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A Day in the Life of a Spoken Word

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Abstract

Two experiments tracked the emergence of lexical competition effects for newly learnt spoken words (e.g., "cathedruke"). Experiment 1 compared form-only learning with learning in semantically rich sentence contexts. In both cases, although immediate explicit recognition of the novel words was good, lexical competition effects (e.g., "cathedruke-cathedral") emerged only after a delay of at least 24 hours. Experiment 2 evaluated the timecourse of learning in more detail and used embedding (rather than cohort) new competitors (e.g., "shadowks"). Again results showed no evidence of lexicalization immediately after exposure, but clear lexical competition effects after 24 hours. Furthermore, recognition and free recall improved over time. These results are interpreted in terms of a consolidation process that integrates words into the mental lexicon over a relatively protracted period of time.

1. Introduction

Our knowledge about what information is relevant for language acquisition has increased greatly in the last decade. Factors such as statistical properties of the input (Saffran, Aslin, & Newport, 1996) and current lexical knowledge (Dahan & Brent, 1999) have been shown to influence lexical development. However, less is known about exactly how new vocabulary items are integrated into one's mental lexicon, a process called "lexicalization". The main reason for this state of affairs is that studies on word acquisition have typically used only direct measures of learning, such as the performance in familiarity judgment or recollection tasks. Yet, such measures only tell us about the strength of the traces left by exposure, not whether a new lexical entry *per se* has been created.

A critical methodology for addressing the lexicalization issue looks at whether newly learnt words influence how the learner recognizes preexisting words. For models of spoken word recognition, a key feature of a lexical entry is its ability to be evoked when compatible with the input, and to compete with similar-sounding entities for identification (e.g., McClelland & Elman, 1986). Therefore, a strong test of whether a speech sequence has been lexicalized is whether it engages in lexical competition, and thereby affects the activity within the mental lexicon.

In a recent study (Gaskell & Dumay, 2003), we began to explore how and when newly learnt spoken words become involved in the lexical competition process, or in our terms, produce a "lexical footprint". Adults were familiarized with made-up words that overlapped strongly with existing words (such as "<u>cathedr</u>uke" for "<u>cathedr</u>al"), through repeated presentation in a phoneme-monitoring task. In one experiment, good explicit knowledge of the novel words was obtained after only one training session (i.e., 12 presentations of each item), whereas the inhibitory influence of these new competitors on the identification of existing words in a lexical decision task (LD) required three (successive) days of exposure to emerge.

In another experiment, we disentangled the roles of time and level of exposure in the lexicalization process, using a single training session at a high exposure rate (i.e., 36 presentations). We also swapped LD with a more implicit test of lexical activity, the pause detection task. Here, participants made speeded decisions as to whether a short silence was present towards the offset of the existing words (e.g., "cathedr_al"). As Mattys and Clark (2002) showed, pause detection latencies are positively correlated with the amount of lexical activity elicited by the portion of speech preceding the pause. They hypothesized that the activation of lexical candidates involves the use of processing resources that would otherwise be allocated to pause detection. Our experiment showed good explicit recognition of the novel items right after exposure. In contrast, an increase in lexical activity as indexed by longer pause detection latencies when a new competitor had been learnt was not immediately observed, but had emerged when re-tested a week later.

So, in contrast to phonological storage, lexicalization is apparently not instantaneous and in fact may require a substantial amount of time, possibly to allow the consolidation of episodic traces (cf. O'Reilly & Norman, 2002). Nonetheless, on the basis of the above findings, it is not possible to tell how long it takes after a sufficient level of exposure has been reached for a newly learnt word to be lexically operational.

Furthermore, in Gaskell and Dumay (2003) participants had to learn only the sound-form of the novel words in quite an artificial situation, i.e., phoneme monitoring. Therefore, whether these data give us a good picture of what happens in more normal circumstances when semantic and thematic information are usually available must be addressed. In particular, the delay observed in the emergence of lexical footprint could well result from the relatively impoverished conditions in which the novel words were acquired. Word learning, as measured by recognition and recall, is often improved when a meaning is available to attach to the novel phonological form (e.g., Rueckl & Olds, 1993; Whittlesea & Cantwell, 1987). On these grounds, linking the form of the novel words to some semantic representations during encoding may give rise to a faster lexicalization and, potentially, to a "deeper" lexical footprint.

Finally, so far the onset-matched competitors that have been used to test for the emergence of lexical competition were cohort competitors, i.e., novel and existing items that mismatch towards their offset. Therefore, we do not know whether these effects can be extended to a more general view of lexical competition encompassing all words that overlap to any degree (cf. McQueen, Norris, & Cutler, 1994). The following experiments address these issues.

2. Experiment 1

Experiment 1 examined whether providing some semantic information along with the form of the novel words during exposure would result in a deeper lexical footprint and/or the faster emergence of this effect. On two successive days of learning, novel words (e.g., "cathedruke" for "cathedral") were heard 12 times either in isolation, as carriers in a phoneme monitoring task, or in a sentential context during a semantic verification task. Here, they were associated with the name of a conceptual category (e.g., "vegetable"). The effect of exposure to these new cohort competitors on identification of the base words was evaluated immediately, 24 hours later (before the second exposure) and after a week, using a LD task. In addition, whether the novel words learnt under semantic exposure had acquired a meaning was tested in two ways. First, during the LD task, we also presented each novel word followed directly by their category name, and measured the extent to which the former could speed up responses to the latter (cf. Dagenbach, Horst, & Carr, 1990). Second, we looked at how much the novel words would elicit production of a word related to the meaning of the category name in a free association task.

2.1. Method

2.1.1. Participants. Thirty native British English speakers with no known auditory or language impairment were tested. They were students at the University of York (UK) or lived in the surrounding area, and were all paid for their participation.

2.1.2. Materials and Design. The key materials contained 12 bisyllabic and 24 trisyllabic item triplets (based on Gaskell & Dumay, 2003, Experiment 2). Each triplet included a base word, such as "cathedral", and two nonwords, such as "cathedruke" and "cathedruce". The nonwords diverged from the base word at the final vowel and from each other at the final consonant or consonant cluster. One nonword (e.g., "cathedruke") was presented as novel word, whereas the other one was used as alternative choice in a recognition test. Base words were monomorphemic nouns that ranged in frequency between 2 and 19 occurrences per million and had their uniqueness point (UP) located at or before the final vowel. Hence, if exposure led to lexicalization of the novel word, the latter was expected to become the main competitor of the base word, shifting its UP towards its offset.

For the semantic exposure phase, each novel word was assigned a meaning, based on a conceptual category unrelated to the base word (cf. Battig & Montague, 1969). For example, "cathedruke" was associated with "vegetable". Two sentences in which each novel word appeared were then constructed. One explicitly conveyed information about the category membership of the novel word, such as "*A cathedruke is a variety of vegetable*"; the other provided a more general semantic context, such as "*The cook served the boiled cathedruke with a steak and baked potatoes*".

The test items were divided into three groups, as were the participants. During exposure, a given group of participants heard 12 novel words in a phoneme monitoring task and 12 others in a semantic verification task, the items being assigned to a different exposure condition (phonological, semantic or unexposed) across the three alternative versions of the experiment. Participants were presented with all base words during the LD lexicalization test. Thus, for any participant, new competitors were potentially acquired for 2/3 of the existing words, and overall each item was equally represented at the three levels of the factor "exposure".

Base words, novel words, alternative nonwords, category names and sentences were produced in a soundproof booth by a male native speaker of British English, recorded onto CD, and stored as separate files using CoolEdit.

2.1.3. Procedure. On day 1, participants were exposed to the novel words through the phoneme monitoring and semantic verification tasks, with task order counterbalanced across participants. Next, they were tested for lexicalization effects in a LD task, followed by a two-alternative forced choice (2-AFC) recognition test which assessed explicit knowledge of the novel words, and, finally, a free association task. On day 2, participants performed the LD task, the 2-AFC recognition test and the free association task before a second exposure phase took place. On day 8, the procedure was the same as on day 2 except that there was no further exposure.

The phoneme monitoring component of the *exposure phase* involved 12 novel words and consisted of 12 blocks in which each novel word occurred once. A target phoneme was specified for each block, and in all 6 phonemes were used (/n/, /d/, /t/, /s/, /p/ and /m/). Participants had to make speeded decisions as to whether the target was present or absent in the word, by pressing one of two buttons. The semantic verification component used 12 other novel words, each presented 6 times by way of their "category membership" sentence, and 6 times by way of their "semantic context" sentence. On each trial of a given block, participants had to make a yes/no judgment about the meaning of the novel word. In all 6 questions were used, asking whether the novel word referred to something that was (1) man-made, (2) alive, (3) edible, (4) audible, (5) touchable, or (6) liked by the participant.

The *lexicalization test* required making timed LD to all the base words, the novel words and their associated category names intermixed with a large set of fillers (i.e., 64 words, 102 nonwords). The order of stimulus presentation was the same for each participant but varied every day. It was pseudorandomized such that each base word (e.g., "cathedral") occurred at least 20 trials before its related novel word (e.g., "cathedruke"), which was then immediately followed by the associated category name (e.g., "vegetable"). The proportion of semantically related pairs, i.e., a novel word followed by its category name, was 4.4%. Participants were instructed to press "yes" only to the existing real words, and had 3 s. from stimulus onset to respond. The inter-trial interval was 1 s. The LD latencies to the base words allowed us to estimate the amount of lexical competition induced by prior exposure to the novel words during the training phase. The LD latencies to the category names allowed an estimate of the extent to which these words were semantically associated with the immediately preceding novel word (which could act as a prime).

In the *2-AFC recognition test*, novel words and alternative nonwords were presented in pairs (e.g., "cathedruke-cathedruce"), and participants had to press a button to indicate the item they had to learn. Newly learnt word acoustic exemplars were not those presented at exposure.

Finally, in the *free association task*, only the novel words presented during the semantic exposure phase were played. After each item, participants had to write down the first word that came to mind. This gave us a second measure of how strongly the novel word was linked to the category name or its meaning.

2.2. Results and Discussion

Table 1. Top: Correct response rate in 2-AFC recognition. Bottom: Response probability in the free association task.

	Day		
	1	2	8
2-AFC recognition			
Phonological exposure	93.6	91.9	97.5
Semantic exposure	86.4	91.7	95.8
Free association			
Novel word meaning	.30	.31	.44
Base word	.38	.47	.38
Base word meaning	.08	.06	.06
Other	.24	.16	.11

Performance in the *2-AFC recognition test* was good, with a rate of correct responses of at least 90% on each session (see Table 1). Analyses of variance (ANOVAs) showed an effect of day ($F1(2,58) = 14.7$, $p < .01$; $F2(2,66) = 12.9$, $p < .01$), an effect of exposure, though marginally significant by participant ($F1(1,29) = 3.9$, $p < .06$; $F2(1,33) = 6.6$, $p < .05$), and a day x exposure interaction ($F1(2,58) = 5.1$, $p < .01$; $F2(2,66) = 5.6$, $p < .01$). As planned comparisons revealed, the performance was better on day 8 than on days 1 and 2 (ps < .01), which did not differ from each other. More interestingly, only on day 1 was the performance better for phonological than semantic exposure (ps < .01).

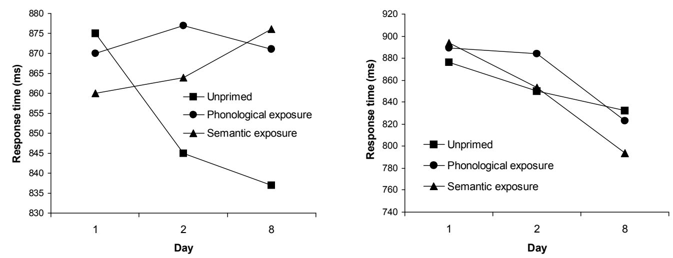

Figure 1. (Exp. 1) Left: Mean lexical decision latency to the base word. Right: Mean lexical decision latency to the category name.

In the *LD lexicalization test* (see Figure 1), latencies to the base words revealed an interaction between day and exposure ($F1(4,108) = 2.6$, $p < .05$; $F2(4,132) = 3.0$, $p < .05$). Here, the important thing was to assess the occurrence of reliable priming effects. Planned comparisons examined the difference between the unprimed condition and both the phonological and semantic conditions. No sign of delayed recognition caused by competition with the novel words was found right after exposure. However, 24 hours later, a clear inhibitory effect had emerged for the novel words trained phonologically ($F1(1,28) = 5.0$, $p < .05$; $F2(1,33) = 7.9$, $p < .01$), but still no significant effect was found in the semantic encoding condition. Finally, on day 8, both phonologically and semantically trained novel words induced inhibition of the base word recognition ($F1(1,28) = 4.1$, $p = .052$; $F2(1,33) = 9.3$, $p < .01$; $F1(1,28) = 6.8$, $p < .05$; $F2(1,33) = 7.4$, $p < .05$). Analyses of errors (2.8%) revealed no significant effect or interaction.

LD latencies to the *category names* also showed an interaction between day and exposure to the preceding novel word (i.e., untrained, phonologically trained vs. semantically trained), although marginally significant by participant ($F1(4,108) = 2.1$, $p = .081$; $F2(4,132) = 3.7$, $p < .01$). Planned comparisons revealed no effect of exposure on day 1. On day 2, an inhibitory effect was found unexpectedly for the phonological condition ($F1(1,28) = 4.3$, $p < .05$; $F2(1,33) = 8.3$, $p < .01$), whereas there no effect for the semantic condition. On day 8, the inhibitory effect in the phonological condition had disappeared, and a facilitatory effect only significant by item had emerged for the semantically trained novel words ($F1(1,28) = 2.3$, $p < .15$; $F2(1,33) = 6.8$, $p < .05$). Analyses of errors (2.2%) revealed no significant effect or interaction.

Responses in the *free association task* were classified using the taxonomy presented in Table 1. Base words and words related to the meaning of the novel words represented the majority of the responses (overall 76%). More interestingly, response probability showed an interaction between day and response type ($F1(8,232) = 5.3$, $p < .01$; $F2(8,264) = 14.7$, $p < .01$). From day 1 to day 2, the probability of producing the base word increased with no parallel reduction in that of producing the meaning of the novel word. By contrast, from day 2 to day 8, there was an increase in the probability of producing the meaning of the novel word, clearly to the detriment of the probability of producing the base word.

Taken together, these results suggest that exposure to a novel word in a meaningful semantic context does not result in faster or deeper lexicalization compared to simple exposure to its phonological form. On day 2, only the competitors learnt on the basis of just their sound-form were able to delay recognition of the existing words, and on day 8, the two conditions of exposure did not differ in terms their lexical footprint effects. Interestingly, the emergence of competition effects on day 8 for the novel words learnt through semantic exposure coincided with a significant change in the ability of these words to prime their related category name, both in the semantically primed LD and in the free association task.

3. Experiment 2

The finding of a lexical footprint effect in the form-only condition after only 24 hours and 12 exposures in Experiment 1 stands in contrast with the late emergence of this effect after three days of exposure under similar conditions in Gaskell and Dumay's (2003) Experiment 2. This new result suggests that lexicalization may take place during the first 24 hours following exposure. To gain further evidence that this really is the case, the present experiment examined more closely the timecourse of lexicalization for phonologically trained novel words using another paradigm than LD as lexicalization test: pause detection. Contrary to LD, this paradigm provides a measure of lexical activity without requiring participants to make any judgment about the lexical properties of the input. Examination of the lexical footprint effect induced by a single massed exposure phase was performed at three time points: immediately after exposure, 24 hours later and a week later. To test whether the lexical footprint would generalize to the level of competition for segmentation, embedding rather than cohort competitors (e.g., "shadowks") were used.

3.1. Method

3.1.1. Participants. Thirty-two native British English speakers with no known auditory or language impairment were tested. They were all students at the University of York (UK), and none had taken part in Experiment 1. They received course credits or were paid for their participation.

3.1.2. Materials and Design. The key materials consisted of 72 bisyllabic item triplets. Each included a base word ending in an unreduced vowel, such as "shadow", and two nonwords such as "shadowks" and "shadowkt", derived from the base word by adding a consonant cluster and which differed from each other in one of the final consonants. As in Experiment 1, one nonword (e.g., "shadowks") was presented as novel word, whereas the other one was used as alternative choice in a recognition test.

Base words were stress-initial morphologically simple nouns that ranged in frequency between 0 and 403 occurrences per million and had their UP located before or at the final vowel. Here, in contrast to Experiment 1 which used cohort competitors, the novel word, if lexicalized, would be the only longer (embedding) competitor of the base word. To have a better chance to index lexicalization of this longer word, base words were therefore not presented in isolation during the pause detection paradigm but in longer carriers, such as "shadowk" or "shadow_k", derived from the new competitor itself (e.g., "shadowks").

In addition, 12 other novel words along with their alternative nonwords were devised, such as "trogist" and "trogisk". They were used as fillers to increase the amount of materials to be learnt, and potentially enhance the sensitivity of the 2-AFC recognition test.

All speech materials were produced by the same speaker and acquired using the same procedure as for Experiment 1.

The test items were divided into four groups, as were the participants. In the lexicalization test (i.e., pause detection) half of the carriers contained a short silence (e.g., "shadow_k"), whereas the other half did not, and within each of these groups, half of the items had potentially a longer competitor as a result of exposure, and the other did not. Four versions of the experiment allowed each item to be equally represented in the four (exposure x pause occurrence) subcells of the design.

3.1.3. Procedure. On day 1 participants were exposed to the novel words through a phoneme monitoring task. Then, the immediate effect of exposure on lexical activity was assessed using the pause detection paradigm. Finally, explicit knowledge of the novel words was examined in a free recall task and a 2-AFC recognition test. The effect of exposure on lexical activity and explicit knowledge of the novel words were re-tested on two subsequent occasions: 24 hours after exposure, and one week later. On each occasion, the pause detection task was administered first, followed by the free recall task and the 2-AFC recognition test.

The *exposure phase* was similar to the phoneme monitoring component of Experiment 1. Here, the 36 test novel words and the 12 lexically unrelated fillers were involved. Each of them was presented 36 times over 12 blocks of trials. The 6 target phonemes were /n/, /d/, /k/, /l/, /t/ and /s/.

The *lexicalization test* used the pause detection task. On each trial, participants had to decide by pressing one of two buttons whether a short silence (of 200 ms) was present in any location within a bisyllabic spoken item. On the pause-present trials, base word carriers had the silence inserted just before the final consonant (e.g., "shadow_k"). Fillers were 144 bisyllabic words ending in a consonant or consonant cluster, half of which contained a pause. The pause was inserted just before or after the first or second vowel.

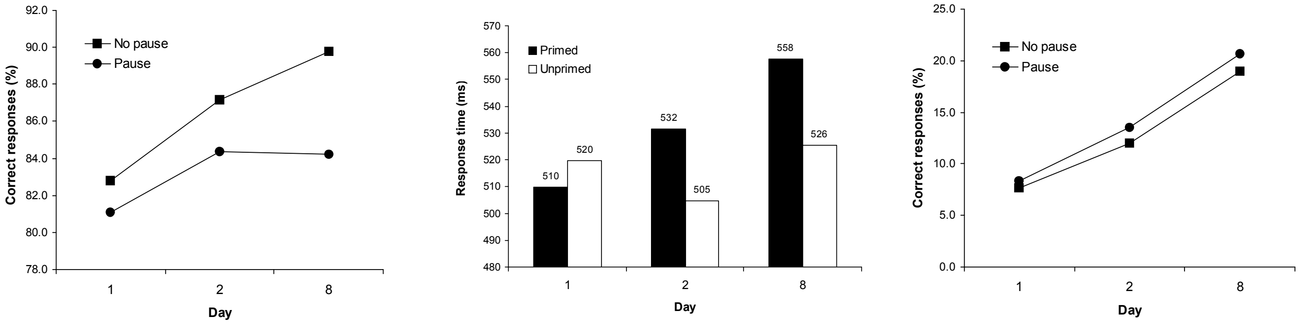

Figure 2. (Exp. 2) Left: Correct response rates in 2-AFC recognition. Middle: Mean pause detection latency (across pause-present and pause absent trials) as a function of day and exposure. Right: Correct response rates in free recall.

In the *free recall task*, participants had 3 min. to recall orally as many novel words as they could from the exposure phase. Finally, the *2-AFC recognition test*, similar to that of Experiment 1, involved all the 48 novel words presented during exposure, along with their alternative choice (e.g., "shadowks-shadowkt").

3.2. Results and Discussion

Performance in the *2-AFC recognition test* was good, with a rate of correct responses of at least 80% on each session (see Figure 2). ANOVAs taking into account day and whether the item had been disrupted by a pause during the lexicalization test revealed that the main effects were significant (day: $F1(2,56) = 6.1$, $p < .01$; $F2(2,136) = 6.2$, $p < .01$; pause: $F1(1,28) = 6.9$, $p < .05$; $F2(1,68) = 7.9$, $p < .01$), but did not interact with one another (*Fs* close to 1). As planned comparisons showed, performance increased from day 1 to day 2 (*p*s < .05), but not from day 2 to day 8.

In the (pause detection) *lexicalization test*, latencies revealed a clear-cut interaction between day and exposure ($F1(2,56) = 6.4$, $p < .01$; $F2(2,114) = 6.9$, $p < .01$). On day 1, the immediate effect of exposure to a novel competitor was to speed-up the pause detection performance, although this effect was only marginally significant by participant ($F1(1,28) = 4.0$, $p < .06$; $F2(1,57) = 1.9$, $p < .2$). In contrast, 24 hours after exposure as well as one week later, the performance on the carriers for which a longer competitor had been learnt was clearly inhibited ($F1(1,28) = 5.7$, $p < .05$; $F2(1,57) = 7.0$, $p = .01$; $F1(1,28) = 9.0$, $p < .01$; $F2(1,57) = 14.0$, $p < .01$). There was no effect of exposure or interaction involving exposure and day on errors (7.4%).

In the *free recall task*, an ANOVA with day and presence or absence of a pause during the lexicalization test only revealed a significant effect of day ($F1(2,56) = 27.8$, $p < .01$; $F2(2,136) = 64.5$, $p < .01$), with better performance on day 2 than on day 1 ($F1(1,28) = 18.7$, $p < .01$; $F2(1,68) = 21.7$, $p < .01$), and better performance on day 8 than on day 2 ($F1(1,28) = 21.3$, $p < .01$; $F2(1,68) = 51.1$, $p < .01$).

On the basis of these results, it thus seems that following a sufficient amount of exposure, lexicalization of the novel word occurs within the next 24 hours, but not immediately. Whereas, on day 1, pause detection was facilitated by prior exposure to a new longer competitor of the base word, on day 2 (as on day 8), there was clear evidence that the new competitor was now contributing to lexical activity. Interestingly, the performance in direct recognition and free recall gradually increased over time.

4. General Discussion

The two experiments reported above allow us to make substantial progress in understanding the full range of factors involved in lexicalization of novel words. Gaskell and Dumay (2003) showed that when words are learned on the basis of only their phonological form, there is a delay associated with their engagement in lexical competition. Experiment 1 looked at whether this delay was eliminated when a richer linguistic context was available during learning. We found no evidence of any earlier or deeper lexicalization using a richer learning environment; if anything, the meaning and sentential context available at encoding led to an increased delay in lexicalization. This result suggests that exposure to a phonological form is both necessary and sufficient for normal engagement in lexical competition, supporting models of language acquisition that have a similar focus on phonological form (e.g., Saffran, Aslin, & Newport, 1996).

Experiment 1 also examined another hallmark of lexical processing: semantic/associative priming. The results suggest that this aspect of lexicalization emerges hand-in-hand with engagement in lexical competition. As for the lexical footprint in the semantic condition, a significant priming effect was observed on day 8, but not at the two preceding test points. We should be careful in interpreting this effect, since the associate of the novel item was repeatedly presented during the exposure session. It is possible that this exposure induced a repetition priming effect instead of, or in addition to, the associative facilitation caused by the pairing of novel items and their associates in LD (e.g., "cathedruke-vegetable). Yet, this account would predict that priming should be just as apparent on days 1 and 2 (cf. Tenpenny, 1995), whereas no such effects were found. Thus, the data do seem to be best explained in terms of the emergence of a lexical link between the novel items and their associated superordinates. This link appears to rely on the establishment of a lexical entry capable of engaging in competition rather than simply a phonological trace.

Experiment 2 widened the domain of reference for our lexical footprint test. Previously we had employed standard "cohort" competitors, in which the novel and existing items mismatch towards the end of the word. In Experiment 2 the novel items had no segmental mismatch with the existing items, but instead they were embedding competitors (e.g., "shadowks"). This experiment marks the beginning of an extension of our research to lexical competition at the level of lexical segmentation. These items appeared to behave in a very similar way to standard cohort competitors, strengthening the general conceptualization of lexical competition as involving lexical items with any degree of overlap (cf. McQueen et al., 1994).

Experiment 2 had the further advantage of involving a larger set of stimuli with more sensitive measures of explicit recall and recognition performance. The explicit measures demonstrate that even in the absence of further exposure to the novel sequences, recall and recognition performance improves. One potential explanation of this finding is that the processes that operate to engage the novel representations in lexical competition also refine or focus the phonological representations. This interpretation has some support from developmental studies suggesting that well-established lexical representations are more clearly specified in terms of phonological form than newly learnt ones (Stager & Werker, 1997; Swingley & Aslin, 2000).

Perhaps the most conspicuous finding relates to the timecourse of lexicalization. In the phonological condition of Experiment 1, and more crucially in Experiment 2, we found a clear profile of lexical competition effects across the three testing occasions. Immediately after learning, there was no evidence that lexicalization had emerged, as defined by engagement in lexical competition. However, without further exposure, this lexical competition effect was observed 24 hours later, and was essentially unchanged by day 8. We can therefore narrow down the critical time period for emergence of lexical competition to somewhere between 1 and 24 hours after exposure. This suggests that under normal circumstances, lexicalization will not be hurried. This profile of learning fits in with the idea that engagement in lexical competition requires the new information to be interleaved with existing representation as is the case for distributed connectionist networks (O'Reilly & Norman, 2002). Our current research effort is focused on whether lexicalization is reliant on the kind of memory consolidation thought to occur during sleep (Walker, in press).

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