Introduction

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Since Saussure, it has been recognized that contrast is central to phonological theory. Goldsmith (1996), in his introductory article in *The Handbook of Phonological Theory*, identifies contrast as the question that "lies at the doorstep of phonemic theory." Contrast played an important role in the major phonological schools of the twentieth century, and is again the subject of renewed interest. Despite its centrality, few works have explicitly taken contrast itself as their central theme; this volume puts contrast at the center, so as to make explicit how it works and its importance to phonology.

In particular, we focus on the role that contrast in phonology plays in three areas: phonological theory (grammar), perception, and acquisition.

1. Phonological theory

This section is concerned with the role of contrast in phonological theory and the description of phonological systems. How is contrast determined in a given inventory? To what extent does it play a role in accounting for sound patterns in language? How is it represented? What is the role of noncontrastive features?

Dresher looks at how phonologists decide which feature specifications are contrastive and which are redundant in the phonemes of a given phonological inventory. He argues that phonologists have vacillated between two different and incompatible approaches to this question, one based on minimal pairs, and the other based on a hierarchy of features (Jakobson and Halle 1956). He argues that the former approach is fundamentally inadequate, despite its intuitive appeal, and that the latter approach is superior.

One consequence of adopting an approach to contrast that depends on a feature hierarchy is that the same inventory can be assigned different sets of contrastive feature specifications under different orderings of the features. It follows that the set of contrasts operative in a given inventory are not self-evident, and allow for variability, to the extent that the ordering of features can vary from one language to another.

Hall and Kuroda both address, from very different perspectives, the problematic behaviour of certain phonemes with respect to voicing assimilation.

Hall builds on the general approach to contrastive specification advocated by Dresher and investigates what role redundant features play in phonology. He formulates the strongest version of what he calls the *contrastivist hypothesis* as follows: "redundant features are not present in the phonological computation." He argues that Czech voicing assimilation demonstrates that this strong formulation is not correct. In particular, while an analysis employing minimally contrastive specifications can account well for various subtleties of the Czech voicing assimilation, it also incorrectly predicts that the Czech phoneme *ř* ([r̝]) should become [t] when devoiced; instead, it becomes a voiceless [r̝̥], which is not an underlying phoneme in Czech. To solve this problem Hall proposes a weaker version of the contrastivist hypothesis: "redundant features are not active (but may be present) in the phonological computation." That is, they may play a prophylactic role, preventing mergers that would be expected if only contrastive features were in play.

Kuroda shows that different processes affecting voicing in Japanese do not treat nasals, liquids, and glides in a consistent way: a rule of regressive voicing assimilation is triggered by voiced obstruents, nasals, liquids, and glides; progressive assimilation is triggered only by voiced obstruents and nasals; and rendaku (which causes voicing) is blocked only by voiced obstruents. Kuroda proposes a feature geometry that encodes dependencies that mirror the properties of the vocal tract. In this framework, he proposes that the equivalent of the feature [+voice] is contrastive in obstruents and nasals, but redundant in liquids and glides. In his analysis, progressive assimilation is triggered by contrastive [+voiced], regressive assimilation by any phonetically voiced segment (contrastively or redundantly voiced), and rendaku targets a level of the feature geometry that isolates voiced obstruents, to the exclusion of nasals and other sonorants. Despite the differences in their frameworks, both Hall and Kuroda make crucial use of a distinction between contrastive and redundant feature specifications, and both observe processes that refer to contrastive as well as redundant specifications.

Though making distinctions between contrastive and redundant properties of phonemes, both contributions also illustrate how these distinctions depend on a phonological analysis; they do not simply flow from the phonetics of the inventory. Identifying what the laryngeal contrasts are in Czech and Japanese is a function partly of the general theory and partly of the particular analysis.

Scobbie and Stuart-Smith take the idea of indeterminacy of contrast further, arguing that contrast must be treated as an inherent gradient phenomenon. They argue that ambiguity in deciding whether a surface contrast is phonemic or allophonic, or which properties are contrastive and which are redundant, is not something that the analyst or native speaker language learner can neces-

sarily always resolve. This is particularly so with respect to contrasts that are "marginal" to the system, where marginality is a heterogeneous characteristic that can be due to diverse causes. They propose that "exemplar" approaches to phonological representation (Pierrehumbert 2001, Coleman 2002) might have the flexibility to account for what they call "quasi-phonemic" contrasts in a "fuzzy" inventory.

In the final chapter of this section, **Hansson** considers how contrast affects phonological systems, with special attention to the interplay between vowel harmony and the neutralization of lexical contrast. He observes a striking difference between consonant harmony and vowel harmony with respect to contrast. Consonant harmony often results in the neutralization of an underlying contrast; for example, sibilant harmony in Ineseño Chumash changes underlying /…s…ʃ…/ to […ʃ…ʃ…] as well as /…ʃ…s…/ to […s…s…]. A similar pattern of neutralization, however, is unattested for vowel harmony; there are no known cases, for example, of a language with backness harmony that neutralizes an underlying contrast between a front and back vowel, so that underlying /…æ…+…a…/ becomes […a…+…a…] and /…a…+…æ…/ becomes […æ…+…æ…]. Hansson proposes that the recoverability (Kaye 1974) of a neutralized underlying contrast is much easier in consonant harmony than in vowel harmony, because of the sizes of consonant and vowel inventories and the relative frequency of neutral segments in each type of harmony.

2. Perception

In recent years the effects of contrast on perception have been studied from various points of view. Conversely, perceptual explanations have been suggested for why some contrasts are less likely in certain positions. An important question is the role that non-contrastive features play in the perception of contrasts in first and second languages. Because of the special connection between contrast and perception, it is fitting that this be one of the main themes of this volume. The chapters dealing with perception focus on different aspects of contrast. While Boomershine, Hall, Hume, and Johnson examine surface contrasts that reflect different underlying relationships in different languages, Mielke focuses more on differences in perception that arise due to phonotactic differences between languages. Kochetov addresses perception in a different way, examining the relationship between vowel inventories and the existence of secondary articulations in a language.

Boomershine, Hall, Hume, and Johnson begin their chapter with a discussion of Trubetzkoy (1939), noting that he identifies native language contrasts as

having an important influence on perception of speech sounds. They focus on one assumption that he makes, that different degrees of contrast may have different consequences for speech perception. These authors examine the impact of contrast versus allophony on the perception of speech sounds by Spanish-speaking and English-speaking listeners. More particularly, they examine the perception of three sounds, [d], [ð], and [ɾ], that group together differently in English and Spanish in terms of the type of contrasts they participate in. They conclude, supporting findings in the literature, that phonemic contrasts are more perceptually distinct than allophonic contrasts, with English speakers finding [d]/[ð] more perceptually distinct than Spanish speakers, while Spanish speakers found [d]/[ɾ] to be more distinct. Thus, phonemic contrast influences speech perception, and, in addition, surface phonetic detail influences perceptual discrimination judgments. The authors argue that this distinction between contrast and allophony is best accounted for by an exemplar model. Their conclusion is particularly important for an understanding of the role of contrast in perception, showing the important role of phonemic contrast, and, in addition, recognizing that allophony and non-contrastiveness are not treated in the same way.

Mielke, like Boomershine, Hall, Hume, and Johnson, deals with perceptual salience and contrast. He is concerned with the influence of perception on contrast and how contrast influences perception. He focuses specifically on a contrast between /h/ and its absence in four languages. Mielke finds that /h/ deletes in environments where it is perceptually weak cross-linguistically. Nevertheless, differences exist between languages, with /h/ being more perceptible by speakers of some languages than others. Mielke relates this difference to phonotactic restrictions in the different languages. He further argues that, in addition to acoustic factors, functional load has an influence on contrast, with increased functional load associated with contrast maintenance. He thus finds that a variety of factors are important in the preservation or loss of contrast.

Kochetov, too, studies perception, in this case focusing on misperception. He takes as his study the relationship between secondary articulations on consonants and vowel contrasts in phonological inventories. Kochetov argues that interactions between a speaker and listener/learner constrain the relationship between secondary articulations on consonants and vowel inventories, with languages with secondary articulations not having complex vowel systems and languages with complex vowel systems not having secondary articulations. He argues that limitations on production and perception create this tendency to avoid a language having both distinctive secondary articulation contrasts and multiple distinctions in rounding/backness and vice versa. These markedness effects are not part of universal grammar, he argues, but rather result from low-

level interactions. He investigates this claim in a simulation between a speaker and a listener, and argues that there is perceptual confusion of vowels and secondary articulations; when both are present they are difficult to replicate, with frequent undershoot. No a priori knowledge of markedness is necessary. Thus, a contrast of the type investigated is very unlikely to develop, as a system of this sort will shift to a stable pattern.

3. Acquisition

The third major focus of this volume is on first and second language acquisition. Much research in child language has looked at the order of acquisition of contrasts; explaining the observed sequence is one of the main goals of this research. At the same time, there have been major advances in the study of the perception of contrasts by infants. Researchers in second language acquisition have devoted much attention to the perception of contrasts, and the extent to which this is disrupted by the different contrastive system of the first language.

3.1. First language (L1) acquisition

Research on infant perception has established that 6–8 month old infants can discriminate contrasts that are not used in the ambient language more easily than adults, and gradually lose this ability in the next few months. **Weiss and Maye** point out that there are also studies that show that some contrasts are difficult for infants to perceive, though adults whose native language uses these contrasts perceive them well. It follows that exposure to these contrasts facilitates their discrimination. Weiss and Maye consider the extent to which statistical learning might facilitate the perception of difficult contrasts. They design an experiment in which continua of synthetically manipulated tokens ranging from prevoiced to short-lag velar stops are presented to infants in two conditions: in one condition more tokens are chosen from the extremes of the continuum, simulating a bimodal distribution; in the other condition more tokens are selected from the middle of the continuum, resulting in a unimodal distribution. Infants exposed to the bimodal distribution indeed do better at discriminating test pairs of prevoiced and short-lag velar stops.

Being able to discriminate phonetic sounds is a prerequisite to acquisition of phonology. But being able to distinguish between two sounds in a phonetic discrimination task does not mean that infants are able to store or represent

these contrasts in their developing phonology. Thus, it has been shown that children's ability to discriminate sounds deteriorates significantly when the sounds are presented in the form of contrasting words. **Fikkert and Levelt** propose that there is a fixed order to the development of phonological point of articulation contrasts in words. In considering the patterns exhibited in their database of five Dutch children recorded weekly for about a year, they address some fundamental differences between child language phonology and adult phonology. In particular, child phonology is frequently characterized by an extensive "consonant harmony"; if this kind of harmony reflects universal markedness constraints, it is unexplained why it is unattested in adult phonology. They propose instead that "consonant harmony" in children results from a combination of factors. In early stages of acquisition, children cannot use point of articulation contrastively within a word, resulting in the appearance of harmony. Later, when children begin to make such contrasts, they extrapolate from their developing lexicon to formulate constraints that do not hold, or do not hold as strongly, of adult language. Thus, in their model, children's lexical representations are not adult-like to begin with, as is sometimes assumed, but develop as they are able to manipulate more contrasts independently.

3.2. Second language (L2) acquisition

The final three chapters deal with the acquisition of contrasts in a new language (the target language) and the role that the native language plays in this acquisition. Boersma and Escudero (Dutch learners of Spanish) and Cebrian (Catalan learners of English) look at the acquisition of vowel systems, while Goad (French and English learners of Thai) focuses on laryngeal contrasts. The three chapters all involve perceptual experiments. Taken as a whole, these chapters show that learners do not blindly map from their first language phonetics onto the second language phonetics, though Boersma and Escudero argue that in the initial stages this is the default strategy. Rather, learners dealing with a new phonemic system recalibrate their perception of it in a language-specific way.

Boersma and Escudero ask how learners whose native language has a large number of vowel contrasts (Dutch, in this case) will handle a system (Spanish) with a smaller vowel inventory. They shed light on the mechanisms responsible for the development of a separate "perception grammar" for the second language. They show that while beginning Dutch learners initially will tend to identify Spanish vowel tokens with the auditorily most similar Dutch vowels, over time they tune their perception of Spanish vowels to better align with the Spanish system of contrasts. Thus, proficient learners per-

ceive a token [æ] as the vowel /ɛ/ when they are told it is a Dutch vowel, but as /ɑ/ when listening in "Spanish mode". Boersma and Escudero present an Optimality-Theoretic model of how learners converge on the appropriate perception grammar.

Cebrian looks at how Catalan speakers fare in the perception and production of front vowels in English, where there is a mismatch between the two languages. He shows that native Catalan speakers with little or no knowledge of English readily identify English [i] with Catalan /i/, but have no consistent Catalan mapping of English [ɪ], since Catalan has no such vowel phoneme. Interestingly, native Catalan learners of English do less well in categorizing English [i]. Cebrian finds that whereas native English speakers rely mostly on spectral cues to distinguish /i/ from /ɪ/, Catalan speakers rely more on duration. This study shows that where a new contrast (/i ɪ/) must be acquired, the perception system may have difficulty in reallocating the vowel space, even when one of the vowels (/i/) is an almost perfect fit with one of the vowels (/i/) in the native language system. This result underscores that, as Cebrian writes, "vowels are not acquired individually but as part of a system of contrasts with the consequence that the formation of one vowel category can directly affect the categorization of another vowel."

Goad examines what the acquisition of a new contrast can reveal about the nature of the underlying contrasts in the native language. She focuses on the acquisition of the three-way voicing contrast in Thai (voiced, voiceless unaspirated, and voiceless aspirated) by speakers of French and English, languages with a two-way voicing contrast. As English and French differ in the phonetic implementation of the voicing contrast, it is reasonable to assume that English speakers may perceive the Thai contrasts differently from French speakers. French has a contrast between a plain voiceless stop and a voiced stop; lacking aspiration, it is not surprising that French listeners have difficulty discriminating Thai voiceless unaspirated and voiceless aspirated stops. English voiceless stops are aspirated; nevertheless, English-speaking subjects fare no better than the French-speaking subjects in discriminating the aspirated and unaspirated voiceless stops.

These results can be explained if, as traditional phonological analyses have proposed, English speakers represent only the feature [voice] in their lexical representations, and not aspiration, encoded by the feature [spread glottis]. Goad concludes that lexical representations are abstract, and that a feature that is present in the phonetics, but not in lexical representations, does not necessarily aid in the perception of L2 contrasts that use that feature. Goad goes on to discuss results that appear to point in another direction, arguing that the position that English stops are unspecified for [spread glottis] can be upheld.

4. Summary

The three main areas covered in this volume – theory, perception, and acquisition – are tightly interconnected: research on the acquisition of a contrast may assign a central role to perception; neither of these can be studied in isolation from an account of the place of contrast in phonological theory and description. We hope that this volume will help to illuminate these interconnections and a variety of approaches in contemporary research on contrast, and that it will stimulate further research in these areas.

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