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## Research Note

# PHONOLOGICAL CORRELATES OF MIDDLE-EAR INVOLVEMENT IN SPEECH-DELAYED CHILDREN: A METHODOLOGICAL NOTE

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The purpose of this note is to illustrate the potential contribution of phonological analysis to the study of the origins of developmental phonological disorders (delayed speech). Speech samples from two clinical populations of children with delayed speech were inspected. Within each group, children were subdivided on the basis of case records data on their histories of middle-ear involvement. In both clinical samples, children with positive histories of middle-ear involvement had statistically higher frequencies of occurrence of two sound change categories. Several analyses of one of the sound change categories were undertaken to determine whether these errors could be related to current deficits in underlying forms, to phonetic output constraints, or to perceptual-acoustic characteristics of the sounds involved.

Of the 2% of children with moderate-to-severe speech delays of unknown origin (Winitz & Darley, 1980), possibly one-third have histories of recurrent middle-ear involvement (Shriberg & Kwiatkowski, 1982a). This methodological note describes phonological findings for two clinical populations of children with developmental phonological disorders, henceforth referred to as *delayed speech.* The primary research question is whether speech-delayed children who have a positive history of middle-ear involvement can be differentiated from those who do not on the basis of phonological data. Some possible applications of phonological analyses are illustrated.

## METHOD

### *Sample*

Case records from a data base of 50 children referred to clinics of the University of Wisconsin–Madison for



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speech delays of unknown origin were screened for the presence of one or more of the following four indicators of what we termed *Middle-Ear Involvement:*

1. parental records indicating frequent, persistent earaches with at least one referral for suspected acute otitis media or middle-ear effusion
2. ventilation tubes placed in one or both ears
3. at least one audiometric evaluation indicating reliable air conduction thresholds at least as poor as 15–20 dB HL (ANSI, 1969) in the speech frequencies
4. at least one acoustic immittance assessment indicating abnormal findings in one or both ears.

We found 11 children who maximally met one or more of these four criteria. Most of the children either had had ventilation tubes placed in one or both ears or were being considered for tube placement.

From the remaining children in the data base, 11 children with negative histories on the four criteria were selected to comprise a *Non-Middle-Ear Involvement* group. As indicated in Table 1, children in the Non-Middle-Ear Involvement group were group-matched as closely as possible in age, sex, severity of phonological delay, and mean length of utterance. The mean age of the Middle-Ear Involvement children was slightly lower than that of the Non-Middle-Ear Involvement group, but the difference was not statistically significant. Based on the available demographic and case history data, the two groups appeared to be comparable in intelligence and socioeconomic level.

TABLE 1. Descriptive statistics for two samples of children referred for delayed speech of unknown origin.

| | *Middle-Ear Involvement* | | | *Non Middle-Ear Involvement* | | |
|---|---|---|---|---|---|---|
| *Variable* | $\bar{x}$ | *SD* | *Range* | $\bar{x}$ | *SD* | *Range* |
| Age (in months) | 54.7 | 10.3 | 42–72 | 63.9 | 7.3 | 49–74 |
| Severity[a] | 61.7 | 13.3 | 43–81 | 63.6 | 7.8 | 52–74 |
| MLU | 3.2 | 1.1 | 1.5–5.2 | 3.5 | 1.4 | 1.5–6.9 |

*Note.* $n$ = 11 for each group, with 9 and 8 boys in the middle-ear involvement group and the non-middle-ear involvement group, respectively.

[a]Severity values are the percentage of consonants correct in the continuous speech sample; see Shriberg and Kwiatkowski (1982b) for details of this metric.

## *Transcription and Phonological Analysis*

Audio recordings of continuous speech samples from the 22 children were available in the case folders. Procedures for eliciting, recording, and on-line glossing of the samples followed those described in Shriberg and Kwiatkowski (1980). Data on the representativeness of continuous speech samples collected according to these procedures are provided in Shriberg and Kwiatkowski (1982b). At least 50 utterances from each sample were transcribed by an experienced transcriber using the narrow phonetic transcription symbols and conventions described in Shriberg and Kent (1982). At the time of transcription, specific research hypotheses had not been discussed. Whole-word agreement on 750 words selected randomly from the transcripts was 81% with another trained transcriber. Discrepancies involved levels of narrow phonetic transcription unrelated to the data to be reported.

Preliminary review of the transcripts suggested that the children in the two groups were essentially similar in their use of natural phonological processes as assessed by the procedure in Shriberg and Kwiatkowski (1980). However, further analyses indicated that the Middle-Ear Involvement children produced several sound changes that were not apparent in the other group of speech-delayed children. From these preliminary observations, two classes of sound changes were derived (see Table 2).

TABLE 2. Description and examples of two sound change classes observed in children with delayed speech of unknown origin.

| | | *Examples* | |
|---|---|---|---|
| *Sound change* | *Description* | *Gloss* | *Transcription* |
| I Initial consonant change | Initial consonants are: | | |
| | -deleted | "got" | [ɑt] |
| | -replaced by [h] | "tie" | [hɑ͡ɪ] |
| | -replaced by [ʔ] | "to" | [ʔu] |
| II Nasal consonant change | Nasal consonants are: | | |
| | -substituted for one another | "not" | [mɑ] |
| | -partially denasalized | "knee" | [n̆iː] |
| | -replaced by a stop | "my" | [bɑ͡ɪ] |
| | -preceded/followed by an epenthetic stop | "no" | [ᵈno͡ʊ] |

Sound Change I includes three surface form changes involving word initial singleton consonants: deletion or replacement by a glottal fricative [h] or a glottal stop [ʔ]. Sound Change II includes four changes which may affect nasals anywhere in a word: nasal interchange, partial denasalization, replacement by a stop, or nasal accompanied by an epenthetic stop. To be considered positive for Sound Change I a child had to exhibit at least four occurrences of the sound change among the 22 consonants, including at least one consonant other than /h/ or [ʔ]. These criteria were considered sufficiently stringent to eliminate false positives due to transcription reliability boundaries and casual speech forms (Shriberg & Kwiatkowski, 1982b). For similar purposes, to be scored as positive for Sound Change II a child had to show at least two occurrences of any of the four nasal sound changes.

# RESULTS

The left panel in Figure 1 is a graph of the results. Tests of differences in proportions (Bruning & Kintz,

1968) indicated that a statistically higher proportion of the Middle-Ear Involvement children evidenced one or both of these sound changes in comparison to the Non-Middle-Ear Involvement children.

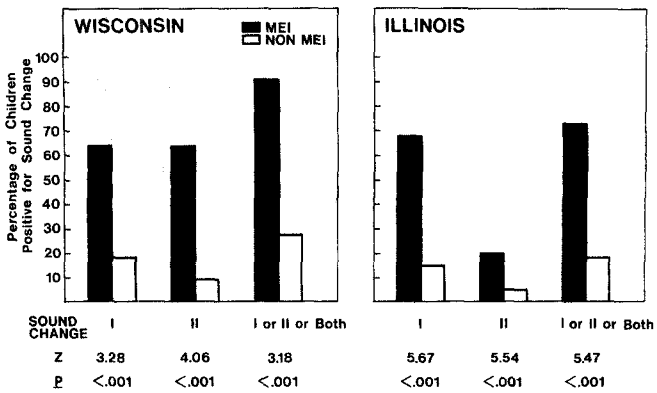


FIGURE 1. Percentage of delayed-speech children positive for Sound Change I, Sound Change II, or Both Sound Changes. For both the Wisconsin and Illinois data, dark bars represent children with histories of middle-ear involvement (MEI), and white bars represent children without such histories (NON-MEI).

In the right panel of Figure 1 are data from a cross validation study based on phonetic transcription of articulation test results from 55 children with delayed speech. These data from a clinical population in Illinois were generously provided by Dr. Barbara Hodson. Using a double-blind approach, Dr. Hodson independently identified 15 children from this group who met one or more of the four criteria for middle-ear involvement used in the Wisconsin study. Another examiner used a coding template to identify which of the original 55 children produced one or both of the sound changes described above. As shown in Figure 1, the proportions for the two groups are very similar to the Wisconsin data; all proportions differ statistically between the two middle-ear history groups. The lower proportions of nasal sound changes should be considered in relation to the low frequency of words containing nasals in the articulation test data. Only three words were appropriate to inspect for this sound change.

## *Additional Analyses*

Given the retrospective status of these data sets, support for the generality of the two sound change findings in middle-ear involved children awaits additional study. The continuous speech samples from these children did afford an opportunity to examine some concepts in phonological analysis. At the time of sampling, each of these 11 children was at Stage III of phonological development (Ingram, 1976). A working hypothesis was that their speech delay was at least in part due to their suspected or confirmed history of hearing loss. It seemed interesting to examine the transcriptions to see if additional phonological analyses could shed light on the nature of the deficit and perhaps suggest the time of onset.

The first question posed was: Do these children's Sound Change I errors reflect current deficits (i.e., at the time of sampling) in their underlying representations of English sound and/or lexical forms? This possibility seemed particularly interesting because fluctuant hearing loss presumably would affect perception and discrimination of speech sounds. Children with such a history might be expected to have difficulty establishing stable underlying representations of sounds and lexical forms.

Three simple analyses of the transcriptions failed to yield positive support for the view that Sound Change I errors were due to deficits in underlying forms at the time of sampling. First, we examined the speech samples to determine whether there were any consonants that never appeared as surface forms. Within each transcript there were only three or four consonants that were not said correctly somewhere in the sample, and no one consonant was missing from the gloss (i.e., "avoided" in) of all 11 transcripts. The phonetic inventories of all these children were almost complete, averaging 86% of the 24 consonants. Second, across all transcripts, an average of 85% of consonants appeared correctly in word-initial position at least once. That is, Sound Change I errors occurred on sounds that the child was producing correctly at least some of the time in word-initial position. Third, and perhaps most telling, the children had variably correct production of words in which Sound Change I occurred; they did not evidence Sound Change I consistently on certain lexical forms. While the findings of these three analyses do not confirm that the children had essentially adult-like forms for words, they do fail to support the view that deficits in underlying forms at the time of sampling could account for Sound Change I errors.

A second question posed was: Were the Sound Change I errors context sensitive? Evidence in support of a complexity constraint could be marshalled if Sound Change I errors occurred only in certain complex environments or perhaps more often in complex environments. To attempt to support this possibility, we tabulated all Sound Change I occurrences partitioned by word length, canonical form, the place of the word in utterances categorized by length, and by grammatical function. The evidence of these tallies again was negative. Across transcripts, Sound Change I occurred in both short, canonically simple words (e.g., CV) and in long, phonetically complex words; it occurred in words positioned everywhere within the sentence and in words of every grammatical function.

To this point there was no evidence that at Phonological Stage III the Middle-Ear Involved children's Sound Change I errors were related to deficient underlying segments or lexical forms or that they occurred as simplifications due to linguistic complexity. We undertook a final series of analyses to inspect the sound-by-sound occurrence of Sound Change I in the 11 transcripts. The question was whether some linguistic characteristic of the error sounds might be causally associated with these children's history of middle-ear involvement. We calculated percentage of involvement for each consonant and then computed Spearman correlations between a rank ordering of these frequencies and rank orderings of consonants on a number of potentially interesting linguistic characteristics for which there were available data in the literature. As indicated in Table 3, some of the obtained correlations are moderate, but none are strong. That is, no one linguistic characteristic of the sounds emerged as a potential source to eventually understand the origins of Sound Change I in children with middle-ear involvement.

TABLE 3. Correlations for six rank orderings of consonants on assorted characteristics with their rank-ordered occurrence in Sound Change 1.

| *Characteristic* | *Source of rank ordering* | *RHO* |
|---|---|---|
| Articulation difficulty | Locke (1972) | .01 |
| Visibility | Jeffers & Barley (1971) | .06 |
| Phonetic power | Fletcher (1953) | −.33 |
| Frequency of occurrence | Carterette & Jones (1974) | −.39 |
| Developmental order | Prather, Hedrick, & Kern (1975) | .41 |
| Perceived pitch | Peterson & Asp (1972) | .49 |

## DISCUSSION

The primary purpose of this note is to illustrate the potential utility of phonological analysis in studying the origin of speech errors. To recapitulate the approach:

1. The speech-delayed children with positive histories of middle-ear involvement were found to make certain sound changes more frequently than the speech-delayed children without such histories.
2. Analyses failed to support the inference that these sound changes reflected current (Phonological Stage III) deficits in underlying forms.
3. Analyses failed to support the inference that these sound changes reflected an output constraint (i.e., that their occurrence was limited to complex linguistic environments).
4. Correlational analyses failed to yield a linguistic characteristic of the error sounds that might suggest why certain consonants might be more affected than others by the presumed fluctuant hearing loss.

Two possible conclusions from these results are that the additional phonological analyses (2, 3, and 4 above) were unproductive or that these analyses were, in fact, revealing. We favor the second view, assuming that the findings summarized as no. 1 above warrant further study and eventual explanation. One possible explanation for the negative findings in the additional analyses is that the time of sampling was too far removed from the time of onset of the disorder. Until the appropriate longitudinal data can be collected, the following speculative account of these retrospective data is offered.

The possibility that some speech-acoustic variable, such as phonetic power or perceived pitch (see Table 3), mediates the origin and resolution of Sound Change I errors in middle-ear involved children is promising but theoretically incomplete. A more embracing view should account for the onset of middle-ear involvement in relation to the child's concurrent stage of phonological acquisition. Given the statistical evidence for the frequency of occurrence of Sound Changes I and II in the speech-delayed, middle-ear involved children, and the "unnaturalness" of such sound changes (Edwards & Shriberg, 1983), we suspect that they reflect some stage-dependent aspect of phonological acquisition. Episodes of middle-ear involvement are most frequent in the first 18 months of life (Teele, Klein, & Rosner, 1980), a period which corresponds well with Phonological Stage I (birth–12 months) and Phonological Stage II (12–18 months) in children acquiring speech normally (Ingram, 1976). If the two sound change categories have their origins during either of these stages, the causal sequence might be as follows. Consequent to deficits associated with eustachian tube function, recurrent middle-ear disease causes fluctuating hearing thresholds. The resulting inconsistent auditory input affects the child's establishment of underlying feature sets for the consonants in early CV syllables (Sound Change I) (Branigan, 1976; Shibamoto & Olmstead, 1979) and delays productive control of velopharyngeal closure for nasals (Sound Change II). With the cognitive and pragmatic developments associated with Phonological Stage III these sound changes begin to resolve—perhaps as a function of the differential salience of linguistic and acoustic cues within and across consonant classes.

Until prospective studies along the lines suggested above are available, this note only can point to the potential contribution of phonological analysis to the study of the origins of speech delay.

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