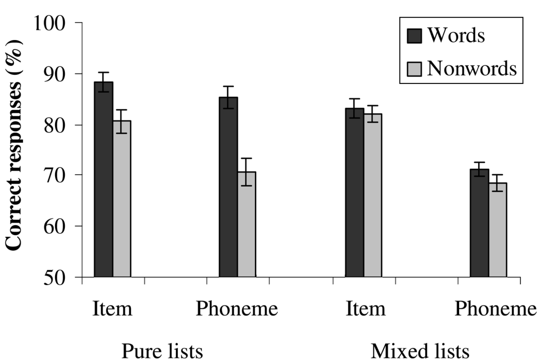

Figure 1. *Summary of findings for normal participants comparing item/phoneme order changes for pure/mixed lists (Experiments 1 and 2). Error bars show standard error of the mean. 50% = chance level.*

There was no significant interaction between either frequency or imageability and change type, $F(1, 46) < 1$. Lexicality is arguably a more potent variable than either frequency or imageability in verbal STM tasks and typically produces larger behavioural effects. There was a three-way interaction for frequency, imageability, and change type, $F(1, 46) = 4.54$, $p < .05$. The change type by imageability interaction approached significance for low-frequency words, $F(1, 46) = 3.03$, $p = .09$, but not for high-frequency words, $F(1, 46) = 1.62$, *ns.* Therefore imageability may have impinged on the recognition of phoneme changes more than item order changes for low-frequency words only.

In a by-items analysis, the main effects of change type, $F(1, 78) = 33.17$, $p < .0001$, lexicality, $F(1, 78) = 49.75$, $p < .0001$, and frequency, $F(1, 36) = 10.86$, $p < .01$, remained significant, and the effect of imageability approached significance, $F(1, 36) = 3.12$, $p = .09$. As before, the lexicality by change type interaction was significant, $F(1, 78) = 9.97$, $p < .01$, indicating that the item order change task was less sensitive than the phoneme order change task to the impact of lexicality. The three-way interaction among frequency, imageability, and change type approached significance, $F(1, 36) = 3.64$, $p = .06$.

Discussion

This experiment demonstrates that lexical and semantic variables—namely, lexicality, frequency, and imageability—significantly influence matching span, even though this task does not involve overt recall. We found that the standard matching span task, which entails the identification of changes in item order, was relatively insensitive to the effects of lexicality. Larger lexicality effects were obtained in a novel matching span task that involved the detection of phoneme order/item identity changes. This patterns well with research showing that lexical/semantic factors influence item identity but not item order errors (Gathercole et al., 2001; Hulme et al., 1997; Poirier & Saint-Aubin, 1995, 1996; Saint-Aubin & Poirier, 1999, 2000; Walker & Hulme, 1999): This is apparently true for recognition as well as recall. Previous studies may have observed little effect of lexical/semantic factors on matching span because they employed tasks that primarily tapped memory for item order. These results call into question the suggestion that matching span shows little influence of lexical/semantic factors because the task bypasses a redintegrative process during recall (e.g., Gathercole et al., 2001).

EXPERIMENT 2: MATCHING SPAN FOR MIXED LISTS OF WORDS AND NONWORDS

This experiment contrasted matching span for unpredictable mixed lists and pure lists of words and nonwords. When healthy participants recall lists containing a variable arrangement of words and nonwords, they show frequent word phoneme migrations similar to those made by semantic dementia patients, suggesting that the phonological stability of words is reduced in mixed relative to pure lists (Jefferies et al., 2004). In matching span, mixing words with nonwords should specifically impair the detection of phoneme order but not item order changes if the phoneme order change task is sensitive to a loss of phonological coherence. This hypothesis is supported by the observation that semantic dementia patients are poor at detecting changes in matching span tasks that mirror the errors they make in ISR. They are impaired at detecting changes in phoneme order and make frequent phoneme migration errors in recall; in contrast, they are less impaired at detecting changes in item order and do not show an elevated number of order errors in recall (see Jefferies, 2004; Jefferies, Jones, Bateman, & Lambon Ralph, 2004, for details). We also predicted smaller effects of lexical/semantic variables in matching span for mixed than for pure lists, as this has previously been observed for ISR (Hulme, Stuart, Brown, & Morin, 2003; Jefferies et al., 2004).

Method

Participants

The participants were 72 undergraduates, aged between 18 and 23 years, who spoke English as a first language and had normal hearing. They were tested individually or in pairs and took part for course credit.

Design and materials

The design was similar to that employed in the previous experiment. Change type (phoneme vs. item order) was varied across subjects using the same lists; however each list contained a mixture of two words and three nonwords in unpredictable serial positions. Exchanges could occur between two words, two nonwords, or a word and a nonword, giving rise to three levels of lexicality. Phoneme order changes did not affect the lexical status of the items. Lexicality, frequency, and imageability were varied within subjects. We manipulated frequency/imageability even for mixed lists that involved exchanges between two nonwords, as these factors influence nonword recall in mixed lists and might conceivably affect matching span for nonwords as well (Jefferies et al., 2004).

The serial position of the words and nonwords was varied across the lists to prevent participants from anticipating the lexical status of items in advance.[1] The experiment included five arrangements that maximized the degree to which the words and nonwords were mixed: wnwnn, wnnwn, nwnwn, nwnnw, and nnwnw (where "w" stands for word and "n" for nonword). The changes were made between nonadjacent items in Serial Positions 1 and 3, 1 and 4, 2 and 4, 2 and 5, and 3 and 5. There were equal numbers of changes at each of these serial positions for each condition.

The same pairs of words/nonwords exchanged phonemes/serial positions in Experiments 1 and 2. Experiment 1 contained a subset of the items used in Experiment 2 in a different arrangement. There were 40 additional trials in Experiment 2, which involved exchanges between a word and a nonword (total = 120 lists). There were 10 lists in each of the frequency by imageability by lexicality conditions ($2 \times 2 \times 3$ conditions), with equal numbers of change and no-change trials in each condition. As in Experiment 1, half the participants received each list as a change/no-change trial. Lists were assembled so that vowels were not repeated within a list. Consonants were never repeated in the same syllabic position within a list. Items were not repeated over the course of the experiment. The stimuli are provided in Appendix B.

Procedure

The participants were told in advance that the lists contained a mixture of words and nonwords. There were six practice trials, on which feedback was given. No feedback was given on the experimental trials. The computer controlled list presentation and recorded participants' responses. Other aspects of the method were as described for the previous experiment.

Results

Table 2 shows the number of same and different lists that were correctly recognized as a function of lexicality, word frequency, imageability, and change type (whether item or phoneme order was changed). An analysis of variance was performed on the number of correct trials in each condition to examine the influence of these factors. There were significant main effects of lexicality, $F(2, 140) = 3.30$, $p < .05$, and word frequency, $F(1, 70) = 9.04$, $p < .01$, but not imageability, $F(1, 70) < 1$. Participants showed better recognition of lists containing high- than low-frequency words and were better at detecting

[1] Other experiments have utilized alternating lists of words and nonwords (e.g., wnwnwn; Hulme et al., 2003). It is not clear whether these predictable lists reduce phonological stability for words to the same extent as unpredictable lists (Jefferies et al., 2004). The current experiment aimed to examine the impact of reduced phonological stability on the detection of phoneme and item order changes; consequently, mixed lists with an unpredictable structure were used.

Table 2. *Matching span for mixed lists of words and nonwords (Experiment 2)*

		Phoneme order changes							*Item order changes*						
		Word–word		*Word–nonword*		*Nonword–nonword*		*Mean*	*Word–word*		*Word–nonword*		*Nonword–nonword*		*Mean*
Word type	*List type*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*
High frequency,	Same	70.0	25.5	65.0	23.6	74.4	23.7		81.7	21.0	77.8	19.0	83.3	18.8	
high imageability	Different	78.9	23.4	71.1	22.6	67.2	28.7		87.2	19.2	87.2	15.2	85.0	18.1	
	M	74.5		68.1		70.8		71.1	84.5		82.5		84.2		83.7
High frequency,	Same	66.7	22.4	75.6	24.0	71.1	21.1		83.9	23.3	81.1	16.5	80.6	18.8	
low imageability	Different	75.0	21.6	65.6	24.2	69.4	26.4		87.2	15.2	85.6	17.0	82.8	18.0	
	M	70.9		70.6		70.3		70.6	85.6		83.4		81.7		83.5
Low frequency,	Same	73.3	25.3	60.6	23.2	60.0	24.4		76.1	20.7	75.0	22.1	80.0	17.9	
high imageability	Different	73.3	19.7	66.7	23.9	69.4	26.8		84.4	16.6	82.2	20.2	88.3	14.6	
	M	73.3		63.7		64.7		67.2	80.3		78.6		84.2		81.0
Low frequency,	Same	65.0	26.3	67.2	24.4	65.0	22.6		83.3	16.2	82.2	14.9	71.7	22.6	
low imageability	Different	66.7	27.0	66.1	23.8	70.6	24.6		82.2	22.3	84.4	18.0	84.4	17.3	
	M	65.9		66.7		67.8		66.8	82.8		83.3		78.1		81.4
High frequency	*M*	72.7		69.4		70.6			85.1		83.0		83.0		
Low frequency	*M*	69.6		65.2		66.3			81.6		81.0		81.2		
High imageability	*M*	73.9		65.9		67.8			82.4		80.6		84.2		
Low imageability	*M*	68.4		68.7		69.1			84.2		83.4		79.9		
Mean		71.1		67.2		68.4			83.3		81.9		82.0		

Note: Figures denote % trials correct. 50%=chance level.

changes involving words than nonwords. There was a highly significant between-subjects effect of change type, $F(1, 70) = 55.36, p < .0001$, indicating that participants were better able to detect changes in item order than phoneme order.

There was a significant three-way interaction for imageability, lexicality, and change type, $F(2, 140) = 5.54, p < .01$. In the item order change data, participants showed no significant effects of lexicality for either high- or low-imageability words. In the phoneme order change data, participants were more accurate at detecting changes involving two words than they were with a word and a nonword for high-imageability lists, $t(35) = 4.66, p < .001$, but not for low-imageability lists, $t(35) < 1$. They showed no difference between changes involving two nonwords and a word and a nonword, for either high- or low-imageability lists, $t(35) < 1$. This interaction is evident in Table 2. Although the effect of lexicality was small in the data set as a whole (there was only a 1% difference in recognition accuracy for item order changes involving two words and two nonwords), it was rather larger for high imageability words in the phoneme order change condition (4–13%). The two-way interaction between imageability and lexicality contained within this three-way interaction also reached significance, $F(2, 140) = 3.55, p < .05$. None of the other interaction terms was significant.

An additional by-items analysis replicated many of these findings. Again, there were significant main effects of change type, $F(1, 108) = 239.94$, $p < .0001$, and word frequency, $F(1, 108) = 5.06$, $p < .05$, although the main effect of lexicality did not reach significance, $F(2, 108) = 1.28$, *ns*. There was no main effect of imageability, $F(1, 108) < 1$. As before, the three-way interaction for imageability, lexicality, and change type was significant, $F(2, 108) = 4.61, p < .05$, suggesting that imageability had a larger influence on the detection of word changes involving exchanges in phoneme order (and, consequently, changes in item identity) than on the detection of changes involving exchanges in item order. No other interactions reached or approached significance.

Mixed versus pure lists of words and nonwords

The two experiments above examined the ability of participants to detect identical phoneme/item order changes in different contexts (mixed vs. pure lists of words/nonwords). This section assesses the impact of list type (mixed vs. pure) on matching span, including only those trials that were presented in both experiments. A summary of the findings from the two experiments is shown in Figure 1.

There was a main effect of list type, $F(1, 116) = 8.55, p < .01$, indicating that accuracy was higher for the pure lists overall. The interaction between lexicality and list type was significant, $F(1, 116) = 24.96, p < .0001$, but there was no interaction between frequency/imageability and list type, $F(1, 116) < 1.1$, *ns*. Bonferroni tests revealed that there was a highly significant effect of lexicality for pure lists of words/nonwords, $t(47) = 6.81$, $p < .0001$, but not for mixed lists, $t(71) = 1.85$, *ns*. Therefore, lexicality effects in matching span were smaller for mixed than for pure lists, mirroring the findings obtained for ISR (Hulme et al., 2003; Jefferies et al., 2004).

In addition, the interaction between list type and change type reached significance for the word trials, $F(1, 116) = 6.39, p < .05$. Bonferroni tests indicated that word phoneme order changes were less likely to be correctly detected for mixed lists than for pure word lists, $t(58) = 5.97, p < .0001$. In contrast, the detection of item order changes did not differ for the mixed and pure lists, $t(58) = 1.79$, *ns*. These findings are consistent with the notion that mixing words with nonwords reduces the phonological coherence of words.

It is also interesting to note that when the data from the two experiments were combined, a significant interaction between imageability and change type emerged, even though this interaction did not reach significance for either of the experiments independently, $F(1, 116) = 4.24, p < .05$.

A by-items analysis revealed the same findings. There was a significant main effect of list type, $F(1, 78) = 36.68, p < .0001$, and also interactions between lexicality and list type, $F(1, 78) = 30.83$, $p < .0001$, and list type and change type for words, $F(1, 36) = 20.21, p < .0001$. The interaction between imageability and change type approached significance, $F(1, 36) = 3.24$, $p = .08$.

Discussion

This experiment examined matching span for unpredictable mixed lists of words and nonwords. In ISR, normal subjects make more frequent phoneme migration errors for words in mixed lists than for words in pure lists: This methodology is thought to reduce the stability of phonological representations for words in STM (see Jefferies et al., 2004). In the current study, matching span was poorer for mixed than for pure lists; this difference was larger for the phoneme than the item order change detection task. Therefore, participants struggled to detect changes in mixed lists that resembled the phoneme migration errors seen in mixed-list recall. The reduction in phonological coherence for mixed lists would have made it particularly difficult for participants to detect single phoneme transpositions.

Small but significant effects of frequency and lexicality were found in the experiment as a whole. In addition, the standard matching span task that entailed the identification of changes in item order was less sensitive to the effects of lexicality and imageability than was a task involving phoneme order change detection. Previous studies may have observed little effect of lexical/semantic factors on matching span because they employed tasks that primarily tapped memory for item order. As in Experiment 1, lexical/semantic factors made a greater contribution to memory for item identity than for item order. This is true of both immediate recognition and ISR (Gathercole et al., 2001; Hulme et al., 1997; Poirier & Saint-Aubin, 1995, 1996; Saint-Aubin & Poirier, 1999, 2000; Walker & Hulme, 1999). It seems likely that we observed a three-way interaction for lexicality, imageability, and change type because imageability had a stronger influence on the words than on the nonwords they were mixed with.

Lexicality had a greater impact on matching span for pure lists of words and nonwords. Participants were better able to detect changes to words that were presented alongside other words than they were to detect changes to words presented with nonwords. This pattern, which is argued to be inconsistent with the notion of *item-specific* redintegration (see Hulme et al., 2003), has also been observed in ISR (Jefferies et al., 2004), and its replication across tasks is informative. The impact of mixed versus pure lists on lexicality effects in recall has been variously attributed to (a) strategic reconstruction for pure lists predicated on the knowledge that every item is a real word, (b) influences of inter-item association on redintegration, which should be reduced for words in mixed lists (Hulme et al., 2003; Stuart & Hulme, 2000),[2] and (c) an effect of the phonological coherence of other list items on the stability and subsequent recall of a particular item (nonword phonemes that are not tightly bound together by semantics can recombine with the elements of neighbouring items, impairing word recall in mixed lists; Jefferies et al., 2004). The similarity between our matching span results and those reported for ISR is consistent with the last of these explanations. If nonwords have a detrimental effect on word recall in mixed lists because their phonemes are not tightly bound together, then parallel effects of list composition should occur for ISR and matching span.

GENERAL DISCUSSION

This study examined the influence of lexical and semantic factors on immediate recognition. Several previous studies have failed to find effects of lexical/semantic factors in matching span, despite their sizeable impact on immediate serial recall (Gathercole et al., 2001; Knott et al., 2000; Thorn & Gathercole, 1999; Thorn et al., 2002; Walker & Hulme, 1999). It has been argued on

[2] The extent to which interword associations are disrupted in mixed lists depends on the exact arrangement of words and nonwords in the lists. There were insufficient items in the current experiment to examine the impact of this variable.

the basis of these findings that lexical/semantic effects in verbal STM arise during a redintegrative process at recall. An alternative explanation, however, is that the traditional matching span task is minimally sensitive to lexical/semantic effects because it primarily taps memory for item order, whereas lexical–semantic knowledge largely affects memory for item identity. In this study, the traditional matching span task, which required changes in item order to be detected, was compared with a novel matching span task requiring changes in phoneme order (and consequently item identity) to be detected. The results, summarized below, suggest that lexical/semantic factors may affect matching span and ISR in strikingly similar ways and encourage a reinterpretation of the existing matching span literature.

Lexicality, frequency, and imageability were found to affect matching span performance. Moreover, the standard matching span task, requiring changes in item order to be detected, was relatively insensitive to lexical/semantic factors. The participants showed larger lexicality and imageability effects in a novel matching span task that involved changes in phoneme order/item identity. These findings are consistent with research showing that lexical/semantic factors reduce the frequency of item identity but not item order errors in ISR (Gathercole et al., 2001; Hulme et al., 1997; Poirier & Saint-Aubin, 1995, 1996; Saint-Aubin & Poirier, 1999, 2000; Walker & Hulme, 1999). In recall, lexical and semantic variables appear to make a major contribution to phonological coherence: semantia dementia patients make frequent phoneme migration errors for words that they no longer fully understand (Jefferies, Jones, Bateman, & Lambon Ralph, 2005; Knott, Patterson, & Hodges, 1997; Knott et al., 2000; Patterson et al., 1994), and healthy participants show effects of these variables on phoneme order/identity errors (Jefferies et al., 2004). Our findings indicate that in serial recognition as well as in ISR, lexical and semantic factors influence the phonological coherence of words and so primarily impact on memory for item identity/phoneme order as opposed to item order.

Several previous studies have cited the absence of lexical/semantic effects in matching span as support for the hypothesis that long-term linguistic knowledge comes into play during a redintegration process at recall (Gathercole et al., 2001; Knott et al., 2000; Thorn & Gathercole, 1999; Thorn et al., 2002; Walker & Hulme, 1999). Our findings are more consistent with the view that these effects occur throughout STM tasks. Earlier failures to find an influence of lexical/semantic factors on matching span might have resulted from the use of tasks that tapped memory for item order (and therefore lacked sensitivity to lexical/semantic variables), rather than the absence of overt recall, as argued by the authors.

Although linguistic knowledge had a stronger influence on the detection of phoneme order changes, lexical/semantic variables also influenced the detection of item order changes. Lexical/semantic factors may impact on item order memory because they help to constrain phoneme order: A perfect representation of phoneme order is sufficient to allow items to be recalled in the correct sequence. In addition, even though the traditional matching span task does not explicitly require participants to remember item information, they may still use item information to perform the test (see Neath, 1997, for a similar argument). It may not be possible to detect item order changes without some knowledge of the items themselves. Therefore, the traditional matching span task is unlikely to be a pure measure of order memory.

In summary, our findings point to strong similarities between immediate serial recall and recognition tasks. (a) We found that matching span was sensitive to the effects of lexicality, frequency, and imageability. Numerous studies (reviewed in the Introduction) show that these variables have a similar effect on ISR. (b) In the matching span task, lexical/semantic factors exerted a stronger influence on memory for item identity/phoneme order than on memory for item order. A similar conclusion for ISR tasks is based on the differential effect of lexical/semantic factors on item/order errors. (c) We demonstrated comparable effects of presenting mixed versus pure lists of words and nonwords in matching span and ISR. Mixed lists are associated with smaller lexicality effects and difficulty maintaining phoneme order/item identity in both tasks.

In our view, this pattern of results is highly consistent with a model of verbal STM in which recall and recognition draw on the same underlying processes. The semantic binding theory (Patterson et al., 1994) envisages that lexical/semantic factors contribute to phonological coherence during encoding and retention as well as recall and so does not predict qualitative differences between ISR and matching span. This notion emerges naturally from the perspective that there are no specific STM stores: Instead, verbal STM is viewed as ongoing activation in the language system (see also MacDonald & Christiansen, 2002; Martin & Saffran, 1997). The semantic binding theory specifically proposes that lexical/semantic factors help to coalesce the phonemes of a single item together—preventing elements of one item from recombining with those of another in ISR and, by extension, facilitating the detection of phoneme exchanges in matching span. This hypothesis can accommodate the effects of list composition (i.e., pure vs. mixed lists) on recognition/recall because the phonological coherence of each item (which is dependent on the strength of its semantic representation) affects the likelihood that its phonemes will migrate, impinging on the recall of neighbouring items. Lexical/semantic effects are smaller in mixed than in pure lists in both recognition and recall possibly because the presence of words reduces the opportunity for nonword phonemes to migrate, whereas nonword phonemes recombine with the elements of words, damaging their coherence. The semantic binding perspective also predicts that list composition will primarily affect the detection/production of changes in phoneme order/item identity rather than item order, as this factor is thought to affect the phonological stability of list items.

Several of these findings (the impact of lexical/semantic factors on phonological coherence, the effects of list composition, and the similarities between recall and recognition) fit poorly with the notion of late-stage item-specific redintegration (as proposed by, for example, Hulme et al., 1997). However, with modification, the redintegration perspective might be able to accommodate at least some of our findings. List composition effects are inconsistent with the view that each item is reconstructed independently. However, a recent version of the redintegration hypothesis proposes that interitem associations affect the availability of representations for reconstruction (Hulme et al., 2003). If so, the composition of lists will, by definition, affect ISR. This might account for some of the differences that we observed between unpredictable mixed and pure lists of words and nonwords in both immediate recall and recognition, although it is not clear that this account can capture all of the data (see Jefferies et al., 2004). In addition, matching span may draw on some recall processes. One suggestion consistent with the redintegration account is that, in matching span, the phonological trace of the first list is reconstructed as the second list is being presented, allowing the two lists to be compared. Another possibility is that participants encode and retain both semantic and phonological information as they listen to the lists: Word meaning could then be used to reject some changes altering item identity. By this view, semantic memory makes an important contribution to matching span but does not play a role in phonological binding. Although these mechanisms could contribute to matching span performance, they do not appear to provide a complete account of the finding that, in both recall and recognition, the lexical/semantic characteristics of one list item can affect memory for phoneme order across the other list items (see Jefferies et al., 2004). More importantly, articles promoting redintegration theory have not made it clear that lexical/semantic effects should be possible in matching span (see Gathercole et al., 2001). We have demonstrated that lexical–semantic and list composition effects occur not only in immediate serial recall but also in immediate recognition, prompting a reinterpretation of previous null results. We propose that this is because word meaning makes a critical contribution to phonological stability/encoding in verbal STM tasks.

Original manuscript received 29 September 2004
Accepted revision received 23 February 2005
PrEview proof published online 24 August 2005

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APPENDIX A

Pure lists of words and nonwords used in Experiment 1

Words				
High frequency, high imageability				
phone	head	**bag**	wall	youth
light	rain	dog	**bed**	walk
foot	**well**	mouth	**board**	gun
wine	**book**	teeth	red	**court**
food	night	**shop**	town	**hell**
male	horse	**seat**	room	wife
rock	house	girl	**sun**	feet
road	**ball**	face	**team**	heart
home	**fish**	neck	king	**white**
farm	men	**hill**	love	**wood**
High frequency, low imageability				
lack	safe	**bit**	warm	voice
need	half	shape	**fine**	long
form	**deal**	mass	**rate**	type
main	**side**	keep	loss	**role**
lord	wrong	**week**	miss	**size**
look	nice	**turn**	force	move
make	lead	course	**while**	job
feel	**term**	base	**wide**	thought
mean	**sight**	call	thick	**hope**
piece	might	**name**	work	**god**
Low frequency, high imageability				
dive	foam	**hen**	lark	shawl
fork	dove	hedge	**cart**	lace
fog	**goat**	sword	**cage**	barn
coin	**hoof**	shed	pill	**ram**
cane	loot	**hose**	web	**pearl**
leaf	harp	**thorn**	rug	toad
noose	hog	limb	**jet**	duck
mouse	**pole**	keg	**hawk**	rat
morgue	**rib**	dime	weed	**nail**
bud	moth	**wig**	fan	**pet**
Low frequency, low imageability				
kale	hush	**dip**	wrath	lease
bang	thud	wharf	**foul**	sop
hide	**psalm**	rush	**keel**	whiff

(*Continued overleaf*)

Appendix A (*Continued*)

knoll	**mash**	curse	beat	**loan**
foal	whack	**bard**	vice	**lodge**
ton	dirge	**peel**	myth	bet
toil	loon	gem	**rack**	thong
toll	**zone**	jade	**sap**	rhyme
fail	**lean**	sod	verb	**whoop**
dell	nip	**sage**	hurt	**win**

Nonwords

sart	**theed**	kun	**joll**	bime
wid	**rowl**	lem	sonn	**deesh**
waith	deeve	**nUl**	rike	**tass**
lorp	feek	**mang**	turl	pid
werje	shate	norl	**feem**	tonn
hame	**thunn**	nike	**weff**	rorl
lunn	**piff**	kaig	nurl	**hoosh**
thoat	fime	**wess**	nid	**parl**
ket	mon	**feeg**	guyle	haid
fith	hoak	naze	**jaowed**	lon
shol	**poat**	lorm	**feeth**	werb
munn	**fooss**	lart	raybe	**wal**
rorf	soam	**haig**	fis	**bine**
widge	shart	**sime**	bol	fees
murl	hon	sade	**rorb**	poam
dus	**fee-the**	pell	**hik**	lurt
pem	**rark**	gort	woole	**feege**
harl	soat	**jock**	lorg	**beeve**
libe	kem	**toag**	sorl	fuv
hooss	sem	rorg	**tiv**	fol
nork	**hong**	dibe	**waipe**	fidge
lipe	**reet**	waig	mork	**gell**
miv	vert	**sal**	rorss	**dife**
waithe	nurt	**sike**	junn	moass
werp	boose	hime	**kaot**	nade
paim	**thoad**	torss	**weck**	deethe
vid	**foosh**	woe-ss	tal	**maig**
tid	waan	**rorm**	kooss	**beye-ve**
kaiz	tiss	**fung**	hool	shet
raim	ful	hes	**thert**	boip
woab	**thit**	serl	**jopp**	kang
rUss	**dutt**	gack	joth	**lep**
dort	kade	**leb**	poil	**hidge**
dush	yat	**torg**	kide	rooss
nang	hort	loak	**wem**	fide
keet	**toess**	lann	**bozz**	hile
heg	**nide**	bul	weess	**jowth**
nate	pode	**buth**	deek	**serm**
mout	heek	**fipe**	lorss	woal
waat	roosh	lork	**deef**	noil

Items that exchange: **bold type**. Celex code: U-ʊ.

APPENDIX B

Stimuli used in Experiment 2

High-frequency, high-imageability words

Changes between two words

phone	dus	**bag**	hame	sherl
light	hal	feep	**bed**	sim
lunn	**well**	jong	**board**	hoas
shan	**book**	deeth	mel	**court**
buv	nid	**shop**	sart	**hell**
male	dipe	**seat**	kess	bVsh
rock	beej	gid	**sun**	lurm
fuv	**ball**	raig	**team**	shid
pake	**fish**	rUl	korp	**white**
bup	deeve	**hill**	nart	**wood**

Changes between a word and a nonword

gun	kal	DOG	**bife**	torm
sign	fum	**lorg**	CASE	hoat
feese	**wife**	bon	HEAD	**noyl**
lorf	**nose**	mep	**shol**	FOOT
HORSE	bipe	**men**	naze	**poil**
home	fot	MOUTH	**kun**	werg
town	hoaf	**dup**	WALL	vate
holl	**fat**	mun	LEG	**koess**
lort	**youth**	kidge	**tQn**	RED
ROOM	mon	**note**	gade	**biff**

Changes between two nonwords

RAIN	**theed**	LOVE	**joll**	bime
WALK	**rowl**	lem	HEART	**deesh**
waythe	MINE	**nUl**	FEET	**tass**
lorp	NIGHT	**mang**	turl	FARM
werje	shate	HALL	**feem**	NECK
FACE	**thunn**	TEETH	**weff**	rorl
FALL	**liff**	kaig	WINE	**hoosh**
thoat	FOOD	**wess**	KING	**parl**
ket	ROAD	**feeg**	guyle	HOUSE
fith	hoak	GIRL	**jaowed**	PAGE

High-frequency, low-imageability words

Changes between two words

lack	poam	**bit**	feeve	woole
need	woam	pooss	**fine**	rarl
lork	**deal**	fis	**rate**	mide
kerm	**side**	mot	beeth	**role**
haid	Tan	**week**	fol	**size**
look	j6d	**turn**	shart	waim
make	fiD	leet	**while**	pon
soat	**term**	yun	**wide**	ral
taid	**sight**	werve	mek	**hope**
rorg	b6th	**name**	lat	**god**

(*Continued overleaf*)

Appendix B (*Continued*)

Changes between a word and a nonword

thing	deeje	MIGHT	**soam**	fup
thick	fUsh	**pell**	CAUSE	beess
geed	**long**	thail	FORM	**sighje**
nurl	**keep**	sade	**dudge**	WRONG
PIECE	vade	**half**	meg	**lorm**
lead	sorm	PART	**raybe**	futh
short	pid	**taig**	LOSS	han
roass	**till**	fom	LORD	**kem**
lon	**base**	feek	**pem**	RIGHT
FORCE	geel	**shape**	roak	**tith**

Changes between two nonwords

CALL	**poat**	MISS	**feeth**	werb
TALK	**fooss**	lart	JOB	**wal**
rorf	MASS	**haig**	FEEL	**bine**
widge	MAIN	**sime**	bol	COURSE
murl	hon	SAFE	**rorb**	NICE
WARM	**feethe**	SOUTH	**hik**	lurt
VOICE	**rark**	gort	MOVE	**feege**
harl	TYPE	**jock**	RACE	**beeve**
libe	MEAN	**toag**	sorl	FIRM
hooss	sem	THOUGHT	**tiv**	WORK

Low-frequency, high-imageability words

Changes between two words

dive	kooss	**hen**	vert	mork
fork	moess	vid	**cart**	paim
fack	**goat**	thorl	**cage**	hes
mort	**hoof**	kile	boip	**ram**
kime	lek	**hose**	jid	**pearl**
leaf	hoad	**thorn**	thaze	kell
noose	rol	dibe	**jet**	yaid
shet	**pole**	tiss	**hawk**	wan
p2g	**rib**	het	torss	**nail**
s2l	larp	**wig**	thaid	**pet**

Changes between a word and a nonword

bat	hime	COIN	**nork**	roaf
foam	rorss	**nurt**	HEDGE	tal
shoat	**cane**	vel	SWORD	**lipe**
lowss	**bud**	jaowt	**mip**	WRECK
MOUSE	thate	**limb**	feesh	**joff**
keg	shaowed	LOOT	**porm**	fon
dime	bod	**laig**	FAN	hUl
nade	**pill**	fUss	HARP	**moag**
f2the	**rat**	sork	**von**	DOVE
WHIP	fush	**geese**	yan	**nake**

Changes between two nonwords

BEAN	**hong**	SHAWL	**waipe**	fidge
MOTH	**reet**	waig	PINE	**gell**

Appendix B (*Continued*)

miv	FOG	**sal**	BARN	**dife**
waithe	BOOT	**sike**	junn	TOAD
werp	boose	SHED	**kaot**	RUG
LACE	**thoad**	TOMB	**weck**	deethe
LARK	**foosh**	woess	SURF	**maig**
tid	WEB	**rorm**	HOG	**buyve**
kaiz	PIT	**fung**	hool	LAMB
raim	fVl	WEED	**thert**	MORGUE

Low-frequency, low-imageability words

Changes between two words

kale	yat	**dip**	sorf	beesh
bang	loat	deek	**foul**	wid
woab	**psalm**	torp	**keel**	rife
keet	**mash**	worss	jomm	**loan**
searle	weess	**bard**	gann	**lodge**
ton	loak	**peel**	hurm	wowed
toil	paiz	fide	**rack**	bQth
kade	**zone**	liss	**sap**	fime
pode	**lean**	h6t	sayze	**whoop**
heek	norl	**sage**	fub	**win**

Changes between a word and a nonword

bid	wote	LATHE	**mal**	sonn
tuck	joth	**sarl**	COPE	bUs
lan	**fill**	rUs	HURT	**nike**
voad	**curse**	meb	**tordge**	THONG
BEAT	hurk	**save**	foad	**nool**
loon	murt	FAIL	**baoge**	sark
lease	boosh	**seff**	GERM	rart
rooss	**dell**	fiv	HIDE	**sorp**
heg	**jade**	bot	**rork**	ZEAL
SOD	wole	**bet**	fip	**d2the**

Changes between two nonwords

thit	DIRGE	**jopp**	kang	**thit**
dutt	gack	MYTH	**lep**	dutt
RHYME	**leb**	TOLL	**hidge**	RHYME
NIP	**torg**	kide	VERB	NIP
hort	RUSH	**wem**	VICE	hort
toess	WHACK	**bozz**	hile	**toess**
nide	bVl	WHARF	**jowt**	nide
JOIN	**bVth**	WHIFF	**serm**	JOIN
HUSH	**fipe**	lorss	WRATH	HUSH
roosh	SOP	**deef**	THUD	roosh

Items that exchange: **bold type;** words, unchanging: UPPER CASE; nonwords, unchanging: lower case. Celex code: V-ʌ, U-ʊ, Q-ɒ, 6-aʊ, T-e, U-ʊ, D-ð, U-ʊ, 2-aI, V-ʌ, U-ʊ, 2-aI, V-ʌ, 6-aʊ, Q-ɒ.