Learning New Words: Effects of Lexical Competition and Age of Acquisition

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Abstract

Recognizing spoken words involves lexical competition. A newly learned word will engage in competition with existing words that share its onset (e.g. the novel word 'cathedruke' will compete with 'cathedral'), as measured by increased recognition times to the existing word (Gaskell & Dumay, 2003). We sought to replicate this finding in a longitudinal design where the effects of lexical competition were followed up over the course of eight months. Novel words were taught at different points in time, allowing us to vary, on a small scale, the age of acquisition (AoA) of the novel items. Robust lexical representations emerged for the novel words, and remained competitors to existing words throughout the study. A dissociation in AoA effects between lexical competition and naming also emerged.

Keywords: Psycholinguistics; speech; lexical competition

Introduction

While a great deal of research has focused on language acquisition in children, less is known about these processes in adults. One way to probe the acquisition of new words is through lexical competition, which is central to many theories of spoken word recognition. When the acoustic information of a spoken word unfolds over time, the incoming incomplete information activates matching word candidates in the listener's mental lexicon (see e.g. Marslen-Wilson, 1993). For example, the word 'captain' briefly activates competitors such as 'capsule' and 'captive' before acoustic information distinguishes it from its competitors. It has also been shown that words are more difficult to recognize if they have high frequency competitors (e.g. Luce, Pisoni, & Goldinger, 1990), providing further evidence for lexical competition.

Gaskell and Dumay (2003) chose real trisyllabic words with early uniqueness points (the point at which a word diverges from all its competitors), such as 'cathedral', as base words. A "novel word" was created for each base word by changing the ending of the base word so that the novel word diverged from it at the final vowel ('cathedruke'). The purpose of this manipulation was to shift the uniqueness point of the base word by introducing a new competitor in the lexicon, which diverged from the base word at a late point. If 'cathedruke' becomes a part of the lexicon and engages in competition with 'cathedral', one should see a slowing in the recognition time to the base word.

The results showed that direct recognition of the novel words was good. The participants were accurate in judging whether they had been exposed to 'cathedruke' or a foil ('cathedruce'). However, directly after learning there was no sign of slowing down of base word recognition. This seemed to indicate that the novel words had not been fully lexicalized yet, despite accurate performance in the explicit recognition task.

To examine whether competition effects emerged over a longer timescale, Gaskell and Dumay (2003) carried out another experiment involving two sessions separated by a week. A pause detection task (Mattys & Clark, 2002) was used to measure lexical competition, and the data indicated that no competition was evident on the first day. However, a week later participants were slower to detect the pause if the base word had a novel competitor. These results suggest that it requires some considerable time for the representations of the new words to become fully active members of the lexicon. This may be caused by a need for the new information to be integrated in memory.

The word learning in Gaskell and Dumay (2003) differed from normal vocabulary acquisition in two key ways. First, the words were learned in the absence of a referent or a meaningful sentential context. Second, the effects of learning were studied only in the short term. Dumay, Gaskell and Feng (2004) addressed the first of these issues by presenting novel words in a semantic context. This did not affect the speed of lexicalization, suggesting that exposure to just the phonological form is adequate for lexicalization to take place.

The current study addresses the second key difference by examining the implications of novel word learning over the following months rather than weeks. If words learned in the lab still have measurable effects on the recognition of existing words after a period of months then we can be confident that their representations are as robust as normal word representations.

The existing data suggest that adults are good at learning new words, even without extended training sessions. It should thus be possible to create an artificial vocabulary to address psycholinguistic questions. Many psycholinguistic variables have been difficult to study due to confounding effects of related variables. The age of acquisition (AoA) variable has been particularly difficult to examine due to its close association with word frequency. Words acquired early in life are typically responded to more quickly than later acquired words. However, early-acquired words tend to be of high frequency, while late-acquired words tend to be of low frequency (Morrison, Chappell, & Ellis, 1997).

Another challenge to AoA has been the theory of cumulative frequency (e.g. Lewis, Gerhand, & Ellis, 2001). Conventional frequency measures the number of times a given word occurs in a large body of text or speech. Cumulative frequency measures the number of times a given word is encountered over time between first exposure and the current time. While evidence suggests that AoA predicts performance in linguistic tasks when conventional frequency is controlled, proponents of cumulative frequency have argued that such AoA effects are only cumulative frequency effects in disguise (e.g. Lewis et al., 2001).

The advantage of working with novel words is that factors like frequency can be controlled carefully. Thus a second aim of the study reported here was to look for AoA effects among novel words learnt at different points in time. Three sets of novel words were learnt (early, middle, and late), and direct AoA effects were measured by lexical decision and naming latencies to the novel words. Also, if early novel words turn out to be more robust competitors than late novel words, base words with early acquired competitors will be recognized more slowly than those with late acquired ones. This would constitute evidence for a role for AoA in lexical competition. It is equally possible that AoA effects will be observed only in the tasks not directly reflecting competition (i.e. tasks with a stronger output than input component, such as naming), suggesting a different locus for the effect.

Method

Participants Thirty-one participants from the University of York were tested. All were native English speakers (mean age of 20) without visual or auditory impairments. During the course of the study some participants dropped out, and the number was reduced to 24 by the last session.

Stimuli and Design Sixty-eight monomorphemic words were chosen to act as the base words (e.g., 'cathedral'). Thirty-four of these were taken from Gaskell and Dumay (2003), and the remaining words were selected using similar criteria. All words were bi- or trisyllabic, the number of phonemes ranging from 6 to 11 (M = 8.0). The frequencies, as reported in the CELEX database (Baayen, Piepenbrock, & van Rijn, 1993), ranged from 2 occurrences per million to 18 (M = 4.3). All base words had an early uniqueness point, located before the final vowel.

Fictional "novel words" were then created for each base word (e.g., 'cathedruke'). These were constructed so that they diverged from the base words at their final vowel, and were presented to the participants during the learning phases of the experiment. For each novel/base word pair a foil was also created for use in an explicit recognition test (e.g., 'cathedruce'). This foil diverged from the novel word only at the final phoneme.

Filler words and nonwords were chosen for the lexical decision tasks. The properties of these items were similar to those of the experimental items. Nonwords were created by changing one phoneme of a real word to form a nonword.

The AoA variable was manipulated by teaching the novel words at three different points in time. Novel words in the early condition were taught in the first session. The middle novel words were taught one week later, and the late novel words about 17 weeks later. The stimulus triplets (base word and two novel words) were randomly divided into four lists of 17 triplets each, and rotated across the four conditions (control, early, middle, late) so that each triplet occurred in all conditions.

Procedure *Session 1*. The purpose of the first session was to teach participants the early-AoA group of novel words and to assess the immediate effect of these items on their lexical neighborhood. The session began with a familiarization phase. This phase consisted of a phoneme-monitoring task and a word repetition task. Each novel word occurred 15 times in both tasks.

Each phoneme-monitoring trial started with presentation on screen of the target phoneme for 500 ms, followed by auditory presentation of the novel word. The participant was asked to indicate whether the target sound was present in the novel word by pressing a key.

Word repetition trials involved simultaneous presentation of the visual and auditory forms of the novel word. The participant was asked to repeat the word aloud after hearing and seeing it. The reason for the repetition task was to familiarize the participants with the visual forms of the words, in anticipation of a naming test at a later stage.

The lexicalization test then followed. A lexical decision task was used here, with the participants making responses to the base words, control words (base words without a new competitor), and filler items. Each trial started with the auditory presentation of an item. Responses were made, as quickly and accurately as possible, using the keyboard.

The session ended with a forced-choice recognition test. The novel words were presented auditorily, paired with their corresponding foil. The participant was asked to indicate which one of the two words had been heard in the familiarization phase. The procedure of these tests was kept identical in following sessions.

Session 2. The second session took place on average seven days after Session 1 (range 6-9 days). This session was used to teach the middle AoA novel words, and to test for the lexicalization of the early and middle novel words. It included a familiarization phase, a lexical decision task, and a forced-choice recognition test.

Session 3. This session took place roughly seven days (range 6-8 days) after Session 2. Its purpose was to test for the lexicalization of the novel words learned in the first two sessions. The session started with a lexical decision task, including the base words of the early and middle novel words, and control words. The test also included the novel words taught in the previous two sessions. The reason for the inclusion of these items was to compare the early and middle AoA novel word groups in terms of simple recognition speed. The data revealed that all participants responded to them as nonwords.

Finally, the naming test included the novel words from the early and middle sets. Each word was read aloud as quickly and as accurately as possible. A trial started by the novel word being presented on the screen. The participant was given 2500 ms to read it aloud and the response was recorded and timed.

Session 4. This session took place on average 116 days after Session 3 (range 110-134 days). The session included a familiarization phase in which the late novel words were taught, as well as a lexical decision, naming, and explicit recall tasks.

Session 5. This session took place on average eight days after the fourth session (range 6-13 days), and its purpose was to test the explicit recall, lexicalization, and naming speed of all the novel words, and to compare these with the performance of earlier sessions.

Session 6. The last session was held on average 92 days after Session 5 (range 79-122 days). The session was identical to Session 5.

Results and Discussion

Only the participants who completed all sessions were included in the analyses. Following Raaijmakers, Schrijnemakers, and Gremmen (1999), and Raaijmakers (2003), only by-subject analyses were carried out, as by-items analyses are unnecessary in counterbalanced designs. Also, in all analyses reported below, participant group was included as a dummy variable to increase statistical power (Pollatsek and Well, 1995). Main effects and interactions involving this variable are not reported.

Lexicalisation Effects RTs to the base words in the lexical decision tasks were analyzed to examine the extent to which the learning of the novel words resulted in extended lexical competition. All erroneous responses were discarded, as well as responses slower than 3000 ms or faster than 300 ms. An inverse transformation was then carried out on the data in order to reduce the effect of remaining outliers (Ulrich & Miller, 1994). The means in Figure 1 have been transformed back to harmonic means to aid interpretability.

Lexicalization of the early AoA novel words. An analysis of variance (ANOVA), with word group (novel competitor vs. control) and sessions (all six sessions) as variables was carried out. This revealed a significant main effect of word type, $F(1, 20) = 46.01$, $p < .001$, with RTs to base words slower than to control words. An interaction between word group and session was also found, $F(5, 100) = 2.33$, $p < .05$, indicating that the effect was not similar across sessions. Planned comparisons were then carried out to examine the effects within each session. There was no significant main effect of word group in the first session but in all subsequent sessions the RTs to base words were significantly slower than to control words, $F(1, 20) = 4.92$, $p < .05$ for Session 2, $F(1, 20) = 16.57$, $p = .001$ for Session 3, $F(1, 20) = 4.90$, $p < .05$ for Session 4, $F(1, 20) = 14.72$, $p = .001$ for Session 5, and $F(1, 20) = 14.03$, $p = .001$ for Session 6. In other words, like Gaskell and Dumay (2003), we found that lexical competition effects emerged only after a delay, suggesting some kind of consolidation process. The current results demonstrate that this change in the competition environment

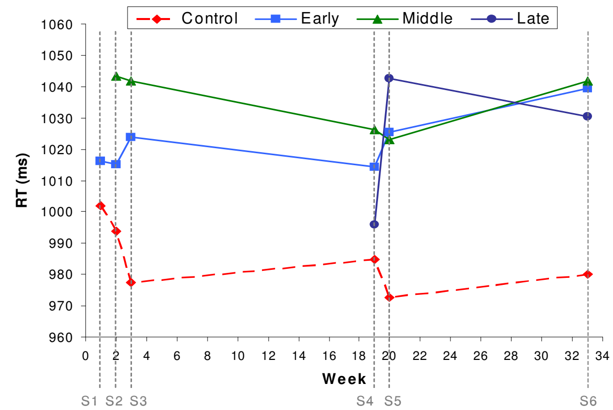

Figure 1: Mean RTs to base words across all sessions.

of the existing words is stable over the weeks and months following exposure.

Lexicalization of middle AoA novel words. An ANOVA revealed a significant main effect of word group, $F(1, 20) = 39.79$, $p < .001$, but this time no interaction between group and session, suggesting that in this case the novel words engaged in lexical competition immediately after the familiarization. All of the planned comparisons reached significance, indicating that lexicalization took place immediately and that the novel words remained in the lexicon in all sessions, $F(1, 20) = 13.03$, $p < .05$ for Session 2, $F(1, 20) = 25.86$, $p < .001$ for Session 3, $F(1, 20) = 10.30$, $p < .05$ for Session 4, $F(1, 20) = 12.40$, $p < .05$ for Session 5, and $F(1, 20) = 16.99$, $p = .001$ for Session 6.

Lexicalization of late AoA novel words. As for the early words, there was a main effect of word group $F(1, 20) = 13.62$, $p = .001$, and an interaction between word group and session, $F(2, 40) = 4.63$, $p < .05$. Planned comparisons showed that the RT difference between control and base words for late novel words was not significant in Session 4, immediately after exposure, whereas the effect was significant in the last two sessions, $F(1, 20) = 20.09$, $p < .001$ for Session 5, $F(1, 20) = 12.41$, $p < .05$ for Session 6.

Comparing the lexicalization effects between AoA conditions. We compared RTs to base words across the AoA conditions (excluding data from lexicalisation tests immediately following familiarization of the novel competitors, as no lexicalisation effects tend to be found immediately). This was done to examine whether the AoA of the novel words affected their ability to act as competitors in the recognition of the existing words. If so, one might expect slower RTs to base words with early AoA novel words. ANOVAs showed no significant main effects or interactions, suggesting that all three novel word groups were equally strong competitors (all *ps* > .05).

Explicit Recognition Data Error rates in the explicit recognition task immediately after training were low (1.7% for early AoA novel words, 3.3% for middle AoA novel words, 6.6% for late AoA novel words). The forced-choice recognition task was included in Sessions 5 and 6 in order to compare performance across the three AoA conditions. Session 5 revealed a main effect of word type, $F(2, 40) =$

16.99, $p < .001$. Further analyses indicated that the late novel words attracted significantly more errors than early novel words, $F(1, 20) = 17.11$, $p = .001$, or middle novel words, $F(1, 20) = 22.38$, $p < .001$. There was no significant difference between the early and middle novel words.

In Session 6 too a main effect of word type, $F(2, 40) = 28.20$, $p < .001$ was found. The late novel words again attracted significantly more errors than either early novel words, $F(1, 20) = 28.00$, $p < .001$, or middle novel words, $F(1, 20) = 37.23$, $p < .001$. There was no significant difference between the early and middle novel words. Performance immediately after training was good for all conditions, suggesting that all novel words were initially learned well. Nonetheless, the data from the last two sessions indicate that recall of late novel words was worse. This effect is puzzling given that all novel words were lexicalized. It may be that the participants were less motivated to explicitly learn the novel words by the fourth session where the late words were introduced.

Direct Effects of AoA The lexical decision tests for Sessions 3-6 included the novel words to test whether AoA influenced their recognition. In fact, no RT difference between any of the conditions was found, indicating that participants were equally fast to recognize the early, middle, and late AoA novel words (mean RTs to novel words across sessions were 1085 ms to early AoA novel words, 1090 ms to middle AoA novel words, and 1082 ms to late AoA novel words).

Our second measure of AoA effects employed speeded naming of the written form (see Figure 2). In Session 3 participants named the early AoA novel words significantly faster than the middle AoA novel words, $F(1, 20) = 13.67$, $p < .05$. This small effect, reflecting merely a week's difference in time of learning, disappeared by Session 4, and remained non-significant in Sessions 5 and 6. However, the late AoA novel words in these two last sessions had significantly slower naming latencies then either the early AoA novel words, $F(1, 20) = 19.89$, $p < .001$ for Session 5, $F(1, 20) = 29.49$, $p < .001$ for Session 6, or the middle AoA novel words, $F(1, 20) = 19.09$, $p < .001$ in Session 5, $F(1, 20) = 47.33$, $p < .001$ in Session 6.

It is possible that the slower naming times for late novel words are a consequence of poorer learning of these items, caused by e.g. motivational factors. Recall that the explicit recognition performance was worse for late novel words. To check if this might be a confound, we re-analyzed the naming data of a sub-set of 10 participants. These were all participants whose explicit recognition scores showed no or little difference between the AoA groups. In this analysis, the AoA effect observed in Session 5 was no longer significant, but the effect in Session 6 remained reliable, late vs. middle $F(1, 6) = 6.67$, $p <.05$, late vs. early $F(1, 6) = 12.97$, $p < .05$. There was also an advantage for middle words over early words in Session 3, $F(1, 6) = 7.11$, $p < .05$. These data suggest that the AoA effect in naming is not a confound of poorer learning of the late words.

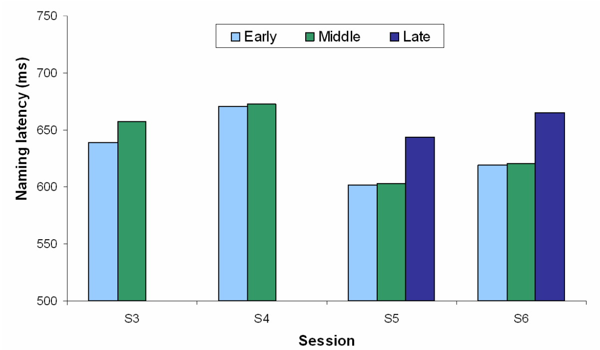

Figure 2: Mean naming latencies to novel words.

General Discussion

The results reported above suggest that novel words learnt at all three time points became lexicalized, as measured by engagement in lexical competition with the base words from which they were derived. RTs to the base words slowed down after the novel words had been learned, as opposed to base words for which no new competitors had been introduced. This can be explained by a change in the base word's uniqueness point. In this respect these data replicate the findings of Gaskell and Dumay (2003).

The time course of lexicalization found in the Gaskell and Dumay (2003) study was replicated in the case of the early and late-AoA novel words. In both cases the lexicalization effect only emerged one week after the familiarization phase. This pattern fits in well with theories of memory consolidation (Alvarez & Squire, 1994; O'Reilly & Norman, 2002), which suggest that transfer of information from a short-term storage (e.g. medial temporal lobe) to a long-term storage (e.g. neocortex) is a process that takes some time. Dumay and Gaskell (in press) have suggested that sleep may be a crucial factor in the consolidation process. Participants who were trained in the evening and tested in the morning, thus getting a night's sleep between the sessions, showed lexicalization effects. Participants who had been trained in the morning and tested in the evening showed no effects, although all participants showed the effect at a later testing session 24 hours later.

The rather different pattern of lexicalization effects for the middle-AoA words is somewhat surprising. Here the initial test of lexicalization immediately after exposure showed a significant lexical competition effect. It is feasible that this is simply a type I error: in our earlier studies there have been perhaps twenty similar comparisons of the immediate effects of novel word learning on lexical competition. Previously, one had shown a similar inhibitory effect and one had shown a facilitatory effect, with the remainder showing no differences. Another possibility is that the middle words benefited from experience gained in the previous session, possibly making the participants more sensitive to learning new words a week later. Such an effect would not be observed in the case of late words as the gap between the middle and late teaching sessions was longer.,.

Another major finding deals with the longevity of the lexicalization effect. Novel words learned in the first session of the study were still competing with the base words 7.5 months after being introduced, with very little exposure in between (just the level of exposure required during testing). Furthermore, all three groups of words demonstrated equivalent competition effects in Sessions 5 and 6, which were separated by a period of three months with no intervening exposure. It is also worth noting that these novel words had no supplied semantic content, a factor that one might assume would make them more difficult to learn. Such long-term effects are in agreement with the results of Salasoo, Shiffrin, and Feustel (1985) who exposed participants to visual nonwords and found that, with adequate repetition, participants were able to recognize the nonwords from rapid presentations as reliably as real words. Even a year after training recognition of the nonwords was as reliable as real words, suggesting that a permanent memory trace had been created.

Another aim of the study was to investigate effects of AoA. No effects were found in the lexicalization data, or in lexical decisions to the novel items, which are primarily tests of recognition. However, the naming task, which has a stronger output component, did reveal slower latencies to late novel words than to early novel words.

Zevin and Seidenberg (2002, 2004) have argued that AoA effects are based on frequency trajectory and cumulative frequency. Frequency trajectory refers to the distribution of the number of times a word has been encountered. Some words are frequent in childhood but rare in adulthood (e.g. ‘potty’), and vice versa (e.g. ‘fax’). The claim is that this pattern of exposure over the life span determines the speed of learning. Words with a high-to-low frequency trajectory (high frequency in childhood) are learned faster, and thus earlier, than low-to-high trajectory words. Cumulative frequency acts as a further influence on learning. Words with a high cumulative frequency are processed faster than words with a low cumulative frequency. In sum, frequency trajectory determines the age when a word is learned, and cumulative frequency affects the ease with which it is processed in adulthood.

The AoA effects reported here are difficult to explain in terms of cumulative frequency. Each novel word was initially presented the same number of times in the familiarization phase. While it is true that, due to the repeated testing sessions, the participants had more exposures to the early novel words than to the later novel words across the study, this difference is too small to be a likely account of the AoA effects observed in the end (at the beginning of Session 6, early novel words had been encountered 38 times, middle novel words 38 times, and late novel words 34 times). Comparable studies (e.g., Dumay & Gaskell, in press) have demonstrated that these small differences have little or no effect on the storage of these items. This suggests that while cumulative frequency may contribute to AoA effects when testing with real words, it is unlikely to be the only source of AoA effects.

Another theory attempting to explain AoA findings places the locus of the effect on a semantic level (Brysbaert, Van Wijnendaele & De Deyne, 2000; Belke, Brysbaert, Meyer & Ghyselinck, 2005). Brysbaert et al. (2000) argued that AoA effects arise because the meanings of late-acquired words are built upon those of earlier acquired words, and that the semantic representations of earlier acquired words are more readily available. The novel words used here did not have a semantic referent. This suggests that the semantic level cannot be the sole locus of AoA effects. It should be noted though, that while no explicit semantic content was attached to the novel words, it is possible that participants created some meaning for the new words. In fact, there was anecdotal evidence from some of the participants that this may be the case for some people.

The current results are also relevant to a connectionist model reported by Ellis and Lambon Ralph (2000). These authors trained their network by introducing sets of patterns at different points in time and examined whether the network learned the early-acquired sets better than later acquired sets. This was found to be the case, but only when training was cumulative. If one pattern was taught first, and then replaced by another pattern without further presentations of the first pattern, the network showed signs of catastrophic interference, in that performance on the early pattern got worse as the number of training epochs was increased. In cumulative training on the other hand, the training of the two sets is interleaved. This training regime is closer to the way people learn new words in natural conditions, and results in learning of both sets in the model, but with an advantage to the earlier acquired set. This finding is in contrast to the data acquired in the current study, where the training was not cumulative. Despite this, participants learned the novel words of all sets, as indicated by both effects of lexicalization and performance on the explicit recognition tests. This suggests that catastrophic interference may not be a property of human learning. In fact the overnight consolidation found in this paradigm by Dumay and Gaskell (in press) may reflect part of the way in which catastrophic interference effects are avoided.

Moore and Valentine (1999) found AoA effects in a task involving reading celebrities’ names in a name familiarity decision task, and in a face familiarity decision task. Recognizing names and faces of “early-acquired” celebrities was faster than for “late-acquired” celebrities. This led the authors to suggest that temporal order of acquisition may be more important than age. Moore and Valentine (1999) argue that early-acquired information in all classes of stimuli may have an advantage over information acquired later. An initial encounter with an exemplar of a new stimulus sets up a new stimulus class. All later acquired stimuli of this class will be represented in a different manner from the early stimuli, which were actively involved in setting up the class. This would explain why AoA effects can be observed in non-linguistic materials, and why they can arise in materials learned in adulthood, such as the novel words used here. Applied to the current study, this theory would require that the novel words triggered the setting up of a new stimulus class. This may well be possible if the participants in the beginning of the study did not consider the novel words as being real words.

While our data show that the lexicalization effects are robust over time, a challenge for future work is to further elucidate the timecourse of the process, especially with respect to the delay in lexicalization. In this respect our data are also informative for more general cognitive principles of memory consolidation. The lexicalization delay can be seen as evidence of a crucial process in memory of transferring information from a short-term storage to a long-term storage. Alvarez and Squire (1994) have suggested that such a process is carried out between the medial temporal lobe and the cortex, and that this transfer can take place without repeated activation of the memory. This corresponds well with our finding of lexicalization occurring during the time between teaching and testing, with no exposure in between.

The mechanism underlying AoA effects also needs to be addressed. Our data suggest that none of the proposed mechanisms are adequate. The dissociation between observing AoA effects in the naming task and not in lexical competition will be informative for future theories.

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