The Application of Phonological Process Analysis to Adult Neuropathologies

Kevin P. Kearns
University of Kansas Medical Center, Kansas City, Kansas

INTRODUCTION

Investigators have demonstrated the relevance of linguistically based principles to the study of articulatory errors of aphasic adults. Specifically, psycholinguists have applied phonological concepts of markedness and distinctive features to demonstrate the lawfulness underlying seemingly random surface errors produced following brain damage (Blumstein, 1973; Lecours and Lhermitte, 1969; Martin and Rigrodsky, 1974a-b; Schnitzer, 1971; Trost and Canter, 1974). Although the theoretical contributions of this area of research has been formidable, the impact of phonological concepts on clinical aphasiology has been negligible. Therefore, the purpose of this paper will be to discuss an analysis procedure, phonological process analysis, which has had a considerable impact on the conceptualization and description of articulatory deficits in children, and which may provide a useful taxonomy for the articulatory errors of aphasic and apraxic speakers.

Phonological process analysis is based primarily on the principles of generative phonology. The concept that articulatory errors are related to underlying forms through phonological rules or processes has been particularly influential. The rules permit a transformation from abstract forms to phonetic realization (Shelton and McReynolds, 1979). Phonological analysis procedures attempt to generate rules which relate phonetic errors to underlying forms and to intended target sounds. An important component of the analysis procedure is the incorporation of environmental (contextual) considerations into the rule derivations.

The applied literature in this area has primarily been restricted to the analysis of articulatory errors of children (Compton, 1970, 1975, 1976; Faircloth, 1976; Lorentz, 1976). The cumulative impact of this work has been the recognition that children's misarticulations can be described by phonological simplification processes similar to those identified in the developmental literature.

Proponents of the process approach view articulation as a part of language at the phonological level. They cite the lawfulness of children's misarticulations, which is made evident by their analyses, as evidence for this claim. In addition, since misarticulations are seen to result from phonological processes, it has been suggested that treatment should attempt to eliminate processes which are creating error patterns. There is, in this view, no need to target single sounds in treatment. Processes affect entire classes of sounds and it has been hypothesized that their elimination would result in generative, efficient training.

Given the implications which such a view holds for articulatory management, the application of phonological process analysis to adult neuropathologies deserves further consideration. The following case exemplifies our efforts in this direction.

EXAMPLE OF A PHONOLOGICAL PROCESS ANALYSIS

N.S. is a 57 year old male who had suffered a single, left sided cerebrovascular accident approximately one year prior to testing. His performance on the Porch Index of Communicative Abilities (Porch, 1971) resulted in an overall score of 12.39 (73rd percentile). A moderate degree of verbal apraxia was evident during his performance on the 'Motor Speech Evaluation' (Wertz et al., 1978).

Data for the phonological process analysis consisted of 97 spontaneous words which were elicited using an experimental articulation test (Elbert, Shelton and Arndt, 1967). Testing was conducted in a sound treated audiometric booth. Point to point interjudge reliability of 90% was obtained for consonants by having judges independently transcribe tape recorded samples. Subsequent agreement was reached for all items for which there had been initial disagreement.

Three categories of simplification processes--syllable structure, substitution and assimilation have been recognized in the literature (Ingram, 1976). Although a total of twenty-nine individual processes were considered in this analysis (Ingram, 1976; McReynolds, 1979), only the general rules which describe processes within these three categories will be discussed. Prior to discussing these trends, however, a brief overview of the consonantal errors produced by this patient will be necessary for comparison purposes. A total of 81 errors were produced by N.S. Approximately one-third (26) of these were deletions and the remaining two-thirds consisted primarily of substitution errors (50). Five additive errors were also noted.

The first category of processes which was examined, syllable structure processes, act to simplify the structure of syllables by reducing them to their basic forms (e.g., CVCs became CVs). Two syllable structure processes accounted for the majority of deletion errors produced. The first of these was final consonant deletion. As a general rule, consonants were optionally deleted from the final position of words on 16% of all possible occurrences (Table 1; I-1). An example of this process is the deletion of the final /b/ from the target word "bathtub." Subrules describing the environment and frequency of occurrence of individual phonemes were also derived.

A second group of syllable structure processes, those involving cluster reduction, were also apparent in this sample. In general, clusters can be reduced through deletion or substitution of a consonant within a cluster, or through the insertion of a schwa between abutting consonants. Overall, 70% of all consonant clusters produced by N.S. were reduced through one of these processes (Table 1; I-2). Eleven of these reduction errors were a result of consonant deletions. For example, the /sp/ cluster in "spider" was reduced to /p/, resulting in the pronunciation /pəɪdə/. Several clusters were also reduced through substitution or schwa insertion. To summarize, two syllable structure processes--final consonant deletion and cluster reduction--accounted for 85% (22/26) of the deletion errors produced by this patient.

Commonly recognized substitution processes also provided a convenient method of characterizing N.S.'s substitution errors. For example, an optional rule for stopping, or the substitution of stops for fricatives and affricates was evident (Table 1; II-1). Stops replaced 36% of all fricatives and affricates in the sample (e.g., /zíbrə/ - /díbrə/). This rule was not

environmentally determined, because it occurred in all positions. Several interesting subrules were evident within the general stopping rule. For example, voicing was maintained for 89% of the substitutions within this category.

Table 1. Summary of general error trends.*

I. Syllable Structure Processes

1. Final Consonant Deletions:
   [C] $\longrightarrow$ θ / _____ # Optional (11/70 = 16%)

2. Cluster Reduction:

   $[C] \longrightarrow \begin{Bmatrix} \theta \\ C \end{Bmatrix}$ $\quad \begin{matrix} \# \_\_\_\_\_ \\ C \end{matrix} \quad \begin{matrix} \_\_\_\_\_ \# \\ C \end{matrix}$

   Optional (14/20 = 70%)

II. Substitution Processes

1. Stopping:

   a. [+ Fricative, + Affricate] $\longrightarrow$ [+ Stop] / _____
   Optional (19/53 = 36%)

   b. Subrule 1.

   $$\begin{Bmatrix} + \text{vd. Fricative/Affricate} \\ - \text{vd. Fricative/Affricate} \end{Bmatrix} \longrightarrow \begin{Bmatrix} + \text{vd. Stop} \\ - \text{vd. Stop} \end{Bmatrix} / \_\_\_\_\_$$

   Optional (17/19 = 89%)

2. Fronting:

   [- Anterior] $\longrightarrow$ [+ Anterior] / _____
   Optional (12/38 = 32%)

3. Vocalization:

   [ɚ] $\longrightarrow$ [ə] / _____ # Optional (4/11 = 36%)

*See Appendix A for description of symbols.

A second substitution process, fronting, or the replacement of sounds produced at posterior points of articulation with anterior sounds, was also evident in the sample. Fronting (32%) occurred less frequently than stopping (Table 1; II-2). In addition, several notable counter-examples to fronting, such as /s/ for /θ/ substitutions, were also produced. A third substitution process, vocalization, or the replacement of syllabic consonants by vowels (e.g., /mɛjɚ/--- /mɛjə/) occurred on 36% of words ending with /ɚ/ (Table 1; II-3).

In summary, two substitution processes--stopping and fronting--accounted for one-half of all substitution errors. In total, 78% (39/50) of the substitutions were categorized as examples of commonly identified phonological processes. All of the identified 'rules' were optional, and several were based on a limited number of examples. Finally, although several substitution and addition errors appeared to be related to other phonemes within target utterances, there was an insufficient number of examples to state rules for assimilatory processes, the third category of processes considered in this analysis.

DISCUSSION

Although the clinical usefulness of phonological processes analysis has yet to be firmly established, this approach warrants further investigation by aphasiologists. As the analysis for N.S. demonstrates, this taxonomy may reveal a degree of lawfulness which may not be evident using other systems. Distinctive feature analyses, for example, do not consider deletion errors. Therefore, a feature analysis for this patient would not have considered approximately one-third of his errors. Similarly, traditional substitution, omission, and distortion analyses would not have revealed the across-phoneme error patterns which were evident using the phonological process analysis. Moreover, potentially useful information regarding the specific contexts in which errors occurred would also have been overlooked using feature or traditional analysis procedures.

It should be noted that the results of process analyses may not represent a patient's rules for transforming abstract phonological forms into phonetic realizations. The need to establish minimal qualitative and quantitative criteria for when a process is present has only recently been recognized (McReynolds and Elbert, 1980). There is, in fact, insufficient data available with regards to whether phonological processes are "psychologically real." Moreover, treatment suggestions regarding the elimination of processes have yet to be refined into operational treatment programs (Shelton and McReynolds, 1979).

Despite the embryonic stage of phonological process analysis, it would appear that the procedures and the rationale for treatment which they foster may have considerable application to the clinical management of adult aphasic and dyspraxic speakers. However, evaluation of the usefulness of this approach must await the collection of empirical data.

APPENDIX A

Common Symbols and Devices Utilized in Writing Phonological Rules

---

1. Square Brackets [ ] enclose features or phonetic realization.
2. Arrow ⟶ designates change; placed between input of a rule and its output.
3. Slash Mark / designates 'the environment' in which change occurs.
4. Underscore ____ marks the location of the target segment within a string of segments.
5. Boundary Marker # indicates initial or final position of a segment within a word.

6. Null Sign $\emptyset$ denotes deletion when it follows an arrow.

7. Braces $\{\ \}$ indicate that two rules can be collapsed into one rule; read "either/or."

REFERENCES

Blumstein, S. Some phonological implications of aphasic speech. In H. Goodglass and S. Blumstein (Eds.), Psycholinguistics and Aphasia. Baltimore: The Johns Hopkins University Press, 123-140 (1973).

Compton, A.J. Generative studies of children's phonological disorders. Journal of Speech and Hearing Disorders, 35, 315-339, 1970.

Compton, A.J. Generative studies of children's phonological disorders; A strategy for therapy. In S. Singh (Ed.), Measurement Procedures in Speech, Hearing and Language. Baltimore: University Park Press, 55-90 (1975).

Compton, A.J. Generative studies of children's phonological disorders; Clinical ramifications. In D.M. Morehead and A.E. Morehead (Eds.), Normal and Deficient Child Language. Baltimore: University Park Press, 61-96 (1976).

Elbert, M., Shelton, R.L. and Arndt, W.B. A task for evaluation of articulation change:1. Developmental methodology. Journal of Speech and Hearing Research, 10, 281-289, 1967.

Faircloth, M. Articulation and Communication. In L. Bradford (Ed.), Communication Disorders - An Audio Journal for Continuing Education (1976).

Ingram, D. Phonological Disability in Children. New York: American Elsevier (1976).

Lecours, A.R. and Lhermitte, F. Phonemic paraphasias: Linguistic structures and tentative hypotheses. Cortex, 5, 193-228, 1969.

Lorentz, J.P. An analysis of some deviant phonological rules of English. In D.M. Morehead and A.E. Morehead (Eds.), Normal and Deficient Child Language. Baltimore: University Park Press, 29-59 (1976).

Martin, A.D. and Rigrodsky, S. An investigation of phonological impairment in aphasia. Part I., Cortex, 10, 317-328, 1974.

Martin, A.D. and Rigrodsky, S. An investigation of phonological impairment in aphasia. Part II: Distinctive feature analysis of commutation in aphasia. Cortex, 10, 329-346, 1974.

McReynolds, L.V. Articulation treatment: An approach derived from phonology. Presented at the annual meeting of the Vermont Speech and Hearing Association. Burlington, Vermont (1979).

McReynolds, L.V. and Elbert, M. Criteria for phonological process analysis, in press (1980).

Porch, B.E. The Porch Index of Communicative Ability. Palo Alto, California: Consulting Psychologists Press (1971).

Schnitzer, M.L. Generative phonology: evidence from aphasia. Ph.D. dissertation, University of Rochester, 1971.

Shelton, R.L. and McReynolds, L.V. Functional articulation disorders: Preliminaries to treatment. In N.T. Lass (Ed.), Speech and Language: Advances in Basic Research and Practice. Vol. 2. New York: Academic Press (1979).

Trost, J.E. and Canter, G.J. Apraxia of speech in patients with Broca's aphasia: A study of phoneme production, accuracy and error patterns. Brain and Language, 1, 63-79, 1974.

Wertz, R.T., Collins, M., Weiss, D., Brookshire, R.H., Friden, T., Kurtzke, J.F., Pierce, J. Veterans Administration cooperative study on aphasia: Preliminary report on a comparison of individual and group treatment. Presented to the Annual meeting of the American Association for the Advancement of Science, Washington, D.C., 1978.

DISCUSSION

Q: How do you determine the percentages for when an optional or required rule occurs?

A: Basically, it's opportunity versus occurrence. So, for example, the number of clusters in a sample are tallied and the number of cluster reductions are taken into consideration. It takes some operational definitions, however, since the definitions in the literature of some of the processes are not sufficient.

Q: If you had 50% occurrence of a rule as opposed to say 89%--would you have written a rule to say that it was rule-governed phonological phenomenon?

A: That's one of the points--we really don't know. From my perspective at least, we don't have good criteria for when something really is a rule or phonological process or transformation--we really dont' know since we only have the behaviors to deal with. The overriding point is that for this patient and for others with whom we have used the analysis, it has provided a convenient taxonomy for describing the system.

Q: It might be tougher to apply the analysis to adult neurological patients than with children. Children would be expected, for example, to have a higher degree of substitution rules as opposed to apraxics where you seem to need a percentage to determine where you are going to go clinically.

A: I agree, I think we need to get the data which will allow us to make these decisions. On the other hand, there are not many data in the children's literature with regards to when a process exists. Some authors take one example of a given "process" and argue for the presence of the supposed process.

Q: You said that we don't have much refinement of treatment technology growing out of this kind of analysis. I suspect you have tried some refinements. Do you have some ideas about how this kind of analysis translates into treatment approaches?

A: I think the implications are tremendous. One of the implications is that if these truly are processes or rules and if they do exist within the phonological system, then we're likely to get generalization from our treatment package. The reason is that the processes are not phoneme bound, but cross phonemes. So, for example, clusters were reduced by deletion of /t/'s and /p/'s as well as other phonemes. The implication is that if we can develop efficient training approaches, then they could be generative.

Q: I go along with what you have just said. We may be better off working with pairs of sounds rather than individual sounds. In addition, training of features may result in generalization to all sounds containing the target feature.

A: That is true to a certain extent, but as Ingram (1976) points out, the analysis does not have to be at the feature level. It can be at the segment level. He also qualifies that by saying that the feature may also be important. Either way, the implication is the same. Ingram, and Edwards and Bernhart (1973) suggest contrastive training. So, for example, with the stopping rule, fricatives and stops might be contrasted in training, as opposed to working on an individual phoneme until it is in the repertoire. I think therein lies the implication.

Q: Were all the rules optional? Also, it would be interesting to repeat the analysis over time.

A: Yes, all of the rules for the patient were optional. We have sampled patients' responses, done the analysis and then probed after one month and repeated the analysis. Essentially what we have found is that the frequency of occurrence changes but the pattern of rules remains pretty consistent.

Q: Would this type of analysis help to differentiate between the errors produced by fluent patients and the motor programming errors seen in nonfluent patients, or would the analysis tend to obscure the differences?

A: I would hope that the analysis would help us sort it out, but there is no guarantee that this would be the case. I think the qualification that you are bringing up is important though. The analysis is not, at this point, refined enough to know exactly who we should use it with. Our experience has been that it is most helpful with moderately impaired patients with verbal apraxia. It is a useful taxonomy for this type of patient. I'm not sure what we'll find if we try to apply it to the fluent patients. However, Blumstein (1973) and others would suggest that we might find similar types of patterns.

Q: I'm not sure that more data would help you answer that question. Don't you have to deal with the issue on a theoretical level first? I'm worried about applying a phonological analysis system to a phonetic disorder. Is that worry unfounded?

A: Well, it's a matter of definition. Not everyone would agree that it is a phonetic disorder. It may not be incongruous, depending on your thinking.

Q: If you call "it" apraxia of speech then you imply that it is a phonetic disorder. Still, don't you have to consider the theoretical point of view first, so that data can never answer the question?

A: If we don't answer it with data I don't know how we answer. However, if I read you correctly, then maybe what you're saying and what I would agree with is that we need to find out whether or not these processes truly exist.

Q: If apraxia of speech is a motor disorder then we have to approach it from motor theory. This might lead to different predictions than if

you consider the impairment a phonological disorder. You have to deal with the theory first. You can apply any system to anything and describe certain behaviors but it may be wrong.

A: I agree in that you can call anything whatever you want, but it is the data which will help you sort out whether or not it is indeed what you call it.

Q: To carry it one step further, I think the implications are critical. The treatment implication may be to work toward minimal temporal-spatial pairs in terms of production, as opposed to approaching a phonological impairment from a given system of phonological analysis. Regardless of how you look at it, a taxonomy such as yours may allow us to look at the consistency and stability of error patterns and is, therefore, indispensable.

A: Thank you. The only point I have been trying to make is that we don't really know at this point--but that it may be a useful taxonomy. I think that ultimately we'll find out when we collect more data. If we apply the analysis with individual patients on a descriptive data basis and refine the presently vague suggestions for treatment, then maybe we'll have some answers to the questions that we all keep wondering about.

Q: What percentage of the errors were you unable to classify as phonological processes?

A: Very few errors couldn't be classified. The errors that I didn't talk about basically involve the five addition errors. An interesting observation, however, is the fact that four of the five addition errors resulted in additions of phonemes which were already in the target word. For example "roze" became /rouɪz/ and /radio/ became /reɪdrio/. So its not that these errors were totally random, it's just that they don't happen to fit this taxonomy. I was uncomfortable, however, calling them assimilatory processes. There were not enough examples to write the rules.

Basically, the vast majority of errors were covered by these processes. Some, like the addition errors, were in the 'vague' ballpark and I'm not sure that you could call them processes. Also, there were some consistencies which might not have been considered processes in the developmental literature. The example previously mentioned of /s/ for /θ/ substitution occurred five of six times in the sample. While it may not be considered a phonological process, it was certainly consistent. Perhaps the processes identified in the developmental literature provide guidelines, but there may be uniqueness in the adults that we need to find out about.

Q: How was the sample obtained?

A: The task was spontaneous picture naming to 3" x 5" colored drawings.

Q: Would you get different distributions depending on your sampling approach, such as having patients respond in an imitative or emotive condition?

A: We have taken imitative samples. For this patient, the trends appeared to be similar to the spontaneous condition, but the frequency of occurrence of errors was less. It becomes, therefore, more and more

tenuous with regards to whether or not you are truly talking about a "process" or rule. The suggestion in the developmental literature is to obtain spontaneous samples, but you run into the problem of whether or not you're sufficiently testing for the processes. You gain some and lose some. I don't know what would happen in the more spontaneous, emotive, or discourse condition. We haven't tried that yet.

Q: For some patients the processes they exhibit appear to be compensatory. For example, cluster reduction and final syllable deletion may be adaptive. On the other hand, additive errors and transpositional errors do not appear to be adaptive. What do you think about this?

A: I agree that some patients may take on compensatory strategies. In fact, even some of the nonspeech, stuttering-like behavior of apraxic patients can be conditioned as the result of attempts to apply different types of strategies. So, number one, I would agree that, perhaps, for some patients there is an adaptive strategy. I don't know how you sort out whether one is or isn't involved. The only way, I guess, is to gather enough data to say, for a large sample, that some patients were consistent along these lines and others weren't. Maybe then you can start to answer the question.

I might also add that I've often thought of the complications that apraxics will provide with regards to additive errors or transpositions. However, there weren't too many of these errors for this patient. Second, the vast majority of errors produced resulted in maintenance of the basic syllabic unit. That is, there was a substitution but the syllable structure didn't change, or a simplification of the syllable structure. I'm not sure how to interpret this, but I found it interesting.