PAIRWISE PERCEPTUAL MAGNET EFFECTS

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ABSTRACT

This paper explores the role of familiarity in speech perception. It is argued that "perceptual magnet effects" (the warping of the perceptual space by prototypical exemplars of a category) can be extended to the perception of pairs of sounds. Specifically, a prototypical exemplar of a contrast (that is, an instantiation of a contrast involving prototypical members of the pair) will be more perceptually distinct than a non-prototypical exemplar of the same phonological contrast. Conversely, a prototypical exemplar of an allophonically related pair of sounds will be perceptually less distinct than a non-prototypical exemplar of the same pair.

Keywords: Allophony, Contrast, Familiarity, Perceptual Magnet

1. INTRODUCTION

One of the most robust and linguistically interesting findings in speech perception is that specific language experience affects how listeners perceive speech [1, 3, 6, 7, 8, 9, 11, 12]. That is, while it is indubitably the case that some pairs of sounds are acoustically more distinct than others (for example, [u] and [k] are more distinct from each other acoustically than [ɹ] and [l]), and that pairs of sounds that are acoustically distinct may be perceptibly different even without native language experience with the sounds (e.g. [3]), it is also quite clearly the case that from the age of at least six months, infants become more and more perceptually attuned to the particular language they are learning [9]. In general, it is widely held that one consequence of this early onset of attunement is that acoustic differences that do not serve a contrastive function in a listener's native language are perceptually less distinct than differences that are contrastive [12].

In addition to the evidence showing that experience is crucial in *shaping* the perceptual system, however, there is also a body of literature that points to a *warping* of the perceptual space through particular language experience. The "perceptual magnet effect," first illustrated by Kuhl [8], is a phenomenon in which a prototypical exemplar of a linguistic category warps the perceptual space so that non-prototypical exemplars of the category are perceptually more similar to each other and to the prototype.

Furthermore, it has been shown that phonological relationships such as allophony and phonemic contrast also affect perception [4]. Pairs of sounds that are in allophonic alternation with each other in a language are perceived as less distinct than pairs of sounds that are phonemically contrastive in the language. It has also been shown that partial contrast plays a role in perception; pairs of sounds in contrasts that are neutralized in a given context are less perceptually distinct than pairs in contrasts that are never neutralized [6].

Taken together, the results of these studies show that phonological relationships affect speech perception [4, 6]; that a *lack* of experience with a non-native contrast can inhibit an adult speaker's ability to perceive the contrast [1, 12]; and that experience with a native category can warp the perception of members of that category [8, 9]. A natural question to ask, then, is whether *experience* with a native-language phonological relationship can warp the perceptual distance between the members of that relationship.

The goal of this paper is to address this question; the hypothesis to be tested is whether familiarity plays a role in enhancing the perception of phonological relationships. That is, does a prototypical contrastive pair—i.e., a pair that is composed of prototypical members of each segment in the pair—cause the members of the pair to "repel" each other perceptually, becoming more distinct as compared to non-prototypical instantiations of the contrast? Similarly, does a prototypical allophonic relationship cause the members of the pair to "attract" each other perceptually, becoming less distinct, as compared to non-prototypical instantiations of the same allophonic relationship?

2. FAMILIARITY AND THE PERCEPTION OF PAIRS OF SOUNDS

2.1. Experimental results pointing to the role of familiarity in speech perception

Hall & Boomershine [5] presented a series of perception experiments designed to examine the cross-linguistic perception of the pairs of sounds [d]/[ɾ], [d]/[ð], and [ð]/[ɾ], and found that the language in which the stimuli were produced had an effect on the perception results.

Their stimuli were pairs of nonsense words of the form VCV; within any given pair, both the talker and the vowels were kept constant while the consonant differed. The vowel was one of [i, ɑ, u]; the consonant was one of [d, ɾ, ð]. Crucially, in English, the pair [d]/[ɾ] represents a pair of sounds whose members are in an allophonic relation with each other, while the pairs [d]/[ð] and [ð]/[ɾ] represent pairs of sounds whose members are allophones of separate phonemes and are thus contrastive.

There were two sets of stimuli of this type; one set was recorded by two native English speakers (one male, one female); the other set was recorded by two native Greek speakers (one male, one female). These sets of stimuli were thus identical in terms of the phonological relationships they represented, but different in terms of the precise acoustic details of the stimuli.

The first experiment in Hall & Boomershine [5] was a speeded discrimination task in which native English-speaking listeners heard pairs of words such as [ɑdɑ] . . . [ɑðɑ] and then had to respond as quickly as possible as to whether the words in the pair were the same or different; reaction times were taken as an indication of perceptual distinctiveness. One group of listeners completed the task listening only to English stimuli; a separate group listened only to Greek stimuli. For this experiment, there was no effect of phonological relationship, but there was a significant main effect of stimulus set. For each pair, reaction times were shorter for English stimuli than for Greek stimuli.

The second experiment was a similarity rating task. Native English-speaking listeners were presented with pairs of stimuli such as [ɑdɑ] . . . [ɑðɑ] and had to rate how similar they thought each pair was, on a scale of 1 to 5. Again, one group listened only to English stimuli and one group only to Greek stimuli. The results of this second experiment showed a clear effect of phonological relationship, with the allophonic pair [d]/[ɾ] being rated as more similar than either of the phonemic pairs. At the same time, within each pair, the English stimuli were rated differently from the Greek stimuli. The allophonic pair was rated as more similar when it was presented in English than when it was presented in Greek, while the phonemic pairs were rated as more different when they were presented in English than when they were presented in Greek.

2.2. An acoustic explanation?

The results from Hall & Boomershine [5] indicate that native English-speaking listeners found Greek stimuli to be different from English stimuli in some global way, despite the fact that the two sets of stimuli presented the same basic phonological information. The most straightforward explanation for this result would be that there is an acoustic difference between the English stimuli and the Greek stimuli that led to different perceptual patterns in the two tasks. An alternative hypothesis is that the listeners' native experience with English—that is, their *familiarity* with the English stimuli—was the cause of the differences. Before pursuing this alternative hypothesis, however, we must evaluate whether an acoustics-based explanation can account for the data. This section presents the results of an acoustic study designed to determine whether the first, acoustics-based, hypothesis is feasible.

For each pair of segments, we examined whether the Greek pronunciation of that pair involved greater acoustic similarity than the English pronunciation, along each of three acoustic dimensions: duration, intensity, and the formant transitions into and out of the consonants.

Figure 1 shows the differences in consonant durations for each pair in each language. Because differences were calculated by pair, with talker and vowel context kept constant within each pair, no further normalization of duration was needed. Wilcoxon sum rank tests show that for each pair ([d] – [ɾ], [d] – [ð], and [ð] – [ɾ]), the difference in the pair as produced in Greek was greater than the difference in the pair as produced in English (all $p < 0.001$).

Figure 2 shows the differences in minimum consonant intensity for each pair. Intensity was measured at the point of minimum root-mean-square pressure within the duration of the consonant, with the expectation that more-sonorant sounds will have a higher minimum intensity than more obstruent-like sounds. Again, because differences were calculated by pair, with talker and vowel context kept constant within each pair, no further normalization of intensity was needed. Wilcoxon sum rank tests show that for each pair, the difference in the pair as produced in Greek was not significantly different from the difference in the pair as produced in English (all p > 0.40).

Figure 1: Differences in consonant durations for Greek and English stimuli for the pairs [d]/[ɾ], [d]/[ð], and [ð]/[ɾ].

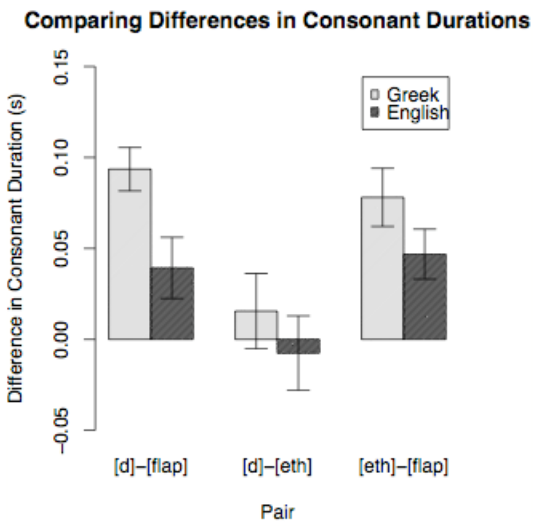
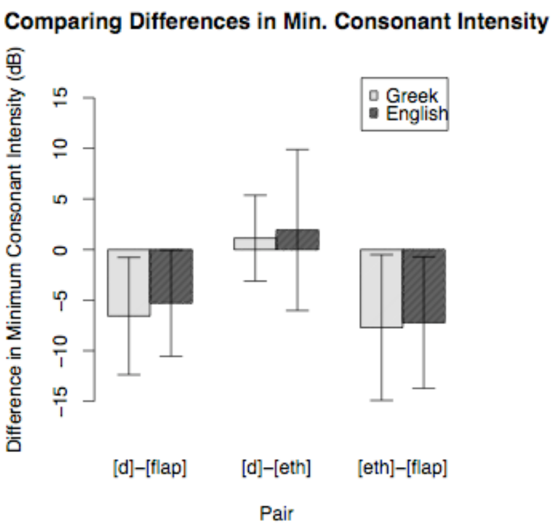


Figure 2: Differences in minimum consonant intensities for Greek and English stimuli for the pairs [d]/[ɾ], [d]/[ð], and [ð]/[ɾ].



F1, F2, and F3 were measured 20 ms before the onset and 20 ms after the offset of each consonant. There were no significant differences between pairs for any of these measurements, although it is possible that differences related to the consonants were masked by overall differences in the vowel quality between Greek and English.

In summary, where there were acoustic differences between Greek and English pairs, there was a greater difference in the Greek stimuli than in the English stimuli.

An acoustics-based account of the perception results from Hall & Boomershine [5] would predict that in the discrimination task, each pair of English stimuli should be acoustically more differentiated than each pair of Greek stimuli, in order to facilitate the judgment that the pairs are "different." For the rating task, an acoustics-based account would predict that the English [d]/[ɾ] pair would be acoustically more similar to each other than the Greek [d]/[ɾ] pair, while English [d]/[ð] and [ɾ]/[ð] would be acoustically more different from each other than the Greek [d]/[ð] and [ɾ]/[ð].

Given these predictions, none of the acoustic measurements examined here can account for the differences in the perceptual results. Only the results from the rating task for the pair [d]/[ɾ] are compatible with the acoustic measurements. Thus, we feel justified in pursuing an alternative explanation for the perceptual results.

One limitation of this acoustic analysis is the finite number of acoustic dimensions that were analyzed. Duration, intensity, and formant transitions, however, are the dimensions along which these consonants are most likely to vary across Greek and English (e.g., [2, 10]).

2.3. A familiarity-based account

While both phonological relationships and acoustic characteristics play a role in determining perceptual distinctiveness, neither factor appears to fully account for the data from Hall & Boomershine [5]. There was no apparent effect of phonological relationship in the discrimination task, and the perception of phonological relationships was different for the English and the Greek stimuli in the rating task. The acoustic analysis in the current study indicated that acoustic characteristics that might be expected to differentiate the English and the Greek stimuli in fact predict results opposite to those found.

By assuming that *familiarity* plays a role in perception, as suggested by Johnson [7], however, we can easily account for the results in [5]. All of the listeners in the experiments were native

English speakers with little or no second language experience. Thus, the acoustic characteristics of the English stimuli were far more familiar to the listeners overall than those of the Greek stimuli. In addition to the fact that the acoustic *differences* in individual pairs of stimuli in Greek were greater than or equivalent to the differences in pairs of stimuli in English, there were also *overall* acoustic characteristics of the Greek stimuli (e.g. precise vowel quality, etc.) that made it fairly clear that the Greek stimuli were not English, although listeners were not explicitly told this. Thus, their native familiarity with English may have helped listeners make faster discrimination responses and may have made their similarity judgments more extreme.

This role of familiarity in the perception of similarity between pairs of sounds can be thought of in terms of a pairwise perceptual magnet effect. A “familiar” pair is analogous to a “prototypical” member of a category; we can define a familiar pair as being composed of members that are prototypical exemplars of their respective categories. In the experiment reported here, the English stimuli can be assumed to be more prototypical of the English-language categories of the listeners than the Greek stimuli, because they were produced by native speakers of English.

The magnetic effect of a pair, however, differs from the magnetic effect of a single segment in at least two ways. First, the magnetic effect of a pair is internal to the pair: that is, it involves the perceptual distance between the members of the pair, rather than between a prototypical exemplar of a category and non-prototypical exemplars. Second, the magnetic effect of a pair depends on the phonological relationship the pair encodes. Thus, a familiar contrastive pair will warp the perceptual space so that the members of the pair are perceptually more distinct (they “repel” each other), while a familiar allophonic pair will warp the perceptual space so that the members of the pair are perceptually more similar (they “attract” each other). Non-prototypical pairs, like non-prototypical segments, do not exhibit the same perceptual warping as familiar or prototypical pairs.

3. CONCLUSION

Based on the experimental results reported here, the perceptual magnet effect can be extended to contrastive and allophonic pairs of sounds. While the effects of familiarity on the perceptual distinctiveness of pairs need to be verified with further experimental work (for example, by showing that Greek-speaking listeners show the opposite pattern of results as compared to the English-speaking listeners), the direction of research is clear. The prediction is that familiarity with the acoustic characteristics of a particular instantiation of a phonological relationship enhances the perception of the members of that relationship, causing contrastive pairs to be perceived as more distinct and allophonic pairs to be perceived as more similar.

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