Abstract

French (or English) native listeners hear /kl/ when presented with the illegal consonant sequence */tl/. This robust case of perceptual repair is usually viewed as operating at a prelexical level of speech processing but the evidence against lexical feedback is somewhat weak. In this study, we report new data supporting the prelexical hypothesis, obtained with a paradigm that avoids most of the possible confounds in previous studies. In a cross-modal auditory–visual priming paradigm, lexical decisions to the same visual target “clavier” are facilitated by the auditory prime */tlavier/, not by */tlavier/. Likewise, the recognition of “glacier” is facilitated by */tlavier/, not by */tlavier/. To summarize, velar stop + /l/ words are exclusively facilitated by the dental-initial derived forms with the same voicing. Derived forms with the opposite voicing tend to induce inhibition rather than facilitation. Hence, the observed facilitation effects are not graded from */tl/ to */dl/ or vice versa. We argue that these rather surprising all-or-none priming effects exclude the possibility that the */tl/→/kl/ and */dl/→/gl/ repairs are due, even partly, to lexical feedback.

Index Terms: phonotactic, perceptual repair, lexical feedback

1. Introduction

In our earlier work, we showed that French listeners tend to perceive word-initial */tl/ sequences as /kl/ [1]. They also perceive */dl/ as /gl/, although the misperception effect is weaker for /dl/ than for /kl/. This effect seems to extend to the languages that do not allow word-initial /kl/ or /dl/, but does not affect the others, for instance, Hebrew [2]. We therefore refer to the misperception of */tl/ as /kl/ as a case of language-dependent dental–velar perceptual repair that takes place at phonological prelexical level. However, as for other cases of repair (e.g., vowel epenthesis in Japanese [3], prothesis in Spanish [4]), it remains unclear whether the so-called phonological repair is solely phonological in nature or is, at least in part, lexically driven. For example, because clou /klu/ ‘nail’ is a French word but /kl/ is not, French listeners might hear */tlou/ as /klou/ more often than */klou/ as /klu/ [5]. But post-hoc analyses reported in [2] do not support this explanation.

An attempt at examining lexical feedback effects more directly in the dental–velar repair was reported in [5], using auditory lexical decision and cross-modal priming lexical decision on visual targets. French speakers were presented with */tl/ or */tlavier/ nonwords derived with the same /kl/-to-/tl/ change from /kl/ or /klavier/ words, respectively (e.g., */tlavier/ clavier vs. *troisière clavier). Participants (falsely) responded “word” more often to */tlavier/ than */clavier/ (about 70% vs. 20% of the time). These false positives are presumably due to repairs into the base words. In the case of *clavier, the repair must be lexical since */tl/ is legal and needs no repair. For */tlavier, the 50% advantage over *clavier may be viewed as due to the */tl/→/kl/ phonological repair. Cross-modal data confirmed this pattern: as an auditory prime, */tlavier/ facilitated “clavier” much more than */clavier/ facilitated “croisière,” suggesting, again, that phonological repair prevails over lexical repair. However, the clavier-croisière paradigm can be criticized on the grounds that phonotactically legal /tl/-initial pseudowords give rise to lexical garden-paths before they can be recognized as nonwords, that is, before there is a reason for lexical repair into the base word form. In contrast, illegal */tl/-initial nonwords might call for immediate repair, hence the advantage of */tlavier/ over *clavier in terms of false positive lexical decisions (or in terms of base-word facilitation).

Unpublished data in response to this criticism used a comparison between */tl/ nonwords derived from /kl/ versus /pl/ words (e.g., */tlavier/ vs. */placier/ ‘cupboard’). Because both types of nonwords begin with */tl/, lexical repair is equally possible for both, without lexical garden-path. The same patterns as for the clavier-croisière comparison was obtained: */tlavier/ was responded “word” more often than */placier/ (about 78% vs. 40% of the time). The “lexical garden-path” criticism raised for clavier-croisière does not apply to the clavier-placard paradigm but this paradigm has a specific drawback. Namely, */t/ might be perceptually closer to /k/ than /p/ (as suggested by [6], Table XVIII). This could explain the lower false positive rates to */t/ nonwords derived from /pl/ than /kl/ words.

In sum, similar outcomes may be obtained with the clavier-troisière and clavier-placard paradigms for two different reasons, which are both compatible with fully lexical repair. Both paradigms have yet another intrinsic weakness: they compare two different sets of target words.

In the present work, we avoid this potential problem by using an audio-visual priming design, in which priming conditions are compared for the same target. We also avoid the lexical garden-path problem by comparing */tl/ primes with */dl/ primes preceding the same /kl/ target. Both types of primes begin with an illegal cluster and are equally unlikely to initiate word cohorts, that is, to engage the listener in a lexical garden-path.

If the */tl/→/kl/ repair is only due to lexical feedback, target facilitation should be determined by the phonetic distance between unrepaired prime and target. For example, “clavier” should be facilitated as a function of the phonetic distance between clavier and */tlavier/ (or */dlavier/), which is presumably reducible to the distance between /kl/ and /tl/ or /dl/). Earlier studies suggest moderate residual priming effects in the case of one- or two-feature deviation in word onset consonant [7], whereas other studies find no priming at all [8]. Thus the lexical feedback account predicts moderate no facilitation of “clavier” by either */tlavier/ or */dlavier/ primes.

If, on the contrary, the dental–velar repair is phonological in nature and operates at a prelexical level of processing,
*dlavier, perceptually repaired into glavier, should only induce moderate facilitation of “clavier” (“residual priming”) or no facilitation at all; in contrast, *tlavier, perceptually repaired into clavier, should strongly facilitate “clavier.” Yet, we also know that the dental–velar repair effect is stronger for */tl/ than */dl/ (cf. [1, 2]). In other words, */tl/ seems less acceptable than */dl/. If weaker facilitation effects of “clavier” by *dlavier than *tlavier are observed, they might be attributable to the lesser acceptability of */tl/ than */dl/. It is thus necessary to compare */tl/ and */dl/ nonword primes for /gl/ targets: for example, *dlavier vs. *tlavier with “glacier” (‘glacier’) as target. If larger acceptability does induce smaller priming effects, weaker facilitation effects should still obtain with */dl/ than */tl/.

To summarize, the following predictions can be made with our new design. If the dental–velar repairs are exclusively due to lexical feedback, moderate or no priming effects should be induced by either */tl/ or */dl/ primes on the associated targets. This is suggested by the work of Connine and colleagues showing residual priming effects with minimally distorted priming form ([7, 9], also see [10]), or by that of Marslen-Wilson and colleagues [8] showing no priming effects from altered primes. The opposite hypothesis, that the repairs are only due to phonological repairs at a prelexical level, leads to the following predictions: */tl/ primes facilitate /kl/ targets much more than /gl/ targets; likewise, */dl/ primes facilitate /gl/ targets much more than /kl/ targets. Experiment 1 compared the priming effects of */tl/ and */dl/ primes for related /kl/ or /gl/ targets (e.g., *clavier vs. *glavier for the “clavier” target). Priming effects were measured using unrelated primes as a reference condition.

2. Experiment 1

2.1. Method

2.1.1. Participants

Forty-six students at the Psychology Institute in Paris 5 University participated in the experiment for course credit. Their mean age was 21 years. None of them reported hearing or reading problems.

2.1.2. Materials and design

For the sake of simplicity, all the primes and the targets were disyllabic. All the primes were pseudowords or nonwords. The spoken primes were recorded by a trained phonetician, who knew Hebrew, and thus could produce [tl]s and [dl]s fluently. We used 24 test target words with “cl” (e.g., “clavier”) and 24 with “gl” (e.g., “glacier”). These targets appeared in three priming conditions: preceded by a related */dl/ or */tl/ prime (derived from the target by a velar-to-dental change), or by an unrelated prime. To avoid a word bias for “cl” or “gl” targets, we also used 48 “cl” or “gl” target nonwords with the same three priming conditions as for the test trials. These materials were supplemented with another 96 filler targets, half of which were nonwords. These filler targets were all associated with unrelated primes and did not contain “cl,” “gl,” “tl,” or “dl.” The 48 test target words were balanced as well as possible between “cl” and “gl” words for usual lexical characteristics, using Lexique [11]: phonemic or orthographic uniqueness point, neighborhood density, length in phonemes or letters. For word frequencies, we used subjective frequency ratings provided by an independent group of 41 subjects. This choice was motivated by the observation of some obvious discrepancies between frequencies as found in Lexique [11] and familiarity for the population of Psychology students that was tested. The 41 subjects were presented with a list of 48 “cl” and 48 “gl” words and rated them for subjective frequency on a 1-5 scale. We retained as test target words 24 “cl” and 24 “gl” words among those that received the highest ratings so that their subjective frequencies were as close as possible in terms of mean frequency and frequency distribution. These subjective frequencies correlated best with the “film” lemma frequencies found in Lexique. We therefore selected 48 filler words roughly matched with the 48 “cl” and “gl” target words for “film” frequency. Word and nonword targets were otherwise matched for phonemic, syllabic, and orthographic length.

Each target word was presented visually only once to each participant. The 48 test target words, as well as the 48 “cl” or “gl” target nonwords, were therefore partitioned into three subsets so that the three priming conditions (*/tl/, */dl/, unrelated) could be counterbalanced across three groups of participants. The three subsets of test target words were balanced as closely as possible for the lexical characteristics we attempted to control. To summarize, participants were presented with three subsets of “cl” or “gl” target words or nonwords, each in a different priming condition. Each subset contained 8 “cl” words, 8 “gl” words, 8 “cl” nonwords, and 8 “gl” nonwords. In addition to the 96 corresponding trials, participants received 96 filler trials, half with a word, half with a nonword target. Each participant received the 192 trials in a different pseudorandom order with the following constraints: at most three word targets in a row, or two “cl” or two “gl” word targets in a row, or two “cl” or two “gl” nonword targets in a row.

The 192-trial test phase was preceded by a training phase of 12 trials, half of which had a word target. All participants received the 12 trials in the same pseudorandom order.

2.1.3. Procedure

Each trial was organized as follows: At trial onset, a fixation cross was displayed at the center of the screen for 500 ms; it was immediately followed by a spoken prime, whose duration was 980 ms on average; at prime acoustic offset, a printed target was displayed for at most 250 ms, or until participant’s response. Targets were displayed at the center of the screen in white characters on a black background (Arial font, ~1.2 cm height). Response time-out was 2 s from target onset; inter-trial interval was fixed at 3.5 s. Participants were instructed to respond as quickly and accurately as possible by pressing a “yes” (word) or “no” (nonword) button on a button box, using their preferred hand for the “yes” response. Participants were tested individually in a quiet, dark room. They were seated in front of a computer screen, with their eyes at about 50 cm from the screen; they were presented with the auditory primes through professional headphones at a comfortable listening level.

2.2. Results and discussion

Data from seven participants were discarded. Two of them were not native speakers of French; five others made more than 20% incorrect responses on word targets. Hence, the data from 39 participants were retained. Five target words (“clavette,” “glycol,” “glapir,” “glaviot,” and “glaucome”) induced more than 50% “no” responses and were not retained
in the analyses. Response times (RT) more than two standard deviation above the mean (per subject and per condition), or shorter than 150 ms were not retained: 2.3% of the RT data was discarded with this criterion.

By-subject analyses of variance were run on the RT and the error data, with Target ("cl" vs. "gl" word target) and Priming (*/dl/, */tl/, and unrelated condition) as within-subject factors, and Group (3 levels) as a between-subject factor. We also ran by-item analyses with the same factors on the RT data. Yet, the three-fold counterbalancing was represented here by the List (of items) instead of the Group (of subjects) factor; List and Target were between-item factors and Priming was a within-item factor. F values are denoted in the following by F1 and F2 and p values by p1 and p2 for the by-subject and by-item analyses, respectively.

The factors linked to the counterbalancing (Group or List) were not significant for both the error and the RT data, ps > .1. Therefore, they will not be further discussed.

![Figure 1: RT data of Experiment 1 according to priming condition (*.tl/, *.dl/, unrelated) and target type (*.cl" vs. "gl" targets).](image)

We first discuss the RT data shown in Figure 1: Target was not significant overall in both by-subject and by-item analyses, ps > .05: average RTs for "cl" and "gl" targets were 656 and 634 ms, respectively. Priming was highly significant overall in both analyses, p < .001, due to a lower average RT in the */tl/ priming condition. But Figure 1 suggests, the interesting pattern is the Priming x Target interaction, which was indeed highly significant, F1(2,76)=37.31, p < .001; F2(2,82)=23.9, p < .001. This means that Priming had different effects on RTs for "cl" than "gl" targets. For "cl" targets, the unrelated condition and the */dl/ condition did not differ, p > .1, whereas RTs were shorter in the */tl/ condition than in the unrelated or */dl/ conditions, ps < .001. This means that */tl/ primes had a significant priming effect on "cl" targets (the effect size was 680-573=107 ms), which may be viewed as a facilitation relative to the unrelated condition; */dl/ primes rather tended to inhibit "cl" targets (680-715=35 ms), although the effect was not significant. Thus, */tl/ but not */dl/ primes significantly facilitated "clavier." The opposite pattern was found for "gl" targets: */tl/ but not */dl/ facilitated "glacier": For "gl" targets, the unrelated and */tl/ conditions did not differ, p > .4, whereas RTs were shorter by about 51 ms in the */dl/ condition than in the unrelated conditions, ps < .01.

We turn now to the error data. As can be seen in Figure 2, priming effects were less clear than those found for the RT data. For "cl" targets, however, the pattern of errors in function of priming condition paralleled that found for RTs. There were less errors with */tl/ than with unrelated primes, ps < .01; there were more errors with */dl/ than with unrelated primes, ps < .01; p < .05. Thus the trend for inhibition with */dl/ primes observed in the RT data emerged significantly in the error data. For the "gl" targets, there were more errors with */tl/ than with unrelated primes, ps < .05; p < .08 (marginal), but no difference between */dl/ and unrelated primes, F < 1.

Figure 2: Error data of Experiment 1 according to priming condition (*.tl/, *.dl/, unrelated) and target.

In the light of the predictions made in the Introduction section, the results clearly support the phonological rather than the lexical hypothesis. The latter hypothesis indeed predicted little or no facilitation of /kl/ or /gl/ targets by both */dl/ or */tl/ primes. We found instead that */tl/ primes strongly facilitated /kl/ targets (by about 107 ms) but not in the least /gl/ targets. The opposite pattern held for */dl/ primes, which facilitated /gl/ targets (by about 51 ms) but tended to inhibit /kl/ targets. This is almost exactly what was predicted by the prelexical repair hypothesis with, however, a rather surprising difference: We predicted residual priming of, for instance, "clavier" by */tl/ and we found a (non-significant) trend for inhibition, especially in the error data. The */tl/, */dl/ primes that were not congruent in voicing with their related /gl, kl/ target systematically induced more errors than in the unrelated condition. We return to this aspect in the general discussion.

Another interesting aspect of the data is the asymmetry between the size of the facilitation effects for the /kl/ and /gl/ targets. The effects seemed larger for */tl/-CLAVIER than for */dl/-GLACIER: 107 vs. 51 ms. This asymmetry is in line with the difference in size found for the dental–velar repair effects, which were found stronger for */tl/ than */dl/ in [1, 2]. Our data suggest that */tl/ is more often repaired as clavier and thus strongly facilitates "clavier," whereas */dl/ is less often repaired as glacier and thus facilitates "glacier" to a lesser extent.

Before we conclude, we briefly address a methodological aspect of Experiment 1, which also holds for cross-modal priming experiments in general. As is commonly accepted, we interpreted the RT difference between unrelated and related priming conditions as a facilitation effect. The problematic point is the "unrelated" condition, which is assumed to provide a control condition for the absence of facilitation. Indeed, it is difficult to avoid unpredictable, idiosyncratic associations of meaning or of form between control primes and targets, however carefully the control primes are chosen. A simple way to gauge the validity of the supposedly unrelated control primes is to replace them with silent primes. This is what we did in Experiment 2. At the same time, the silent prime might shed light on the general interpretation of priming effects. There is indeed another account of priming effects than facilitation, which is usually explained by preactivation. Van Orden [12] proposed that any prime is a perturbation for the
processing of an upcoming target. The larger the discrepancy between prime and target is, the larger the perturbation is. In that view, priming effects observed in form priming experiments simply indicate less perturbation from the primes that are more similar to the target. Logically, a “silent” auditory prime, that is, absence of prime, should produce very little perturbation, hence should not slow down the processing of the target.

3. Experiment 2

In this experiment, we used exactly the same targets as in the preceding experiment, but replaced all the auditory primes by a silence whose duration was about the average duration of the primes in Experiment 1.

3.1. Method

Eighteen students at Paris 5 University’s Psychology Institute, hence from the same population as that used in Experiment 1, participated in the experiment for course credit. They did not participate in Experiment 1 or in the subjective frequency pretest. Their mean age was 21 years. None of them reported hearing or reading problems.

Experiment 2 used the same target materials as those in Experiment 1. Primes were uniformly replaced with a silence of 900 ms, close to the average duration of all the primes used in Experiment 1. Put another way, the paradigm we used in Experiment 2 is a visual lexical decision paradigm, in which two types of targets are compared: “cl” words and “gl” words.

3.2. Results

Data from four participants were discarded. Three of them made more than 25% errors in average on word targets. One of them produced very slow RTs (more than 2 SDs from the mean). The data from 14 participants were thus retained. Since the goal of Experiment 2 was to gauge the validity of the unrelated priming condition in Experiment 1, we excluded the five target words that were not retained in Experiment 1. (They also induced more than 50% errors in this experiment.) We applied the same criterions as in Experiment 1 to discard outlier RT values. This excluded 5.2% of the RT data.

The mean error rates were 8.7% and 9.2% for “gl” and “cl” words, respectively. The RT data are summarized in Table 1, which compares the unrelated condition in Experiment 1 with the sole “silent priming” condition in Experiment 2. Numerically, RTs are slightly shorter for “gl” than “cl” targets by about 26 ms, and slightly shorter in Experiment 1 than 2 by about 24 ms.

Table 1. RT data in Experiment 2 (silent priming) and in Experiment 1, unrelated priming condition.

<table>
<thead>
<tr>
<th>Target type</th>
<th>Priming Condition</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>“cl”</td>
<td>silent prime</td>
<td>700 ms (116)</td>
<td>670 ms (92)</td>
</tr>
<tr>
<td></td>
<td>unrelated prime</td>
<td>672 ms (130)</td>
<td>650 ms (113)</td>
</tr>
</tbody>
</table>

By-subject and by-item analyses of variance were run to compare the RT data from Experiment 2 pooled with that of Experiment 1 for the unrelated priming condition, with Target (“cl” , “gl”) and Experiment (1, 2) as within- and between-subject (by-subject analysis) or between- and within-item (by-item analysis) factors, respectively. Both factors were non-significant in both by-subject and by-item analyses,Fs<1.

We may conclude that the unrelated priming condition of Experiment 1 was roughly equivalent to the silent priming used in Experiment 2, in that similar RT data were obtained. If the trend for slightly longer RTs (by about 20 ms) with silent than unrelated priming could end up being reliable (e.g., in testing more subjects to increase statistical power), the priming effects reported in Experiment 1 could be underestimated.

At any rate, the silent priming data clearly contradicts the view that any prime is a perturbation for the processing of a following target, as proposed in [12]. Indeed, the absence of prime, which can hardly be viewed as a “perturbation,” leads to even slightly longer RTs (numerically) than unrelated primes. We may therefore safely interpret positive priming effects as facilitation effects.

4. General discussion

In this study, we found that */tl/ primes facilitate /kl/ but not /gl/ targets and, symmetrically, that */dl/ primes facilitate /gl/ but not /kl/ targets. This pattern supports the view that the robust dental–velar repairs previously reported in [1, 2] are not due to lexical feedback. We propose that they are phonological in nature and operate pre-lexically. We also found substantial asymmetry in the facilitation effects induced by */tl/ vs. */dl/ primes (107 vs. 51 ms). The stronger facilitation induced by */tl/ than */dl/ primes is consistent with the larger repair effects for */tl/ than */dl/ reported in [1, 2]. We now turn to a somewhat unexpected aspect of the present data: They were more clear-cut than we predicted, with an all-or-none pattern of priming for voice-congruent *tlavier-CLAVIER and *dlacier-GLACIER vs. voice-incongruent *tlacier-CLAVIER and *dlacier-GLACIER targets. Whereas *tlavier strongly primed clavier (as much as is usually observed in cross-modal repetition priming), *tlacier did not prime glacier at all. That is, we did not find any residual priming.

That we found no residual priming at all with the voice-incongruent */tl/, *dl/ primes is more in line with the findings of [8] than [7]. The discrepancy with [7] might be due to the different paradigms used: we used form priming whereas [7] used semantic association priming. Semantic priming might be more resistant to phonetic distortion than form-priming, perhaps due to different timings of activation-deactivation. However, Bölte and Coenen ([10]) also found residual priming with cross-modal form priming. They found that paprika facilitated “paprika” by some 129 ms (repetition priming) and that minimally and maximally distorted primes (with respect to initial consonant), here baprika and zaprika, still facilitated “paprika,” both by about 50 ms. According to these findings, residual priming should have been found for *tlavier–CLAVIER or *dlacier–GLACIER. The reason why we did not find any residual priming but, rather, a non-significant trend toward inhibition, might be related to the increase in processing load imposed by the phonological repair of the illegal clusters */tl/ or */dl/. Additional cost in terms of processing time imposed by */tl/, *dl/ is indeed suggested by the phoneme monitoring data in [1]. Future research needs to address this issue.

5. Acknowledgements

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6. References


