INVESTIGATING THE *CORNER-CORN* EFFECT IN AUDITORY PROCESSING

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ABSTRACT

We present two auditory-auditory priming experiments investigating whether decomposition effects for pseudo-related prime-target pairs like *corner* → CORN are restricted to early visual word recognition [10] or can also be found in auditory processing. Experiment 1 shows no difference in facilitation effects for pseudo-suffixed pairs and purely phonologically-related pairs (e.g., *cashew* → CASH). Experiment 2 uses a delayed repetition paradigm to tease apart pseudo-morphological and phonological effects. Results show a significantly larger decay for the pseudo-related compared to the phonologically related condition, suggesting that pseudo-suffixes also trigger an automatic decomposition process in auditory processing.

Keywords: auditory word recognition, morphological priming, pseudo-suffixation, the *corner-corn* effect

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1. INTRODUCTION

Visual priming studies focus on different types of relations between (apparent) multi-morphemic words and their embedded stem. These include prime-target pairs that are both morphologically and semantically related (e.g., *teacher* → TEACH), and pairs that are merely pseudo-morphologically related (e.g., *corner* → CORN). Adopting a standard view, pseudo-related primes occur with an existing suffix and stem, thus appearing to be morphologically complex, while pairs of this type are not etymologically or semantically related.

Previous research in the visual modality [2,4,7,9,10] has shown an asymmetry between masked and overt priming studies on pseudo-morphological processing. In *masked* paradigms, priming effects have been obtained for related pairs (*hunter* → HUNT), as well as for pseudo-suffixed pairs (*corner* → CORN). No such facilitation occurs for non-suffixed primes that only show an orthographic relation to the target (*cashew* → CASH). These findings have been taken to show that early visual word recognition involves a morpho-orthographic decomposition stage, in which words that are only pseudo-related are segmented on the basis of orthographic properties [8,10]. In contrast, in visual *overt* priming, pseudo-suffixed words do not facilitate their embedded pseudo-stem [6,11].

This asymmetry between masked and overt priming has been attributed to the time a reader has to process the prime. Due to short prime exposure (< 60ms), masked paradigms are assumed to target an automatic decomposition stage. In contrast, prime exposure is much longer in overt visual paradigms. It is assumed that, by the time the target occurs, the processing of the overt prime has reached a stage in which pseudo-complex primes do not facilitate their pseudo-stem. Pseudo-derived stimuli, therefore, can be used to provide a window on the automaticity of the decomposition process.

Importantly, research in this area has only focused on the *visual* recognition of words; it is not clear whether these results translate to the *auditory* modality as well. Although one might expect auditory priming to be similar to overt visual priming, the specific nature of auditory input makes it potentially similar to masked priming. Auditory speech unfolds continuously in time, with the pieces that make up a multi-morphemic stimulus (stem, suffix) arriving at the listeners' ears at different times. In contrast, visual stimuli are presented in their entirety, such that readers have access to the left and right edge of the word simultaneously. The incremental nature of auditory input has important consequences for suffixed words; listeners need to wait for the suffix to be presented, whereas this is not the case with visually presented words. Therefore, we might expect an auditorily presented pseudo-related prime to facilitate the recognition of its auditory target, when the target occurs relatively quickly after the prime. This would resemble results from masked paradigms. In this paper, we present the results of two auditory-auditory priming experiments investigating whether early decomposition effects are merely an artefact of orthographic representations or whether listeners also "falsely" decompose in early stages of auditory processing.

2. EXPERIMENT 1

2.1. Methods

2.1.1. Materials

Stimuli are prime–target pairs that are morphologically and semantically related (MS: *creamy* → CREAM, *treatment* → TREAT), pseudo-morphologically related (pseudo-M: *belly* → BELL, *pigment* → PIG), purely phonologically related with no (pseudo-)suffix (Ph: *dogma* → DOG, *pillow* → PILL), and semantically related (S: *garbage* → TRASH, *painting* → ART). The pseudo-M and MS conditions differ as minimally as possible, as different suffixes appear equally often in these conditions. For instance, four primes with *-er* and two primes with *-ment* occur in both pseudo-M and MS conditions. In addition, due to the auditory presentation of stimuli, the targets are not only orthographic but also phonological sub-strings of their prime. This means that pairs like *legion* → LEG (phonologically dissimilar) and *aisle* → EYE (orthographically dissimilar) were excluded. Following Beyersmann et al. [2], we also exclude M pairs that share a remote or archaic meaning, such as *archer* → ARCH. Furthermore, none of the stems in the pseudo-M condition ending in *-er* were verbs, so that no additional transparent agentive meaning could be formed. The MS pairs were selected such that the meaning of the prime could always be derived from the meaning of its stem as evidenced by their high pairwise Latent Semantic Analysis (LSA) measures [5]. S primes were also selected based on high LSA measures with the target. All targets are monosyllabic words, while the primes are disyllabic words with main stress on the first syllable. The targets and primes are always either verbs, nouns, or adjectives.

For each target, a morphologically, semantically, and phonologically unrelated prime was selected, which was pair-wise matched with its related prime in word type and frequency (Lg10CD from SUBTLEX-US, [3]), as illustrated in Table 1. All unrelated primes, like the related primes, are disyllabic words with stress on the first syllable. The suffixes in the unrelated primes match those of the corresponding related primes as much as possible. The unrelated primes have no semantic relatedness and minimal phonological overlap with the targets. In total, we included 20 (related/unrelated) prime-target pairs per condition. Each subject saw 80 critical pairs of which half were unrelated. Subjects were allocated to one of two lists, so that they saw each target only once.

In addition, 100 filler words (50 monosyllabic; 50 disyllabic) and 260 non-words (130 monosyllabic; 130 disyllabic) were included. Of the disyllabic non-words, 90 were randomly generated through a script such that more frequent onsets, vowels, and codas are more frequently selected, based on the frequency of onsets, vowels, and codas. To ensure that subjects could not determine the lexicality of stimuli based on just the first syllable, 20 disyllabic non-words occurred with a real stem but a nonce suffix (and vice versa for another 20 non-words).

Table 1: Stimuli characteristics of primes in related/unrelated conditions.

Condition	Frequency Related	Frequency Unrelated	LSA Related	LSA Unrelated
MS	2.29	2.29	0.53	0.06
Pseudo-M	2.80	2.32	0.12	0.07
Ph	2.00	1.97	0.05	0.05
S	2.83	2.77	0.47	0.07

2.1.2. Procedure

The stimuli were recorded by an adult male speaker of American English. Sound files were segmented using Praat and normalized to 70 dB. A continuous lexical decision task was implemented in PsychoPy2. The task had a random inter-stimulus interval (ISI) between 600-800ms. Stimuli presentation was randomized throughout the experiment for each participant. Participants were tested individually in a quiet room. They were instructed that they would hear existing and non-existing English words, and that they had to make a lexical decision to each word as quickly and accurately as possible, using a button box. The experiment lasted for approximately 20 minutes with two self-administered breaks. It included a practice trial of 8 items at the beginning of the experiment.

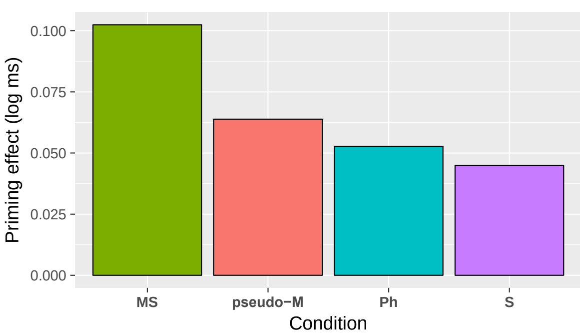
2.1.3. Participants

Participants were 39 undergraduate native speakers of English (23 female; mean age = 19.51). The participants received course credit as compensation.

2.2. Results

Responses were coded for response type (word/non-word) and response time (RT; measured in ms from the onset of the sound file). Differences in duration of the sound files are included as a predictor in the model. Incorrect responses to primes and targets were discarded. One subject was excluded due to overall low accuracy. We combine minimal a-priori data trimming with model criticism [1]. All targets with outlier RTs (< 200 and > 2500ms) were excluded (33 data points). Removal of log-transformed RT outliers was done for individual subjects and items with non-normal distributions on Shapiro-Wilk tests, excluding 96 data points. In total, a-priori screening led to the removal of 129 data points or 4.71% of the data. We analyzed log-transformed RTs to targets with linear mixed-effects models, using the lme4 package (version 1.1-12) in the R environment. Fixed effects were TARGET TYPE (MS, pseudo-M, Ph, S, with the reference level set to different conditions for multiple comparisons) and PRIME TYPE (related, unrelated) and their interactions, TRIAL, TARGET and PRIME FREQUENCY, ISI, TARGET DURATION, and LOG PRIME RT. We included random intercepts for SUBJECT, PRIME, and TARGET. Model criticism was performed on the full model to identify overly influential outliers. The model was refitted after excluding 60 data points with absolute standardized residuals exceeding 2.5 standard deviations.

Figure 1: Priming effects in Experiment 1.



The results are shown in Figure 1. The model indicates significant priming effects (related vs. unrelated) in all conditions (MS: 127.23 ms, $\beta = 0.09$, $p < 0.001$; pseudo-M: 83.60 ms, $\beta = 0.07$, $p < 0.001$; Ph: 69.33 ms, $\beta = 0.05$, $p < 0.001$; S: 57.51 ms, $\beta = 0.05$, $p < 0.001$). The model further shows a significantly greater priming effect in the MS condition, compared to the pseudo-M ($p = 0.042$), Ph ($p < 0.01$), and S ($p < 0.001$) conditions. No difference is found between pseudo-M and Ph ($p = 0.263$).

2.3. Discussion of the results

On one hand, the significant priming effect in the pseudo-M condition suggests that auditory priming is similar to masked visual priming. On the other hand, it is different from masked visual priming in that the Ph condition also yields similar priming effects. This is surprising, considering that masked visual priming studies typically show a significantly larger priming effect for pseudo-M pairs, compared to orthographically related pairs (e.g., [2,6,7,8,10]). In contrast, our results are consistent with the idea that, at the level of processing of the prime reached when the target is presented, the processing of words with an existing suffix in pseudo-M (e.g., *corner*) is not different from words without a potential suffix in Ph (e.g., *cashew*). The effects in the pseudo-M and Ph conditions are, therefore, worth investigating in more detail. Specifically, the incremental unfolding of auditory stimuli means that the prime's suffix arrives at the listeners' ears relatively late and only shortly before the target. To test the idea that the late presentation of the suffix causes the lack of difference between pseudo-M and Ph, we ran a second experiment with the same stimuli, but with them presented at two different lags: a 0-lag, similar to Experiment 1, and a 1-lag, in which a non-word intervenes between prime and target.

3. EXPERIMENT 2

We ran a second experiment to investigate whether different processing patterns for pseudo-M and Ph can be distinguished when an intervener occurs between the prime and target. The 1-lag condition presumably targets a later processing stage, as there is more time to process the prime's suffix before the presentation of the target.

3.1. Methods

Methods are similar to Experiment 1, with the same set of stimuli. In Experiment 2, however, half of the stimuli were presented at 0-lag and half at 1-lag, with a non-word as an intervening item. The lag between the end of the prime and the beginning of the target in the 1-lag condition was 3.56 seconds on average, compared to 1.43 seconds for the 0-lag. Stimuli were rotated over four lists. Subjects were 80 undergraduate students who were native speakers of English (56 female; mean age = 19.53).

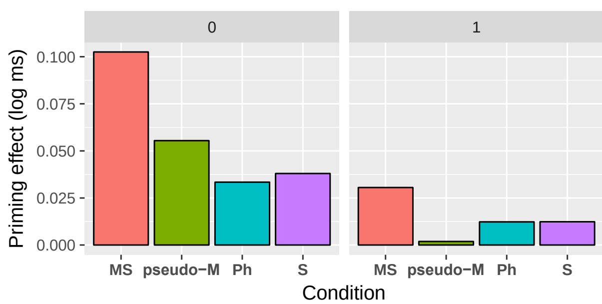
3.2. Results

The RT data were analyzed in the same way as for Experiment 1. Incorrect responses to primes and targets were excluded. All targets with outlier RTs (<200 and >2500ms) were excluded, removing 137 data points. By-item and by-subject outlier trimming further excluded 184 data points. In total, 321 observations (or 5.5%) were excluded. We analyzed log-transformed RT with linear mixed-effects models. Fixed effects were TARGET TYPE (MS, pseudo-M, Ph, S), PRIME TYPE (related, unrelated), DISTANCE (0/1-lag), and their interactions, TRIAL, TARGET and PRIME FREQUENCY, ISI, TARGET DURATION, and LOG PRIME RT. We included random intercepts for SUBJECT, PRIME, and TARGET. The model was refitted after model criticism, which excluded 122 observations.

Figure 2 shows the results. At 0-lag, significant priming effects were found in all conditions (MS: 132.63

ms, $\beta = 0.1$, $p < 0.001$; pseudo-M: 68.23 ms, $\beta = 0.06$, $p < 0.001$; Ph: 43.01 ms, $\beta = 0.03$, $p < 0.001$; S: 49.93 ms, $\beta = 0.04$, $p < 0.001$). However, here, the pseudo-M condition yielded a significantly higher priming effect than the Ph condition ($\beta = -0.03$, $p = 0.04$). The results at a 1-lag show significant priming effects in the MS condition (44.12ms, $\beta = 0.02$, $p = 0.004$) but not in the other conditions (pseudo-M: 2.45 ms, $p = 0.35$; Ph: 13.52 ms, $p = 0.23$; S: 13.65 ms, $p = 0.31$). The difference between the effects of pseudo-M and Ph was not significant at a 1-lag ($p = 0.86$). However, a three-way interaction between CONDITION, PRIME TYPE, and DISTANCE reveals a significantly greater decay in priming between 0-lag and 1-lag for pseudo-M compared to the decay for the Ph condition ($\beta = -0.03$, $p = 0.043$).

Figure 2: Priming effects at two lags in Experiment 2.



4. DISCUSSION AND CONCLUSIONS

In sum, the 0-lag results in both experiments show priming effects in all conditions but significantly larger effects in the MS condition than the pseudo-M, Ph, and S conditions. Additionally, in Experiment 2 at a 0-lag, pseudo-M yielded significantly higher priming effects than Ph. For the 1-lag results, priming effects were only found for MS, but not in the other conditions. However, the decay pattern for pseudo-M between 0-lag and 1-lag was significantly different from the decay pattern of Ph.

Our studies asked whether pseudo-decomposition effects are restricted to early visual word recognition or can also be found in auditory processing. Our results at a 0-lag suggest that auditory priming may be similar to masked priming, because of the significant effects in the pseudo-M condition. However, our auditory results appear to differ from masked priming results, since we also found significant priming in the Ph condition. This is in contrast to visual masked priming experiments in which pseudo-M effects are usually significantly larger compared to orthographic pairs (e.g., [2,6,8,9,10]).

As discussed above, the occurrence of an existing suffix in pseudo-M predicts that listeners may automatically decompose pseudo-M words (in contrast to Ph). The greater decay in priming between a 0-lag and 1-lag for pseudo-M compared to Ph suggests that these conditions may indeed be processed differently at a particular stage of processing. Meanwhile, the significant difference between pseudo-M and Ph in Experiment 2 at a 0-lag and the lack thereof in Experiment 1 calls for further investigation. In future work, we aim to further investigate the potential difference in the processing of pseudo-M and Ph. Overall, our findings support the idea that the incremental nature of auditory input makes it a useful tool to investigate predictions of models making claims about different stages of lexical access.

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