Effects of vocabulary acquisition on lexical competition in speech perception and production

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ABSTRACT

Three experiments examined the roles of time and exposure frequency in lexicalization of novel words. Participants learnt novel items (e.g., *cathedruke*) of varying frequency that overlapped with existing words (e.g., *cathedral*). The effect of learning on lexical competition was tested by measuring responses to the existing words. In lexical decision (Experiment 1), low frequency novel items facilitated responses to existing words immediately after exposure, but had no effect a week later, whereas high frequency items produced inhibition both immediately and a week later. The inhibitory effects indicated that the novel items had engaged in lexical competition. In single word shadowing (Experiment 2) and naming (Experiment 3), all effects were facilitatory, suggesting that the main impact in these cases was on speech production. We interpret these results in terms of the influence of vocabulary acquisition on the competition processes involved in speech perception and production.

1. INTRODUCTION

Vocabulary acquisition is often tested in terms of the direct effects of learning a word (e.g., is the word familiar, or what does it mean?). In models of spoken word recognition, a key feature of a lexical item is its engagement in lexical competition, whereby the recognition of a word is dependent on discrimination from phonologically similar words. Recently [1], we examined the involvement of newly learnt words in lexical competition (their "lexical footprint"). The research utilized spoken words with an early uniqueness point or *UP* (e.g., *cathedral*), matched with nonwords that diverged on or after the UP (e.g., *cathedruke*). Our assumption was that if the nonwords are treated as novel words and enter the mental lexicon, then these items should become strong competitors of the existing words, with behavioral consequences for recognition of the existing words.

Participants were familiarized with the novel phonological sequences through repeated exposure (12 per item) in a phoneme-monitoring task. This exposure led to good recognition of the novel sequences in a 2AFC test (e.g., *cathedruke* vs. *cathedruce*). In contrast, the inhibitory influence of these items on existing words only emerged after multiple sessions of exposure over the course of several days. Thus, lexical competition effects appear to be dissociable from simple recognition memory in the acquisition of a new word.

Crucially, these inhibitory effects were restricted to novel sequences that diverged from the existing words at offset (e.g., *cathedral-cathedruke*) rather than at onset (e.g., *cathedral-yothedral*), supporting models of spoken word recognition that incorporate a directional left-to-right matching process [2][3] rather than a more global one [4]. Furthermore, we replicated the lexicalization effect swapping lexical decision with a more implicit test of lexical activity, the pause detection task [5]. Here, participants were asked to detect the presence of a 200 ms pause inserted towards the end of the word (e.g., *cathedr_al*). In this final experiment, we tested the participants twice: once immediately after an extended exposure session (36 per item), and again a week later, with no intervening exposure session. This experiment showed no effect of lexicalization immediately after exposure, but robust effects a week later, suggesting that lexicalization may require a significant amount of time, possibly in order to allow consolidation of phonological memory [6].

In the present study, we examined in more detail the twin roles of time and frequency of exposure on the lexicalization process. The earlier research showed that 36 presentations of a stimulus led to lexicalization effects 3 or more days later, and demonstrated an important role of time in the development of a new lexical competitor. However, this left open the possibility that similar effects could emerge for less substantial exposure levels over a similar timescale, or that a greater exposure level would lead to swifter lexicalization effects. We tested both these possibilities in the current study.

A further goal was to look at the generality of the lexicalization effects that we had observed. Lexical neighbors delay recognition in speech perception, because they must be discriminated before the word can be identified. However, in speech production, there is some evidence for the opposite effect. Vitevitch [7] showed that words from dense phonological neighborhoods are named more quickly than words from sparse neighborhoods. This effect was attributed to the lexical retrieval process in speech production. Although Vitevitch's experiments involved only monosyllabic words, it seems plausible that similar effects might be found for longer words. Therefore, the lexicalization of a novel sequence such as *cathedruke* should have an inhibitory effect on the recognition of a neighbor such as *cathedral*, but might have a facilitatory

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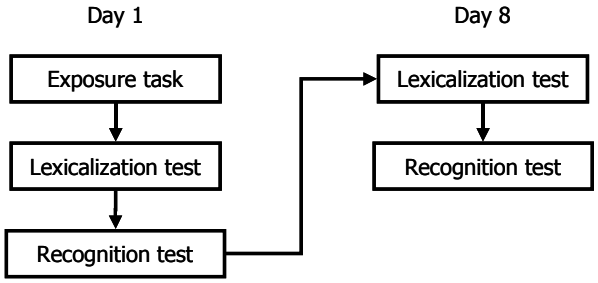

Figure 1. Illustration of test order in Experiments 1-3.

effect on the production of the same word. To compare effects of lexicalization on speech perception and production, we ran three experiments using the same materials, but varying the type of response required on presentation of the existing words (e.g., *cathedral*). Experiment 1 focused on the perceptual side, using lexical decision as our measure of word recognition performance. In Experiment 2, participants were required to shadow (repeat as quickly as possible) the target word, thus incorporating a combination of recognition and production components. In Experiment 3, the focus was purely on speech production; participants were asked to name the words as quickly as possible, given their printed form.

2. METHOD

Apart from the lexicalization test, the overall procedure was identical in the three experiments, and is illustrated in Figure 1. Participants took part in a phoneme monitoring task as a way of familiarizing themselves with the novel sequences (e.g., *cathedruke*). The effect of exposure on the response to neighboring existing words (e.g., *cathedral*) was then tested in the lexicalization test, which differed between experiments, and there was then an explicit recognition test, in which participants were required to pick out the familiar novel words from minimal pairs (e.g., *cathedruke*/*cathedral*). The participants returned a week later and were retested only on the lexicalization and recognition tests.

2.1 PARTICIPANTS

Ninety-six participants were tested, 32 in each experiment. All were adult native British English speakers with no known auditory or language impairments.

2.2 MATERIALS AND DESIGN

The materials contained 12 bisyllabic and 24 trisyllabic triplets of test items. Each triplet consisted of a base word (e.g., /kəθidrəl/ *cathedral*), a "novel word" nonword (e.g., /kəθidruk/ *cathedruke*) and a foil nonword (e.g., /kəθidrus/ *cathedruce*). The nonwords diverged from the base words at the final vowel and from each other at the final consonant or consonant cluster. Base words were monomorphemic and had a frequency of between 2 and 20 per million. The UP was located at or before the final vowel. Therefore, if exposure to the novel items generates a new lexical entry, the effect on the base word will be to shift its UP towards word offset.

Half of the novel items, the high frequency (HF) set, were presented 60 times in the exposure task, whereas the low frequency (LF) items were presented 12 times. The two sets were matched on frequency, UP location, number of phonemes, number of syllables, nature of the first phoneme (vowel, stop, fricative and liquid/nasal), acoustic duration, and (based on a pretest) lexical decision latency.

The test items were also divided into 2 lists and the participants were divided into two groups, such that each participant group was exposed to half the novel items in the phoneme monitoring test, and all the base words in the lexical decision test. This meant that for each participant competitors were acquired for half the base words, but across the two groups, each item was represented at each level of the "competitor acquisition" variable.

The phoneme monitoring (exposure) task involved 18 novel items (9 HF and 9 LF), and consisted of 12 blocks. Each block involved 1 presentation of the LF items and 5 presentations of the HF items. At the beginning of each block a target phoneme was displayed on the screen, and in all 6 different targets were used (/n/, /d/, /t/, /s/, /p/ and /m/) twice each. Participants were instructed to press one button if the target was present at any location in the word or press another if it was absent. The session lasted roughly 30 minutes.

In Experiment 1, the lexicalization test involved making timed lexical decisions to the base words, intermixed with a large set of filler items (64 words, 102 nonwords). Experiments 2 and 3 required a vocal response, and only made use of the word stimuli. In Experiment 2 participants were required to shadow (repeat) the words as quickly as possible, and in Experiment 3 they had to name the words, given their printed form. In both these experiments, the response onset was determined using a software voice key.

The forced choice recognition test involved the two nonwords derived from each of the base words. A second recording of each novel item used in the phoneme monitoring phase (e.g., *cathedruke*) was presented to participants along with its related foil nonword (e.g., *cathedruce*), and participants were instructed to press a button to indicate the familiar item.

2.3 RESULTS

Recognition rates in the explicit tests were good, with above 90% performance (chance = 50%) in all conditions (see Figure 2). Recognition tended to be better for the HF novel items, although this effect was only fully significant in Experiment 2. The effect of Day was not significant in any experiment (although Experiment 3 showed a marginal effect). Thus, the week's delay between testing periods did not appear to affect recognition memory for the novel items.

For the lexicalization tests (see Figure 3), the data for each experiment were analyzed using the variables day, frequency, and competitor acquisition. In Experiment 1 (lexical decision), there was an interaction between

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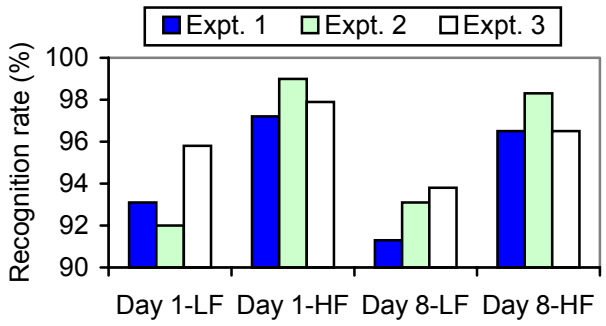

Figure 2: Explicit recognition rates across the three experiments.

frequency and competitor acquisition ($F_1[1,30] = 15.4$, $p < .01$; $F_2[1,32] = 8.8$, $p < .01$), implying that the high and low frequency novel sequences had different effects on the responses to the existing items. There was also an interaction between frequency, competitor acquisition and day ($F_1[1,30] = 5.3$, $p < .05$; $F_2[1,32] = 4.0$, $p = .055$). The effect of competitor acquisition for the HF words was stable across the two time points, whereas the immediate effect of competitor acquisition for LF words was very different from the effect a week later. Planned comparisons showed that on day 1 there was a significant facilitatory effect of the LF novel items, and a significant inhibitory effect of the HF sequences. The facilitation effect for the LF sequences was consistent with earlier results, which we interpreted as a medium-term priming effect rather than an effect of lexicalization. In line with this interpretation, the effect had disappeared a week later. On the other hand, the inhibitory effect for the HF items on Day 1 was compatible with their lexicalization, and remained a week later.

Experiments 2 and 3 showed quite different results. In Experiment 2, the acquisition of novel items had an overall facilitatory effect on the shadowing of the base words ($F_1[1,30] = 20.6$, $p < .01$; $F_2[1,32] = 11.0$, $p < .01$). The only other fully significant effect was of day ($F_1[1,30] = 20.9$, $p < .01$; $F_2[1,32] = 300.0$, $p < .01$), with faster responses overall for the second test session. There was a marginal interaction between frequency and competitor acquisition ($F_1[1,30] = 3.8$, $p = .059$; $F_2[1,32] = 2.9$, $p = .10$), which was suggestive of more facilitation for the LF novel items compared to the HF ones. Planned comparisons showed that the effect for the LF words was significant both immediately and a week later. In contrast, there was no significant effect of HF novel sequences at either point.

Experiment 3 (naming) showed similar effects. There was once again a facilitatory effect of competitor acquisition ($F_1[1,30] = 10.3$, $p < .01$; $F_2[1,32] = 13.3$, $p < .01$), and naming latencies were faster on the second test occasion than the first ($F_1[1,30] = 7.8$, $p < .01$; $F_2[1,32] = 36.9$, $p < .01$). The effect of novel word exposure showed a marginal interaction with day ($F_1[1,30] = 5.6$, $p < .05$; $F_2[1,32] = 3.1$, $p = .087$), with facilitatory effects somewhat stronger immediately after exposure than a week later. Planned comparisons showed that the facilitatory effect of competitor acquisition was significant for the HF condition on day 1, but not day 8, whereas the effect for LF sequences was marginal on day 1 (both p-values < .06) and day 8 (both p-values < .075).

3. DISCUSSION

The results for the Experiment 1, which looked only at the perceptual side of lexical competition, are clear. The LF novel items appear to fall below the frequency of exposure level for which lexicalization occurs (at least in the learning environment tested here). They show a medium term facilitation effect on the first testing occasion, and no evidence of lexical competition effects a week later. In contrast, the HF items appear to be lexicalized immediately. The exposure to these items immediately caused listeners to respond more slowly to neighboring items, presumably due to the presence of a new close cohort competitor. This inhibitory effect remained a week later.

Our previous study [1] emphasized the importance of time in the lexicalization of sequences with an exposure

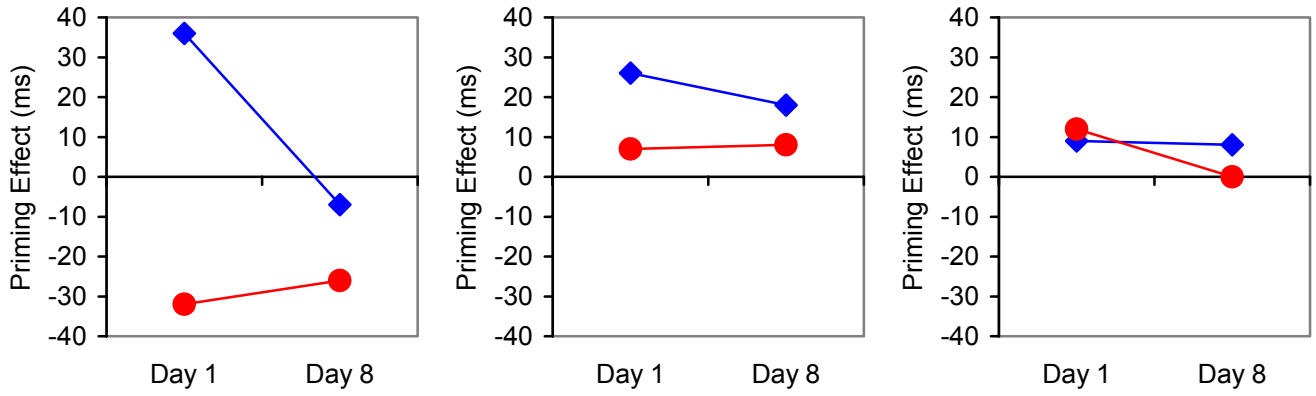

Figure 3: Effects of novel item learning on recognition of target words for lexical decision (left panel), shadowing (middle) and naming (right). The data are summarized in terms of priming effects, with positive values implying facilitation and negative values implying inhibition (◆ = low exposure frequency, ● = high exposure frequency).

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frequency half way between the levels tested here (36 exposures). These intermediate frequency items showed no instant lexicalization, but a clear effect a week later, despite the lack of any intervening exposure session. The current results add to this finding, demonstrating the critical nature of exposure frequency, and suggesting that the delay associated with lexicalization of medium frequency words can be overridden in the case of a more extreme level of exposure. We should add a note of caution here, since our earlier results were backed up using the pause detection task, which does not require a decision about the lexical properties of a stimulus. It would be valuable to carry out the same validation of the current data before drawing strong conclusions.

Turning to the shadowing data, here we could reasonably expect lexical competition effects to emerge in both production and perception. The effects we actually found were all facilitatory, suggesting that production effects were dominating. On Day 1, there is the possibility that medium term priming mechanisms were contributing to the effects, as we found in Experiment 1 for lexical decision, but this is not possible on Day 8. Here, the LF condition still showed a significant effect, suggesting that lexicalization of the novel sequences had facilitated production of neighboring words.

The results of this experiment are intriguing. Experiment 1 showed that on the perception side, the HF condition led to quite a strong delaying effect on recognition, whereas the LF words did not. If the perception and production effects are additive in shadowing, then the lack of any effect for the HF words is understandable: possibly a facilitatory effect in production combined with a strong inhibitory effect in perception to yield a net null effect. The LF items, in contrast, were not hampered by the perception effect, and so showed facilitation. But this explanation contains a potential inconsistency. We assumed that the lack of an inhibitory effect in the LF condition was because these items had not been lexicalized. Experiment 2, however, suggests that these items have, in that they can facilitate production of a neighboring word a week after being heard.

Experiment 3 is conspicuous in demonstrating a lexicalization effects for LF items in speech production, despite the fact that participants have never been asked to name these items. Therefore, the lexical "footprints" previously demonstrated in speech perception are also present in speech production. Surprisingly, this effect was not found for the HF condition. We assumed that the inhibitory effects found in Experiment 1 would be absent once the recognition modality was switched to the visual domain. Despite this switch, the results were similar, with HF items showing no effects.

4. CONCLUSIONS

These experiments have extended our earlier research in two ways. First, we have shown that frequency of exposure has a critical role in the lexicalization of novel words. In terms of recognition, our lower level of frequency (12 exposures) resulted in no lexicalization effects a week later. Higher levels of exposure have previously been demonstrated to show lexicalization effects after a delay, whereas in Experiment 1, we found immediate lexicalization for very high exposure frequency.

The research has also demonstrated that lexicalization can be assessed via lexical competition in speech production as well as perception. Despite our exposure method that focused on perception, we found facilitatory lexical neighborhood effects in production tasks that complemented the inhibitory effect in perception. Surprisingly, these production effects dominated in the low exposure frequency condition, whereas the perception effects dominated in the high frequency condition.

5. ACKNOWLEDGEMENTS

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