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The Impact of Partial Phonological Contrast on Speech Perception[1]

Elizabeth Hume, Keith Johnson
Ohio State University
E-mail: ehume@ling.osu.edu, kjohnson@ling.osu.edu

ABSTRACT

In this paper, we consider the perceptual consequences of phonological contrast, a topic that has been of interest to both phonologists and speech perception researchers for some time. Drawing on perception data on Mandarin tone, we illustrate the impact of partial contrast on native and non-native speech perception. Partial contrast results when an otherwise contrastive pair of elements is neutralized in some context. We conclude that perceptual distinctiveness is a function of phonological contrast and that partial contrast reduces perceptual distinctiveness for native listeners

1. INTRODUCTION

It is well-established that phonological systems have an influence on speech perception. Studies in second language learning have found that listeners are more adept at perceiving sounds of their native language than those of a second language acquired later in life, e.g., [1], [2], [3], [4], [5], [6]. Familiar illustrations include the perception of English /l/ and /r/ by Japanese listeners, and that of Hindi dental and retroflex stops by American English listeners. Since the liquids are non-contrastive in Japanese, listeners have difficulty distinguishing between them [7]. For the same reason, perceiving a distinction between the Hindi stops is more challenging for English speakers [8]. The conclusion that can be drawn from these and other studies is that while listeners have no difficulty distinguishing between contrastive native sounds, they are less successful when it comes to non-native sounds that do not serve a contrastive function in their own language.

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However, phonological relations are more nuanced than is often assumed in the speech perception literature. For example, non-contrastiveness need not be viewed as a monolithic category. In some cases, non-contrastiveness describes a situation in which both elements occur in a language's inventory but where the relationship is allophonic. For example, the non-contrastiveness of Malayalam's dental and alveolar nasal consonants is due to their complementary distribution: [n̪] occurs morpheme-initially; [n] occurs morpheme-finally and intervocalically [9]. Lack of contrast can also result from the absence of one or more sounds from an inventory. In English, for example, a contrast between alveolar/retroflex nasals does not occur because there is no retroflex nasal in the language.

The relation between phonological elements can also be one of *partial contrast*. Consider the low-falling-rising tone (214) and the mid-rising tone (35) of Mandarin Chinese. In this case, the two tones are neutralized after a low-falling-rising tone; only the mid-rising tone occurs in this position. In all other contexts, the two tones are contrastive [10], [11], [12], e.g. /hao^{214} mi^{214}/ $\rightarrow$ [hao^{35} mi^{214}] 'good rice'. The tones 214 and 35 are thus partially contrastive; that is, they can be contrastive as well as non-contrastive in the language, depending on the context.

The above patterns exemplify a variety of phonological relations resulting in at least four degrees of contrast, as summarized in (1). These range from fully contrastive at the top to non-occurring at the bottom.

(1) PHONOLOGICAL RELATIONS
Fully contrastive, e.g. English l/r
Partially contrastive, e.g. Mandarin 214/35
Allophonic, e.g. Malayalam n̪/n
Non-occurring, e.g. English n/ɳ

The richness of phonological relations naturally leads to the question of whether listeners are sensitive to more subtle degrees of contrast than has previously been assumed. In this paper we take up this question by focusing on one particular relation: partial contrast. Drawing on perception data on Mandarin tone [13], we illustrate the impact of partial contrast on native and non-native speech perception. Due to the contextual neutralization of the otherwise contrastive tones /214/ and /35/, the pair is both contrastive and non-contrastive in Mandarin. By virtue of their contrastive status, we might expect the tones to pattern with fully contrastive sounds. Thus, the tones would be more easily distinguished by Mandarin listeners than by the non-native listeners. On the other hand, since the tones undergo contextual neutralization and thus, carry less of a functional load than that of fully contrastive pairs, we might expect them to pattern as if they were non-contrastive. Viewed from this perspective, Mandarin listeners would be expected to perceive the pair in a manner similar to the non-native listeners for whom the tones are non-contrastive. As we discuss below, the results support the latter hypothesis. We will conclude that perceptual distinctiveness is a function of phonological contrast and that partial contrast reduces perceptual distinctiveness for native listeners.

2. BACKGROUND

The research reported on in this paper forms part of a larger research program investigating the interplay of phonology and external factors such as speech perception, articulatory ease, social factors, and cognition. Some of the research questions addressed in this program include: Do external factors shape phonological systems and if so, how?; Do phonological systems shape external factors, and if so, how?; What is in the synchronic grammar of a language? Do external factors directly influence phonological theory? Figure 1 presents the relevant portion of our model [14] which outlines our current views on these questions.

We assume that in the study of language sound systems we work with two symbolic domains: one cognitive, the other formal. The cognitive symbolic representation of a language's sound system, characterized as *p*, is embodied in an individual's brain. We may assume that *p* is a component of *l*, the cognitive symbolic representation of a language. The sound system of a community of speakers/listeners can thus be defined as a collection of *p*'s. The formal symbolic domain defines the inventory of symbols and the procedures for manipulating the symbols. The theory describes sound patterns observed in language, as represented by the arrow pointing from *p* to *formal phonological theory*. It is these sound patterns that constitute the data that the theory is based on. The arrow pointing from formal phonological theory to *p* reflects the main goal of the theory which is to predict possible grammars. The model also illustrates the relationship between external factors, in this case speech perception, and the two symbolic domains. Notice that perceptual abilities can both influence sound systems and be influenced by one's language, shown by the bi-directional arrow in the diagram. In our view, cognitive language sound patterns (*p*) are directly influenced by external forces like perception. However, the connection between formal phonological theory and external forces is indirect. The formal theory describes patterns found in languages and from these, derives cross-linguistic generalizations about those patterns. To the extent that language sound patterns are caused by external factors such as speech perception, these factors are reflected in the theory. Yet, to incorporate them directly into phonological theory erroneously implies that they are exclusive to language. Each aspect of the model constitutes an important area of research which, together, will lead to a more comprehensive understanding of language sound structures.

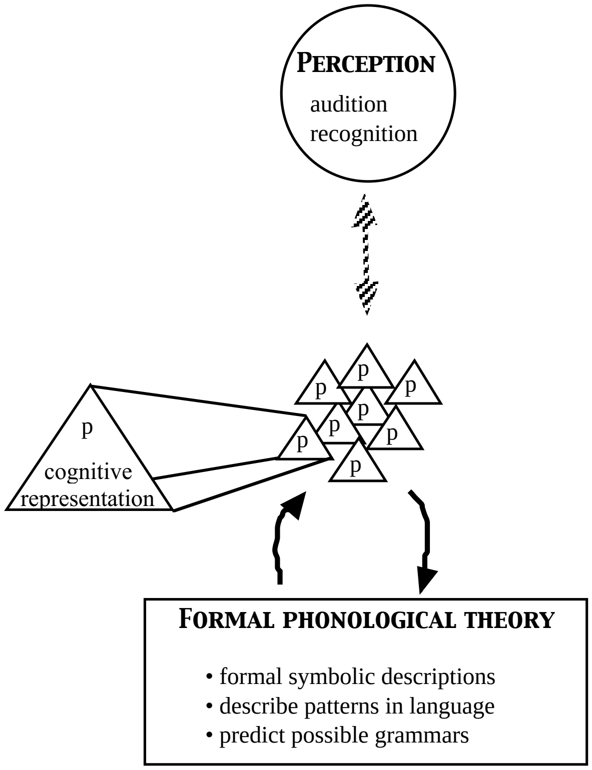

Figure 1: Part of a model of the interplay of phonology and external factors such as speech perception [14].

3. THE IMPACT OF PARTIAL CONTRAST ON SPEECH PERCEPTION

Tone sandhi in Mandarin Chinese illustrates the influence of partial contrast on perception [13]. Mandarin has four lexical tones: level high (55); mid-rising (35); low-falling-rising (214); high-falling (51). (The numbers in parentheses indicate the pitch values of the tones on a five-level scale.) As noted above, the phonological process of interest concerns the well-known Mandarin tone 3 sandhi in which a low-falling-rising tone is simplified to mid-rising just in case it is followed by another low-falling-rising tone, i.e. /214 214/ → [35 214], /hao^{214} mi^{214}/ → [hao^{35} mi^{214}] 'good rice' [10], [11], [12]. Huang (2001) argues that this process is a case of perceptually tolerated articulatory simplification [15], [16], [17]. In other words, the contour tone 214 is simplified to 35, rather than to 55 or 51, one of the other two "simpler" tones in the language, because 214 is more similar to 35 than it is to either of the other tones. To test this hypothesis, native speakers of American English and Mandarin Chinese discriminated pairs of the four Mandarin Chinese tones. Similarity among tones was measured using reaction time from an AX discrimination task, with tones produced by a Mandarin speaker. The perceptual distance was taken as 1/reaction time and these distance estimates were entered into multidimensional scaling analyses to visualize the perceptual tone spaces for American English and Mandarin Chinese listeners. The tone spaces were rotated so that tone 55 and tone 51 fall on a vertical line. The results support Huang's hypothesis; listeners from both languages had the greatest difficulty distinguishing between 35 and 214, as shown in Figure 2.

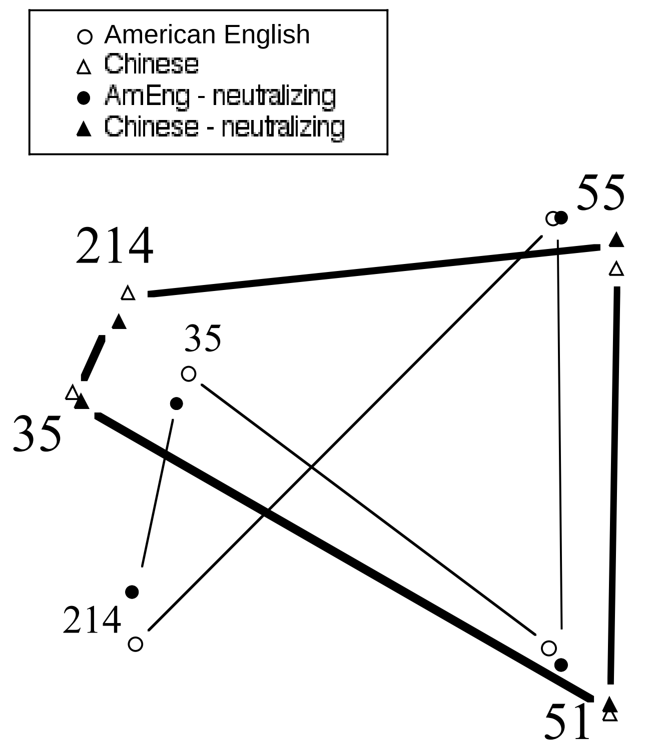

Figure 2. The four tones of Mandarin Chinese in perceptual spaces for Mandarin Chinese and American English listeners [13].

One thing to notice is that the overall perceptual space for Mandarin listeners is expanded, as compared to English listeners. This is just what we expect given that the four tones are contrastive in Mandarin. Of particular interest, however, is the observation that this space is not expanded when it comes to the tones 35 and 214. Instead, we see perceptual merging. Even more striking is the observation that perceptual merging of tones 214 and 35 by Mandarin listeners occurred both when the tones were presented to subjects in the neutralization context, as well as in the non-neutralizing environment. These results strongly suggest that partial contrast has an overall effect on the perception of the relevant features in the language in general, even in contexts in which there is no neutralization.

To further test the effect of partial phonological contrast we presented sinewave analogs of the four Mandarin tones to American English and Chinese listeners in a minimal uncertainty AX discrimination paradigm ("fixed discrimination" [18]).

In this task we found (as did Huang earlier) that the longest reaction times for "different" responses for both the American and Chinese listeners were for the 214/35 discriminations. This is the result predicted by Huang's hypothesis that the Mandarin tone 3 sandhi has a basis in perception.

However, processing the data in the same way as before - with the inverse of reaction time for correct "different" responses as our measure of perceptual distance and mapping the perceptual spaces using MDS - we find that tones 214 and 35 are better separated for these nonspeech sinewave analog stimuli than in the perceptual space for speech tokens (Figure 3).

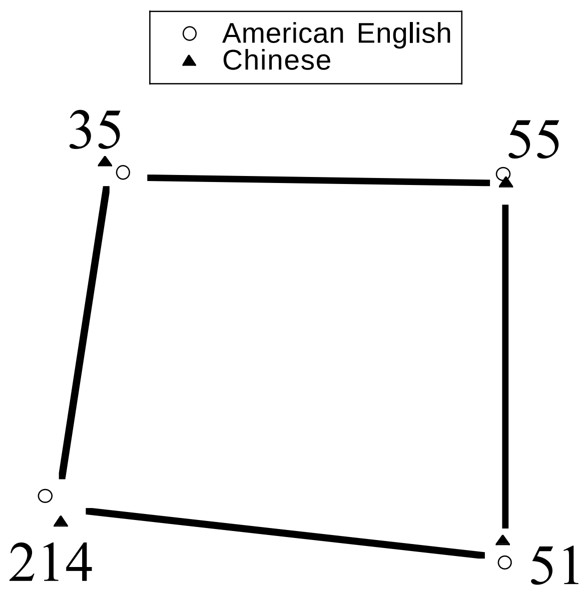

Figure 3. Sinewave analogs of the four tones of Mandarin Chinese in perceptual spaces for Mandarin Chinese and American English listeners.

With these stimuli Mandarin Chinese and American English listeners had remarkably similar perceptual spaces and the spaces resemble the American English space for naturally produced tones. Tones 35 and 214 are not collapsed, and the horizontal dimension corresponds to the starting pitch of the tone and the vertical dimension corresponds to the ending pitch of the tone (with 214 realized more like 21). Thus, one effect of language experience on the perception of Chinese tones is to perceptually merge tones 35 and 214 - the partially contrastive tones. Regarding the main point of this paper, these results with sinewave analogs of the Mandarin tones suggest that the perceptual merger of tones 214 and 35 is a result of the phonology of Mandarin — the partially contrastive tones show heightened perceptual merger.

4. CONCLUSIONS

The Mandarin tone results suggest that the influence of contrast on speech perception is not all or none. Despite their status as contrastive in the language, the 214/35 tonal pair displayed a perceptual merging effect for Mandarin listeners similar to what we might expect for non-contrastive elements. Consequently, we suggest that a fully predictive model of the influence of phonology on speech perception needs to take into account the different types of phonological relations that hold between sounds in a given language. Our results also underscore the fact that speech perception is not a universal, monolithic entity. Language specificity needs to figure into any account that draws on speech perception as a means of predicting phonological patterns.

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