Featural Categories in English Phonemic Acquisition

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1. Introduction

A long-standing issue in the study of developing sound systems concerns the basic units of organization in phonological acquisition. That is, what are the primitives that children first focus on and use as rudimentary building blocks in construction of the phonology? Over the years, a full range of hypotheses have been advanced, spanning all components of word level phonology. The feature (Jakobson, 1968/1941), segment (Templin, 1957), syllable (Waterson, 1971), and word (Iverson & Wheeler, 1987) have each been taken to be the fundamental organizational unit of acquisition.

The purpose of this paper is to examine specifically the feature as a basic unit in phonemic acquisition. Three key questions are addressed: Is the feature a relevant organizational unit? If so, what are the critical featural properties that children acquire and, how does this acquisition process take place? These issues have been the focus of our current research on the development of phonological categories by young children ages 3 to 6 who are acquiring English in a normal fashion, as well as those children who are experiencing phonological delays. We summarize herein psycholinguistic evidence supporting the validity of featural units and their specification in phonemic acquisition (Gierut, 1996 a), and the mechanism children use to elaborate phonemic structure (Gierut, 1994, 1996 b; Gierut & Morrisette, 1996). These data come from experimental studies of phonological categorization and clinical treatment studies of phonological change.

2. Features as units of organization in acquisition

To examine the first issue of feature specification and representation in phonological acquisition, we adapted an experimental methodology known as the *free classification paradigm* within the context of underspecification theory. This paradigm has been widely employed in the study of children's conceptual development, with some extension to concepts of language (Treiman & Breaux, 1982; Walley, Smith, & Jusczyk, 1986; Gerken, Murphy, & Aslin, 1995). The general procedure involves presenting a child with a *standard stimulus* for comparison to a set of *test stimuli* that differ from the standard along certain controlled dimensions. A child judges the perceived similarity of each test item relative to the standard. Similarity judgments may include an identical match of a test item to the standard, but may also include 'errors' or nonmatches. All test stimuli judged to resemble the standard are interpreted as members of a given category. By examining the relationship among category members, the common and defining properties of that category emerge. This then is taken as evidence of a child's conceptual knowledge. In this study, the free classification

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paradigm was used to tap children's conceptual knowledge of distinctive features.

Thirty normally developing children acquiring English ages 3 to 5 participated. For all children, target stops and most fricatives were produced and used appropriately, with exception of interdental / θ /. This was the only systematic pattern of production that provided a way of distinguishing children on the basis of linguistic knowledge. Consequently, children were assigned to one of two experimental groups: those who used / θ / in an ambient-like way (hereafter + θ group) and those who did not (- θ group).

Consonantal contrasts to be classified were selected based on the presumed specification of featural distinctions in fully developed languages as in Table 1. Place distinctions involved the labial–coronal contrast, whereas manner distinctions involved the continuancy contrast among stops and fricatives. The distributed property (associated with degree of stricture) was also added to the test set for linguistic and developmental reasons. Linguistically, both labials and coronals have distributed counterparts within the continuant series (Selkirk, 1993); yet, only the coronal distributed fricative / θ / is relevant to target English. By including both / θ ɸ / as test segments, it was possible to sample children's classification of featural dimensions both present and absent in the ambient system. This addressed the role of linguistic input in phonological categorization. For developmental reasons, it was also important to include distributed segments. It is frequently reported that children acquiring English have difficulty in production and distinctive use of / θ / (Smit, Hand, Freilinger, Bernthal, & Bird, 1990). Even though children may be normally developing, / θ / may not be in the phonemic repertoire, as evidenced by the - θ group of this study. The categorization patterns of the different groups of children, + θ versus - θ, addressed the role of linguistic knowledge in the conceptualization of distinctive features.

Table 1. Featural contrasts sampled in the free classification task

			Manner		
			Marked		**Unmarked**
			Continuant		**Noncontinuant**
Place	**Marked**	**Labial**	f	ɸ	p
	Unmarked	**Coronal**	s	θ	t
			Distributed		

Consonant–Vowel stimuli were prepared for each test segment / s θ t f ɸ p / followed by the vowel / a /. A male speaker trained in articulatory phonetics produced tokens of each syllable in citation form, and these were recorded digitally. From this corpus, one exemplar of each CV stimulus was selected for use in creating master experimental tapes. Each master tape consisted of instructions, the standard stimulus for a particular block of trials, followed by the test items in that block. Each CV exemplar stimulus served as the standard for one block of trials. For example, in one block, / θa / was the standard for comparison to each of the test items / sa θa ta fa ɸa pa /. Similarly, in another block, / sa / served as the standard of comparison to / sa θa ta fa ɸa pa /, and so on.

In game format, a child was presented with a small trash can and a character bank having animate properties. From the master experimental tape, a child heard the bank's favorite sound (i.e., the standard CV stimulus for a given block of trials). The child was to place a chip in the bank every time the bank uttered its favorite sound (i.e., the CV test items for that block). If the bank uttered a sound other than its favorite, then the child was to place the chip in the trash. During the classification task, the examiner scored a child's responses as either resemblents of the standard or not; accuracy of responding was not an issue. Data from the free classification task were analyzed statistically using binomial distributions ($p < 0.05$), with results of the + θ and - θ groups analyzed independently. Binomial distributions established first which test consonants belonged to a given category. Then, test consonants of a given category were further examined to determine which features were common to and shared by all members of that set. These were taken to be the defining features of that category for use in comparison of the + θ versus - θ groups. It was not our intent to describe why a particular segment may have been included in one category but not another, or to project prototypicality and strength of category membership for particular consonants. The present focus was exclusively on defining featural relationships and not on individual segments.

Categorization results for each group ± θ are summarized in Tables 2 and 3. The left-most column lists each standard. Segments classified as resemblents of a given standard are shown in the center column. These were the sounds children judged to be members of a given category. In the right-most column are the common featural properties shared by all of the members of that category following from Table 1.

Beginning in Table 2 with coronals for the + θ group, when / s / was presented as the standard of comparison, children classified / s / and other test items / θ f ɸ / as members of the set. The only manipulated featural property common to all segments of this set is continuant. Thus, continuant was identified as the defining featural property of the / s / category for these children, which is wholly consistent with its presumed specification in fully developed systems. When / θ / was the standard, / θ ɸ / were grouped as resemblents, sharing two features: continuant and distributed. When the standard was / t /, children selected / t f / as similar, but these share no common manipulated features. Thus, the category / t / had no apparent defining featural properties.

Table 2. Categorization results for the + θ group (adapted from Gierut, 1996 a)

Standard stimulus	Resemblents	Defining features
Coronals		
s	s θ f ɸ	continuant
θ	θ ɸ	continuant + distributed
t	t f	—
Labials		
f	f ɸ	labial + continuant
ɸ	f ɸ θ	continuant
p	p f ɸ	labial

The categorization of labials by the + θ group was distinct from coronals, but only for the standards / f p / as in Table 2. That is, the + θ group defined / f / by the features labial and continuant, with / f ɸ / as resemblents. A place distinction between labials and coronals was thus maintained given the uniqueness of the defining properties of the / f s / categories (i.e., labial and continuant as opposed to just continuant respectively). For the standard / p /, category membership included / p f ɸ / related only in labiality. A place contrast between labials and coronals was again observed, given that the noncontinuant standards / p t / were classified in different ways (i.e., labial versus no feature specification respectively). By comparison, the standard / ɸ / was defined by the feature continuant, with / f ɸ θ / identified as category members. The defining property of / ɸ / was identical to that of / s /. These categories were undifferentiated in place (labial–coronal) and manner (distributed–nondistributed). It is noteworthy that this merger specifically involved / s /, the least specified or default fricative segment according to underspecification theory. This suggests that children may resort to default properties when classifying unknown phonological segments like / ɸ /.

Collectively, findings for the + θ group demonstrate that children's category judgments were not random, but derivable from featural specifications proposed for fully developed languages. Only marked features were used to determine category membership, with one value of a feature identified as the defining property (e.g., continuant, but never also noncontinuant). This is consistent with what we would expect from a radical underspecification or alternatively, a

monovalent account. By comparison, if contrastive specification guided children's judgments, we would predict a different pattern of results. For example, for manner, we would expect continuant to be a defining property for fricative standards as the data show, but also that *non*continuant would define the stop standards. Here, we might expect that, when presented with / t / as the standard, children would also include / p / as a member of the set, and vice versa. From a response pattern like this, noncontinuant would emerge as a defining feature of category membership directly in parallel to the feature continuant but, in fact, this did not occur. Similarly, for place within a contrastive framework, we would expect similarity judgments based on labiality as for the standards / f p /, but we would also predict judgments based on coronality for standards / s θ t /. Here, we would expect children to classify only coronal test stimuli together, setting aside labial items. Yet, as the data show, some labials were included as category members of / s θ t / standards. These data suggest that children as young as 3 may rely on featural dimensions that are radically underspecified in conceptualization of sound classes.

Category judgments of the + θ group were also generally consistent with children's linguistic knowledge. Children used / s θ t f p / contrastively in the productive sound system. This was likewise reflected in the uniqueness of the defining features of each of these standards. By comparison, children did not use / ɸ / contrastively in production, and there was a corresponding lack of differentiation in the defining featural property of this category. This collapse was noteworthy for two reasons. First, English does not provide evidence of a distributed contrast within the labial series. Second, the free classification of stimuli may be intimately tied to features that are used contrastively in a child's productive system. It was possible to further establish the relevance of linguistic input and linguistic knowledge in children's categorization by examining the results of the - θ group. For this group, linguistic input was available but linguistic knowledge (in the form of productive contrasts) was not.

Data for the - θ group are shown in Table 3. The key finding for the - θ group was that the featural property defining the coronal categories / s θ / and the labial categories / f ɸ / was identical. For all four standards / s θ f ɸ /, continuant was the only common and defining featural property associating category members. Importantly, these children also did not produce a distinction between / s θ / or between / f ɸ /. However, with regard to place distinctions among fricatives, children did systematically reject / s / as a member of the / f / category, consistent with their distinction between labial and coronal continuants. Of further interest is the / t / standard which had no category members. It is again important to note that children definitively rejected both / s / and / p / as belonging to the / t / set. This suggests that these children knew that / t / is not a continuant or a labial, but like the + θ group, they may not associate any featural properties with this segment.

Table 3. Categorization results for the - θ group (adapted from Gierut, 1996 a)

Standard stimulus	Resemblents	Defining features
Coronals		
s	s	continuant
θ	θ f ɸ	continuant
t		—
Labials		
f	f ɸ θ	continuant
ɸ	f ɸ θ	continuant
p	p	labial

Taken together, the collective findings suggest that children's linguistic knowledge and linguistic input both play a role in the conceptualization of phonological information, but to different degrees. Linguistic knowledge as reflected in productive distinctions appears to be primary to phonological categorization. If a child produces a particular contrast of the language, then that knowledge may be used to guide judgments of phonological categories. This was evidenced, for example, by the + θ group and the uniqueness of their / s θ / categories. However, if a contrast is not maintained productively by a child, then that dimension may be unavailable for defining phonological categories. Likewise, this was the case of the - θ group and their collapse of the / s θ / categories. Linguistic input, on the other hand, did not appear to influence the conceptualization of featural relationships to the same extent. Both groups of children were exposed to / θ / in the ambient phonology, but only the + θ group differentiated this category. If input strongly affected categorization, we might also expect children of the - θ group to perform similarly to the + θ group, but they did not. Presumably, a child needs linguistic input to gain linguistic knowledge, but input alone may not be sufficient in metalinguistic tasks.

The integrated results also suggest that the emergence of phonological categories involves increasing differentiation as the child's productive phonology advances. This has implications within underspecification theory for understanding the way in which early phonological representations may shift with development. The categorization data are consistent with the view that a child constructs representations through the addition of increasingly more

complex featural distinctions as phonemic contrasts of the language are discovered. The children of this study did not seem to begin with fully specified representations in acquisition because if all features were available in a fully specified representation, then the - θ group would have had access to the feature distributed as a defining property in category judgments, but this was not the case.

Finally, these results add to prior descriptive work on phonological acquisition (Dinnsen, 1996) and psycholinguistic work on fully developed languages (Lahiri & Marslen-Wilson, 1991) in evaluation of competing theories of underspecification. Across available studies, radical underspecification has consistently emerged as the preferred account of phonological representation and processing. The present results also underscore basic conceptual differences between the two versions of underspecification theory, particularly with respect to the basic unit that organizes the inventory of a language. As summarized by Archangeli (1988), for contrastive specification, the segment is considered most basic; whereas for radical underspecification, it is the feature. Our findings corroborate this claim that features are most basic in radical underspecification because children as young as 3 were capable of classifying phonological information on the basis of distinctive features. These findings parallel other recent work on the units of organization in acquisition. In evaluation of the segment versus the phonetic feature, Gerken and colleagues (1995) present evidence that children rely on both place-voice-manner features and segments in the recognition of spoken words. Earlier work on children's perception of phonetic features (Graham & House, 1971) also complements the present study on phonological distinctions. Collectively, the data suggest that, at a phonetic or a phonological level, features are important constituents in the structure in children's underlying representations.

3. Cyclicity as a mechanism of phonemic acquisition

If the feature is accepted as a relevant organizational unit of acquisition as supported by these psycholinguistic data, then two further questions must be raised: what are the critical features to be acquired, and how does the acquisition process take place? Toward this end, we have advanced a principle of *Laryngeal-Supralaryngeal Cyclicity* to account for the acquisition of subsegmental structure (Gierut, 1994). The principle states that laryngeal and supralaryngeal properties of a phonological system will be elaborated in continuous cycle with expansion of the inventory first in one domain of the representation and then the other, but not with change occurring in both domains simultaneously. The acquisition cycle is both recursive and bivalent, being defined by consecutive laryngeal (voice) and supralaryngeal (manner and/or place) phases. The principle does not indicate which phase–laryngeal or supralaryngeal–will initiate the cycle; this is left free to vary across children. The principle also does not predict the specific phonological distinctions to emerge within each phase. These are underdetermined so the same general (laryngeal or supralaryngeal) property can be realized segmentally in different ways by different children. It is significant that there are two well-defined

exclusions to the principle that contribute to its falsifiability. These exclusions are especially amenable to experimental test because they limit the kinds of distinctions to be acquired both at a single point and across time by a given child. Specifically, the principle excludes the emergence of the same distinction across consecutive phases of the cycle. That is, across time, a new laryngeal distinction would not likely be followed by the emergence of a second laryngeal distinction, with the same being true for consecutive supralaryngeal distinctions. The principle further excludes the simultaneous emergence of two different distinctions in the same phase of the cycle. Presumably, a child would not acquire both a unique laryngeal and a unique supralaryngeal distinction at a single point in time. It is these two exclusions that motivated our experimental clinical treatment studies of Laryngeal–Supralaryngeal Cyclicity in children with phonological delays (Gierut, 1996 b; Gierut & Morrisette, 1996).

The children who participated were ages 3;4 to 5;8, functioning at age appropriate levels in all domains with exception of their phonological systems. The focus was exclusively on the phonemic nature of consonants, with target English sounds absent from the phonemic repertoire identified for clinical treatment. In both studies, single-subject staggered multiple baseline designs were used, such that each child was exposed to a period of no-treatment followed by treatment. The independent variables were both the linguistic domain of the cycle and the phase relationship of the cycle, and these were fully crossed. That is, children were either taught a new target English laryngeal distinction relative to their pretreatment phonemic system, or they were taught a new supralaryngeal distinction. Additionally, the treated distinction was either the next expected phase of the cycle relative to the pretreatment system, or it was not. To illustrate, some children were ready to advance to the laryngeal phase of the cycle and they were taught a laryngeal distinction *in-phase*. Alternatively, some others were forced to skip this expected laryngeal phase, and instead were taught a supralaryngeal distinction *out-of-phase*. The same manipulation was also involved in treatment of supralaryngeal distinctions, both in- and out-of-phase. The dependent variable throughout was change in the composition of each child's phonemic inventory as measured on probes administered longitudinally. From probe data, it was possible to establish each child's phonemic inventory across time and to plot a sequence of acquisition that reflected the order of emergent laryngeal and supralaryngeal distinctions in the sound system.

Results demonstrated that across subjects and experiments, the basic premise of Laryngeal–Supralaryngeal Cyclicity was supported with no apparent violations. With regard to the domain of the cycle, there was no difference in the course of phonemic acquisition by children taught laryngeal as opposed to supralaryngeal distinctions. Differences were not expected however because, as the principle is formulated, laryngeal and supralaryngeal domains of inventory expansion are presumably coequal and function in a sister relationship in the geometric representation. This finding bears upon linguistic theory because some have argued for fully developed primary languages that the Supralaryngeal node in particular adds unnecessary structure to the representation (McCarthy, 1988; Iverson, 1989). On the contrary, our learning data suggest that

Supralaryngeal is an important organizational dimension, at least for children acquiring the phonological system. These acquisition data may thus provide insights that are otherwise not available from fully developed systems.

With regard to the phase relationship of the cycle, clear differences emerged across children and experimental studies. For children taught in-phase, the general observation was that minimal elaboration of the phonemic inventory occurred. Typically, children added only one new distinction to the phonemic repertoire, thereby completing one phase of the bivalent cycle. For these children, there was no further advancement beyond the phase targeted for treatment. In contrast, children taught out-of-phase evidenced widespread elaboration of the phonemic repertoire, adding at least four new sounds to the inventory and completing two full laryngeal–supralaryngeal cycles. Of particular interest was the observation that these children first filled-in the next expected distinction before they learned the treated distinction out-of-phase. The general pattern was to complete the expected (but untreated) phase before advancing to the treated phase of the cycle. Moreover, teaching out-of-phase had the beneficial consequence of perpetuating the cycle beyond the treated phase. That is, children elaborated the expected but untreated phase, then learned the treated phase, and subsequently continued to propagate the cycle. The reason for continued propagation of the cycle is a question that remains to be explored, but one proposal is that children taught out-of-phase are inadvertently exposed to the alternating phase relationship of the cycle given the nature of their learning patterns (Gierut & Morrisette, 1996). Because these children filled-in other untreated distinctions in the course of acquiring a treated distinction out-of-phase, they were able to observe both phases of the cycle directly. This suggests that the crux of the problem for children with phonological delays may lie in knowing the basic principles of language acquisition. Once these principles are revealed, the child then has the necessary tools to proceed in the course of learning.

From these data, Laryngeal–Supralaryngeal Cyclicity appears to be descriptively and psycholinguistically relevant as a principle model of the acquisition of subsegmental structure. There are additional questions that can be raised about the principle that provide direction for future research. In particular, it will be important to explore the application of this principle in normally developing children and cross-linguistically in other languages that may have richer laryngeal and supralaryngeal contrasts than English. A second issue that requires attention is the potential indeterminacy of phase completion. This is particularly relevant because the principle excludes the occurrence of two consecutive phases of the same type. Independent criteria for phase completion should be invoked, much like in the case of determining the cyclic domain of rule application in lexical phonology (Kiparsky, 1982). Finally, Laryngeal–Supralaryngeal Cyclicity defines only one aspect of the phonology and its acquisition, namely consonantal contrasts. Because the phonological system is multifaceted, other principles may be operative in phonological acquisition. In discovery of these additional principles, it may be possible to look to Laryngeal–Supralaryngeal Cyclicity as a foundation for their formulation. In particular, the bivalent and cyclic nature of this principle may evolve as fundamental properties

of other linguistic principles, yet each principle may differ in its substantive domain (Mohanan, 1993). The identification of the relevant domains of each cycle and the interactions between cycles will likely contribute to a broader understanding of the basic structure and organization of phonological representations in language acquisition.

Notes

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