

MANAGEMENT OF SENTENCE PRODUCTION DEMANDS

ALAN G. KAMHI

Memphis State University, Memphis, TN

HUGH W. CATTS MICHELLE K. DAVIS

Case Western Reserve University, Cleveland, OH

This study examined the effects of variations in language complexity on young children's phonological accuracy and consistency of target words. A more general intent was to understand better the way in which developmental level and children's tolerance of speech variability influenced the management of processing demands. Seven children aged 22-34 months were seen six times over a 4-month period. During these sessions, children were presented with an elicited imitation task consisting of 18 stimulus words, each of which occurred in eight sentences of varying language complexity. Younger children in Language Stage III were found to be more influenced by changes in language complexity than older children in Language Stages IV and V. Within-stage differences were also found. Moreover, in contrast to previous research, children showed as many improvements in phonological accuracy with increases in language complexity as they did decreases in phonological accuracy. It was suggested that between-stage differences were primarily caused by differences in developing speech, language, and cognitive abilities, whereas within-stage differences were primarily caused by differences in the extent to which children tolerated variability in their speech. Based on this contention, some speculations were offered concerning the way in which normal and disordered children manage processing demands.

Research in child language during the past 10 years has begun to look at the interrelations among the different components involved in sentence formulation. It is generally acknowledged that at least six components (processes) are involved in sentence formulation (Clark & Clark, 1977; Foss & Hakes, 1978): conceptual, semantic, syntactic, lexical, phonological, and articulatory. It is generally thought that demands placed on higher level language processes will have an adverse effect on speech production, either by phonologically simplifying it or by making it more disfluent than it would normally be. Both of these adverse effects presumably could occur together. In the current study, we examined whether or not higher level processing demands cause a reduction in the accuracy and consistency of young children's target word productions.

The normative literature in this area is particularly scarce. Scollon (1976) observed that the words of his single subject were phonologically less well formed in longer utterances than in shorter ones. In the same vein, Waterson (1978) found that new longer utterances in her young son's speech contained familiar sounds and a low degree of "phonological differentiation," whereas familiar shorter utterances often contained greater phonological differentiation. Phonological differentiation was a composite measure reflecting the number of words in a sentence, the number of syllables within a word, the number of phonological contrasts within syllables, words, and sentences, and the number of new articulations. Consistent with Waterson's findings, de Villiers and de Villiers (1978; cited in Paul & Shriberg, 1982) reported for their child that more recently acquired structures (2- and 3-word utterances) were associated with simplifications of words that previously had been articulated correctly in single-word utterances.

The most systematic investigations of the relationship between higher level language processes and phonological accuracy have involved disordered children. Panagos, in a series of studies (see Panagos, 1982, for a review), has found that more misarticulations occur with phonologically and grammatically complex sentences than with linguistically simpler sentences. Panagos and Prelock (1982) summarized their evidence this way:

During sentence production syntactic and phonological structures influence one another such that complexity added on either level disrupts performance on the other and cumulative complexity disrupts performance on both. The dominant outcome of complexity mismanagement is the simplification of sentence structures at all levels of hierarchical organization. (p. 176)

In a recent study, Paul and Shriberg (1982) examined the relationship between phonological and syntactic production in 30 speech-delayed children using continuous speech samples. Four different logical patterns of syntactic and phonological performance were described. About half of the children showed some phonological simplification when demands for both phonological and syntactic complexity converged (Patterns I and II). The performance of these children was consistent with Panagos and Prelock's claim about complexity mismanagement. However, the remaining half of the children (Patterns III and IV) did not have more trouble realizing phonetically complex grammatical morphemes (e.g., plurals and possessives), as would be predicted by Panagos and Prelock. Thus, some children are "capable of making their surface forms for phonetically complex morphemes match their underlying level of syntactic performance" (Paul & Shriberg, 1982, p. 545).

Panagos and Prelock's claim about complexity mismanagement is based on the assumption that the processes

involved in sentence formulation operate within limits imposed by the general information processing system. When these limits are exceeded by novel forms or particularly complex structures, a reduction in the accuracy of these forms occurs. Paul and Shriberg's findings led them to question the explanatory value of this "limited encoding capacity model"; however, they offered no alternative theoretical view in its place. Because this model has not actually been disproven by Paul and Shriberg's findings, we assume that it is valid and explore in this study some of the factors that might account for individual differences in the way in which children manage different processing demands.

Children's Response to Processing Demands

The way in which children manage different processing demands seems to depend on several factors, including the sensitivity of the measures used to detect the effect of the processing demands; the developmental level of children's speech production skills, linguistic knowledge, and cognitive abilities; and the extent to which the child tolerates variability in his/her phonological system.

The sensitivity of the measures used to detect the effects of processing demands has obvious importance. Typically these effects result in either perceptible or imperceptible phonological changes. Imperceptible changes in phonological accuracy can be detected only through the use of sensitive instrumentation. Most studies, however, including the current one, have been concerned with perceptible changes in phonological accuracy because the variability in phonological accuracy has been sufficient to be reflected in phonemic-level differences.

Developmental changes in children's speech, language, and cognitive abilities play a significant role in determining how children manage processing demands. For example, certain processes—in particular, low-level ones, such as speech production—become more automatic with age. Bock (1982) suggested that in order to understand the role of processing demands in sentence formulation, one must consider certain general characteristics of information processing. These include the development and maintenance of automaticity in processing, the characteristics of nonautomatized or "controlled" processes, and the way in which automatic and controlled processes are balanced to achieve optimal use of the available processing resources. Using this framework, one can conceptualize the development of language as a gradual automatization of certain sentence formulation processes—in particular, low-level phonological and speech production ones and, to a lesser extent, lexical and syntactic ones. The extent to which a child has become familiar with the speech movements (motorics) of his/her language thus might determine how vulnerable these movements are to increases in higher level processing demands.

There is some support for this conceptualization in the literature. Phonological selectivity has been found to decrease rapidly as children near the acquisition of their 50th word (Leonard, Schwartz, Folger, & Wilcox, 1978; Nelson, 1973). This finding suggests that some of the trade-off between degree of phonological differentiation and language complexity that Waterson (1978) found might disappear at this time. Recall, however, that trade-off is still possible at later points in development, as witnessed by the findings of de Villiers and de Villiers (1978; cited in Paul & Shriberg, 1982).

Developing linguistic and cognitive abilities should also influence children's management of processing demands. Schwartz and Folger (1977) found that Stage VI sensorimotor children demonstrated greater consistency in the production of sounds and syllable structures than Stage V children. They attributed this decrease in variability to an improvement in children's ability to create and maintain stable mental representations of phonological schemas. In a subsequent paper, Schwartz and Prelock (1982) suggested that during the preoperational period of development, within-word variability largely disappears because of the increased systematicity of children's productions. Clearly, certain increases in language complexity should have less of an effect on children's phonological accuracy as they get older and develop better speech, language, and cognitive skills or, as stated above, as certain components in the sentence formulation process become more automatic. It should also be clear that it would be very difficult to differentiate among the effects of these three developing skills. For this reason, we treat these three skills as if they develop synchronously, realizing that in many instances they may not.

A third factor that might influence the sentence formulation process is the child's tolerance of variability in his/her speech productions. Studies such as Leonard, Rowan, Morris, and Fey (1982) have shown that there are many reasons for variability in children's speech relating to the stability or instability of particular segments in words. However, the way in which children manage the production of unstable aspects of words might also be a function of the tolerance these children have for variability in their speech. Scollon's (1976) subject appeared to accept more variability in speech than did Waterson's (1978) son, who seemed to "know" his processing limits and attempted not to exceed them. Ferguson (1979) has suggested that a child who shows a looser and more variable phonological system might reflect an unanalytic, risk-taking style of language acquisition. In contrast, the child who constructs a more rigid, less variable phonological system would show an analytic, cautious approach to language acquisition.

In the current investigation, the effects of increases in language complexity on the accuracy and consistency of children's target word productions were evaluated using an elicited imitation task. An imitation task was used partly because of the experimental control it provided across subjects and partly because previous research by Panagos and his colleagues found that children showed reductions in phonological accuracy with increases in

language complexity using imitated sentence productions. Based on the points raised in the previous section, we predicted that children with more advanced speech, language, and cognitive skills would be less influenced by variations in language complexity than would children with less advanced skills in these areas. We also thought that the children with more variability in their systems would be more influenced by changes in language complexity than would children with less variability in their systems. Children were seen over a 4-month period in order to evaluate the effects of maturing speech/language/cognitive skills on the accuracy and consistency of the target words.

METHOD

Subjects

Subjects were seven normally developing children aged 22–34 months. The three youngest children were girls (22, 23, and 26 months), and the remaining four were boys (28, 30, 34, and 34 months). All were about 4 months older by the final testing session. Language samples obtained at a preliminary testing session indicated that all children were producing multiword utterances and all had more than 50-word vocabularies. Based on these samples, children were assigned to a developmental language stage according to Crystal, Fletcher, and Garman's (1976) developmental chart. The three youngest children were in Stage III, whereas the four remaining children divided equally into Stages IV and V.

Cognitively, all the children were functioning in the preoperational stage of development. All children successfully completed sensorimotor Stage VI means-ends and object knowledge tasks as described in Miller, Chapman, Branston, and Reichle (1980).

To evaluate the children's phonological systems, Hodson's (1980) *The Assessment of Phonological Processes* was administered at the outset of the study. All the children were found to demonstrate common simplification processes, as shown in Table 1. The two youngest children, Abby and Caroline, had the most immature systems, as evidenced by the prevalence of reduplicated syllables in their speech. In contrast, Aaron presented the most mature system, showing only liquid simplification of /l/. Aric's speech was noteworthy for his advanced age and language level in that he exhibited some simplification processes characteristic of younger children's speech, namely, velar fronting and stopping.

Sentence Imitation Task

The sentence imitation task consisted of 144 sentences grouped into 18 "stimulus conditions." Each stimulus condition consisted of a stimulus word that occurred in eight utterances reflecting different levels of language complexity. The eight structures used were: single word,

TABLE 1. Individual subject information.

Subject	Age range (mos.)	MLU	Language stage ^a	Prevalent simplification processes ^b
Abby	22–26	2.30	III	Cluster reduction (all) Unstressed syllable deletion Reduplication Stopping (s,z,v) Labialization (θ)
Caroline	23–27	2.66	III	Cluster reduction (all) Liquid simplification (l) Reduplication Stopping (ð,dʒ,f)
Shannon	26–30	2.56	III	Cluster reduction (all except sk and sl) Labialization (θ) Liquid simplification (l)
David	28–33	4.05	IV	Labialization (θ) Liquid simplification (l)
Tucker	30–34	3.47	IV	Cluster reduction (sn,st) Final consonant deletion (t,v) Labialization (θ)
Aric	34–37	5.64	V	Cluster reduction (st,sn,tr,pl) Stopping (θ,ð,s,f,dʒ) Velar fronting (k,g) Liquid simplification (l,r)
Aaron	34–38	5.34	V	Liquid simplification (l)

^aBased on Crystal, Fletcher, & Garman (1976).

^bFor a process to be considered prevalent it had to affect a segment at least 25% of the time. Affected segments are listed in parentheses.

two-word (modifier + N), simple sentence (SVO), simple sentence plus subject modifier, simple sentence plus the negative contraction *didn't*, Y/N questions beginning with *did*, and two passive sentences. The second passive sentence was included so that the target word could occur in the sentence-final position, as it did in the other six sentences.

These eight sentence types represented different levels of language complexity based on recently published developmental language charts and data (e.g., Crystal et al., 1976; Miller, 1981). Based on the Crystal et al. language chart, one-word utterances occur in Stage I, two-word utterances in Stage II, and SVO sentences early in Stage III, whereas SVO + modifiers occur late in Stage III or early in Stage IV. In Stage IV are found full sentences with negative contractions and appropriately inverted Y/N questions. Finally, passive constructions occur in Stage VI. Miller's data and developmental chart corroborate the increasing complexity of the utterances, with certain utterances clustering at a particular stage (e.g., the negative and question forms). Importantly, these eight sentence types were chosen to reflect forms that children were both currently producing and not producing. Thus, all the children were beyond the two-word

stage, but no child was producing full passive constructions and only three of the four oldest children were producing full sentences with *didn't* and Y/N questions with *did*.

The stimulus words represented nine late-emerging, word-initial phonemes (Sander, 1972): /l/, /r/, /dʒ/, /ʃ/, /s/, /k/, /g/, /θ/, and /v/. The 18 stimulus words were *log*, *lightning*, *rake*, *radio*, *jar*, *giraffe*, *shoe*, *sugar*, *salt*, *sausage*, *cat*, *camel*, *gum*, *garage*, *thumb*, *thunder*, *van*, and *vacuum*. As was the case with the stimulus sentences, no child was able to produce all of the stimulus words accurately. Children's sentence formulation processes, then, were taxed to varying degrees by the unfamiliar sentence structures and target words and/or sounds. As an example of a stimulus word condition, the eight sentences for the word *camel* were as follows: "camel," "fat camel," "The boy rode the camel," "The little boy rode the camel," "The boy didn't ride the camel," "Did the boy ride the camel?" "The camel was ridden by the boy," and "The boy was kissed by the camel."

Procedures

Each child was seen individually for seven sessions, each lasting approximately ½ hr. During the first session, a speech sample was obtained and *The Assessment of Phonological Processes* (Hodson, 1980) was administered. Pilot testing of the imitation task was also performed at this time. This testing indicated that the young children would not attend to the imitation task if the more difficult sentences were presented first. For this reason, the eight utterances were always presented in the same order, beginning with the single-word utterance and continuing through the passive sentences. The possible effects of practice are addressed in the discussion.

During the first 2 months of testing, children were seen four times at biweekly intervals at which time one half of the test (nine stimulus conditions) was administered. By the end of the first 2 months, each child had been administered the entire test battery two times. During the last two sessions, which occurred at monthly intervals, the entire test was administered. If a child produced a word correctly in its eight different language structures during two consecutive sessions, this stimulus condition was not presented in subsequent sessions. By the third month of testing the number of stimulus conditions some children received thus was reduced. For children who never produced an entire stimulus condition accurately during two consecutive sessions, there were four data points at approximately monthly intervals for each of the 18 conditions.

Pictures of each word were initially provided to stimulate imitation of the utterances. For some of the children, a puppet said the sentences first and the child was told to repeat what the puppet said. Use of the puppet was discontinued when the child became familiar with the task. By about the third session, the puppet was no longer needed for any child.

Data Transcription and Reliability

All testing was conducted by the first and third authors. Live phonetic transcriptions were made of the target-word productions. These transcriptions were generally broad phonetic transcriptions. Diacritic markers were used for labialization, dentalization, and lateralization. Tape recordings of the sessions were used to verify the accuracy of the live transcriptions and to note the language structures used. Within a few days of each testing session, reliability checks on all the data from two children were made by the experimenter who did not test the child. Agreement on the language structures produced was 100% across the six sessions, whereas agreement on the phonetic transcriptions of the stimulus words was 84%. These disagreements were resolved through discussion among all the authors.

Data Reduction

The data were scored to reflect changes in phonological accuracy and consistency for each stimulus condition of eight sentence structures. Five patterns were possible: (a) consistent word production, (b) inconsistent word production (i.e., no clear pattern was observed), (c) increase in phonological accuracy, (d) decrease in phonological accuracy, and (e) an unscorable stimulus condition. Only eight of more than 400 stimulus conditions were not scorable. All of these were produced by the same child who, during the first session, was unable to imitate more than the word itself. A potentially unscorable or difficult-to-score situation that did not occur was a change in a word's production without a concomitant change in the complexity of the sentence. Another fortunate aspect of the data was that inaccuracies in children's imitations of the language models had no effect on the scoring of their word productions. In cases in which a child's imitation of a more complex model did not include the additional language structure (e.g., negation) and/or was identical to the previous sentence imitation, the child's target word productions in the two sentences were always the same.

Two different procedures were used to score the stimulus conditions for changes in phonological accuracy and consistency. In the first, more sensitive procedure, children did not need to produce the target word accurately in order to receive credit for an increase in phonological accuracy. Also, the production of the entire word was considered in assigning changes in phonological accuracy. Differences in place, voice, and manner of articulation were used to determine whether or not sound changes within each stimulus condition reflected increases or decreases in phonological accuracy. A change from [kar] to [dar] for the word [dʒar], for example, would reflect an improvement in phonological accuracy. In this regard, the data were surprisingly clear cut. Not only were there not many of these types of decisions to make, but when there were, they were as unambiguous as the example above.

In order to maximize the potential effects of the more structurally complex sentences on target word productions, particularly unstringent criteria were used to attribute an increase or decrease in phonological accuracy. These criteria were formulated to handle the varying number of sentences produced in the stimulus conditions within and across children. When five or fewer utterances in a stimulus condition were produced, an increase in phonological accuracy was scored if there was at least one instance of improvement in phonological accuracy anywhere within the word that was not followed by a decrease in phonological accuracy. In instances in which all eight utterances were produced, the target word was considered to be produced consistently if there was no more than one anomalous word production. When there was more than one anomalous word production, production of the target word in the four less complex utterances was compared to production of the target word in the four more complex utterances. An increase in phonological accuracy was scored when the word was produced more accurately in the four more complex sentences than in the four less complex sentences. Conversely, a decrease in phonological accuracy was scored when the target words were produced less accurately with the more complex sentences. In those instances in which no clear pattern was observed, an inconsistent word production was scored. Three examples involving the target word *log* are provided below to help illustrate the scoring procedures.

1. *Consistent Word Production*: [lag], [lag], [lag], [wag], [lag], [lag], [lag], [lag]. Since there was only one inconsistent production [wag], the target word was considered to be produced consistently.
2. *Increase in Phonological Accuracy*: [wag], [wag], [wag], [lag], [lag], [wag], [lag], [lag]. Since the four more complex utterances contained more correctly produced words (3) than the four less complex utterances (1), an increase in phonological accuracy was scored.
3. *Inconsistent Word Production*: [lag], [wag], [wag], [lag], [wag], [lag], [lag], [wag]. Since there were as many correct productions in the four more complex utterances as there were in the four less complex sentences, an inconsistent word production was scored.¹

To ensure that the scoring procedure described above did not obscure some important variability in the data and that this procedure accurately reflected changes in phonological accuracy, a more straightforward measure, percentage of correct consonant production, was also used to evaluate the phonological variability in children's target word productions. Each target word production was thus scored for the correctness of its initial "target" consonant. In this way, percentage correct consonant productions

could be compared across the eight different sentence structures.

The first author scored all the protocols. Reliability checks made by the second author on all the data from two children found 92% agreement on the judgments made. Disagreements were resolved through discussion.

RESULTS

The data were first analyzed using the more sensitive scoring procedure described in the previous section. It was previously predicted that children with more advanced speech, language, and cognitive skills would be less influenced by changes in language complexity than children with less advanced skills in these areas. To the extent that a child's age and language level also reflected speech and cognitive abilities, there was some support for this prediction. Recall that the three youngest children were functioning in Stage III according to Crystal et al. (1976), whereas the other four children were split evenly in Stages IV and V. From the data in Table 2, it is clear that the three children in Stage III were less consistent in their target word productions than children in Stages IV and V. Less than half (43.0%) of the Stage III children's word productions stayed the same across changes in language complexity compared to four of five (79.0%) of the Stage IV and V children's word productions.

The data in Table 2 also indicate that there were considerable within-stage differences in the consistency of children's word productions. These within-stage differences suggest that there might be some discrepancy in the extent to which these children tolerated variability in their speech. This possibility will be explored further in the discussion.

Looking further at Table 2, for all children the most frequent effect of increases in language complexity was no change in their word productions. Except for the youngest child, Abby, changes in language complexity generally had no clear-cut effect on children's word productions. That is, either no change was found in these word productions or the words were inconsistently produced in the various stimulus conditions.

When increases in language complexity did have a clear-cut effect on children's word productions, there were as many improvements in phonological accuracy as there were regressions in phonological accuracy. This was the case for all children, though slight differences did occur (see Table 2). This finding is particularly important because previous studies have shown that phonological accuracy decreased with increases in language complexity. The fact that unstringent criteria were used to score increases and decreases in phonetic accuracy makes this finding all the more powerful.

Monosyllabic and disyllabic words were not affected differently by increases in language complexity (Wilcoxon Matched Pairs Sign-Rank Test, $p > .10$). However, two of the Stage III children showed a tendency for the phonologically more complex disyllabic words to be influenced more often by increases in language complex-

¹ There were no instances of six-utterance stimulus conditions. There were, however, five instances of seven-utterance stimulus conditions. The procedures used to score these instances followed those described for the eight-utterance stimulus conditions.

TABLE 2. Phonological consistency and accuracy of children's stimulus word productions within stimulus-word conditions. Percentages are given in parentheses.

<i>Measures</i>	<i>Abby</i>	<i>Caroline</i>	<i>Shannon</i>	<i>David</i>	<i>Tucker</i>	<i>Aric</i>	<i>Aaron</i>
Total # of stimulus word conditions	59	62	72	61	60	51	45
Consistent production	19/59 (32.2)	29/62 (46.7)	35/72 (48.6)	40/61 (65.6)	52/60 (86.7)	46/51 (90.2)	33/45 (73.3)
Inconsistent production	11/59 (16.8)	13/62 (21.1)	18/72 (25.0)	7/61 (11.4)	2/60 (3.3)	0/51 (0)	3/45 (6.7)
Increase in phonetic accuracy	14/59 (24.7)	9/62 (14.5)	11/72 (15.3)	9/61 (14.8)	3/60 (5.0)	1/51 (2.0)	5/45 (11.1)
Decrease in phonetic accuracy	15/59 (25.4)	11/62 (17.7)	8/72 (11.1)	5/61 (8.2)	3/60 (5.0)	4/51 (7.8)	4/45 (8.9)
Consistent misarticulations	6/45 (13.3)	11/44 (25.0)	15/52 (28.9)	6/27 (22.2)	13/21 (61.9)	32/37 (86.5)	7/19 (36.8)

ity than the phonologically less complex monosyllabic words. Again, the effect increases in language complexity had on these word productions was to increase as well as decrease phonetic accuracy.

The next analysis considered whether or not children's misarticulated words were less consistent across changes in language complexity than correctly articulated words. These data, which also appear in Table 2, indicated that the two children with the highest proportion of consistent word productions (Tucker and Aric) produced a large proportion of their misarticulated words consistently. This was in direct contrast to the other five children, none of whom produced more than 36% of their misarticulated words consistently.

The final analysis using this scoring procedure considered whether or not children's word productions became less variable over time, as might be expected with maturing speech, language, and cognitive abilities. As can be seen in Table 3, most children's word productions generally showed no change during the 4-month testing period. In addition, with the exception of Abby, the youngest child in Stage III, every child showed more increases than decreases in consistency over time.

TABLE 3. Consistency of children's word productions over time.

<i>Subject</i>	<i>No change</i>	<i>Increase</i>	<i>Decrease</i>	<i>Ambiguous</i>
Abby	9	2	4	3
Caroline	9	3	2	4
Shannon	9	6	2	1
David	10	7	0	1
Tucker	12	5	0	1
Aric	13	5	0	0
Aaron	14	2	1	1
Mean	10.8	4.3	1.3	1.6
SD	2.1	2.0	1.5	1.4

Percentage Correct Consonant Production

As indicated earlier, percentages of correct consonant production were calculated to ensure that the less straightforward scoring procedure did not obscure any important variability in the data. Recall that the first finding reported was that the Stage III children were less consistent in their target word productions than the Stage IV and V children. In terms of correct consonant production, the three younger children did not produce as many correct consonants (58.7%) as three of the four older children (79.9%). The remaining older child, Aric, had the lowest percentage of correct consonants (22.1%) of all the children. Recall, however, that though Aric often did not produce these consonants accurately, he was highly consistent in the way he simplified these consonants.

The next analysis compared the percentage of correct consonants as a function of sentence type. The first scoring procedure revealed no consistent effect of sentence complexity on children's phonological accuracy. This finding was corroborated by the percentage correct scores within and across children. Collapsed across children, the range of percentage correct consonant production varied minimally for the eight sentence types (see Table 4). The range was only from 55.4% for the SVO + modifier construction to 66.7% for the second passive construction, a difference that is clearly negligible. These data also suggest that word position had no effect on children's phonological accuracy because there was no difference in the percentage values for the two passive constructions. Recall that for the second passive sentence, the target word appeared in word-final position, as it did in the other six sentences.

Not surprisingly, there was also little variability across sentence types in the percentage correct consonants for individual children. Though the standard deviations in Table 4 were somewhat large, reflecting individual differences among children (in particular, Aric), they did not

TABLE 4. Percentage correct consonant production.

<i>Subject</i>	<i>One-word</i>	<i>Two-word</i>	<i>SVO</i>	<i>SVO + Mod</i>	<i>NEG</i>	<i>QUEST</i>	<i>PASS-1</i>	<i>PASS-2</i>
Abby	52.5	66.7	52.1	23.1	63.6			
Caroline	66.1	65.6	72.0	47.6				
Shannon	55.9	59.7	59.1	58.0	64.3	0.6		
David	70.5	73.8	72.1	82.0	77.0	72.1	75.4	77.0
Tucker	77.6	75.9	75.9	75.9	81.0	71.6	78.9	80.7
Aric	25.5	25.5	23.5	21.6	21.6	19.6	19.6	19.6
Aaron	84.6	87.0	87.0	73.9	73.9	91.3	90.9	88.6
Mean	61.7	64.7	62.7	55.4	65.7	61.6	66.2	66.5
<i>SD</i>	19.5	19.3	20.3	25.7	22.1	25.9	31.8	31.6

vary much across the first six sentence types. The somewhat higher standard deviations for the two passive sentences reflected the small number of children attempting passives and Aric's particularly low score. The only notable variability occurred in the two youngest children's speech, and this was due largely to the reduced number of attempts involving the more complex sentence types. The reduced number of attempts made the percentage data more variable.

DISCUSSION

Methodological Issues

The most surprising and perhaps controversial finding of this study was that children showed as many improvements in phonological accuracy with increases in language complexity as they did decreases in phonological accuracy. These findings were clearly inconsistent with those of Panagos and his colleagues involving disordered children. One would be justified, however, in questioning the potential effects of practice on these findings. Because the eight sentence types were always presented in the same order, beginning with the simplest structure (one-word) and ending with the most complex structure (passive), practice conceivably could have influenced children's word productions within the stimulus conditions. However, if a practice effect were operating, it was not operating with any regularity either within or across children. A practice effect would predict an increase in phonological accuracy, yet every child showed at least as many decreases in phonological accuracy and inconsistent word productions in the stimulus conditions. Moreover, a practice effect should have caused children to become more consistent in their word productions during the course of the study, yet four of the children actually became less consistent in at least one-word production over the 4-month period. It seems, then, that a practice effect did not cause the discrepant findings in this study. Alternative explanations for these findings are explored in the subsequent sections.

Another methodological issue concerns the use of the sentence imitation procedure to draw conclusions about the interaction of sentence formulation components. Paul

and Shriberg (1982) presented various arguments about the unnaturalness of imitation contexts. Spontaneous speech contexts, however, offer no guarantee of naturalness, given the variability that can exist in such contexts. The other point usually made is that an imitation task places different demands on sentence formulation components than spontaneous speech. Overlooked here, however, is that processing demands also vary considerably within different spontaneous speech situations according to such things as the extent of contextual support, the type of speech act, and the conceptual complexity of the message. Thus, although the conclusions drawn in this study are based on findings from a sentence imitation task, these conclusions are not necessarily limited to imitative speech contexts. To help resolve some of these issues, we are in the process of gathering data that will enable us to compare the interaction of sentence formulation components in imitative and spontaneous speech contexts.

Explaining Individual Differences

In the introduction, it was suggested that three factors seem to influence the way in which children manage different processing demands: (a) the sensitivity of the measures used; (b) the developmental level of children's speech, language, and cognitive abilities; and (c) the extent to which children tolerate or allow variability in their speech productions. In the current study, we were concerned with perceptible phonetic and phonemic changes in children's target-word productions. With regard to factors (b) and (c), we made two predictions: first, that the speech of children with more advanced speech, language, and cognitive skills would be less affected by higher level processing demands than the speech of children with less advanced skills in these areas; and second, that children who exhibited more variability in their speech would be more influenced by higher level processing demands than children who exhibited less variability in their speech.

To the extent that a child's age and developmental language level also reflected speech and cognitive abilities, the data generally supported the first prediction. The three Stage III children exhibited considerably more

variability in their word productions than the four children in Stages IV and V. These findings were consistent with previous research that has found children's speech productions becoming less variable with age and improving speech, language, and cognitive abilities (Schwartz & Folger, 1977; Schwartz & Prelock, 1982).

The fact that the first prediction was supported by the data meant that there was also some support for the second prediction because younger children will necessarily have more variability in their systems than older children. For this reason the more interesting test of the second prediction is whether or not children of the same age and language level showed similar responses to the higher level processing demands. The reasoning here is that within-stage differences would more likely be due to differences in children's tolerance of variability rather than differences in speech, language, and cognitive abilities. Several within-stage differences in children's production of the target words were in fact found. One of the Stage III children, Abby, had 13–15% fewer consistent word productions than the other two Stage III children. Also, two of the Stage IV/V children, Tucker and Aric, averaged 88% consistent word productions in comparison to 69% for the other two children. These three children seem to represent opposite ends of the continuum, from high tolerance of speech variability to low tolerance. More significantly, there is evidence that suggests Abby had more tolerance for speech variability than the two other Stage III children, and that Tucker and Aric had less tolerance for speech variability than the two other Stage IV/V children.

In considering Abby's abilities in comparison to the other two Stage III children, several findings are revealing. First, Abby was the only Stage III child, and only child in the study, whose word productions did not become more consistent during the course of the study. That is, unlike the other children, Abby showed rather protracted periods of variability in her acquisition of sounds and words. Second, in a companion study on cluster reduction involving most of these same children (Catts & Kamhi, *in press*), Abby showed the most overall variability in her reduced clusters, using short and long lag stops as well as fricatives in her reduced forms within the same session on the same word. Finally, Caroline and Shannon, the two other Stage III children, seemed to have phonological systems no more advanced than Abby's, yet showed twice as much consistency in their production of misarticulated words and more consistent word productions overall than Abby. Consider Shannon, for example, who actually had more stimulus conditions containing misarticulated words than Abby. Despite having a phonological system potentially less mature than Abby's, Shannon still managed twice as many consistent productions of misarticulated words as Abby. The same was true for Caroline, who had the same number of stimulus conditions with misarticulated words as Abby (refer to Table 2 for these data). Taken together, these findings suggest that Abby was more tolerant of variability in her speech than both Shannon and Caroline.

The same reasoning can explain the within-stage differ-

ences between Tucker and Aric and the other two Stage IV/V children. For example, when Aric and Tucker acquired sounds that they had not been producing previously (e.g., θ), with one exception, they always used the new sound consistently with the different sentence types. In contrast, the other two advanced children, David and Aaron, usually had a transition period in which they would produce some of the words with the newly acquired sound and some with the old substituted sound (e.g., θ and ϑ /f and ϑ). In addition, David, who had almost as many stimulus conditions with misarticulations as Aric, produced only 22% of these words consistently compared to 86.5% for Aric; and Aaron, who had about the same number of stimulus conditions with misarticulated words as Tucker, was consistent in only 37% of his word productions compared to 62% for Tucker (refer to Table 2 for these data).

Based on this evidence, it seems likely that the within-stage differences found in the consistency of children's word productions were caused primarily by differences in the extent to which these children tolerated variability in their speech rather than by significant differences in these children's speech, language, or cognitive abilities. Conceivably, the extent to which a child tolerates speech variability might be indicative of a more general style of language or phonological acquisition. Recall that Ferguson (1979) suggested that children with a looser, more variable system might reflect an unanalytic, risk-taking style, whereas children who construct a more rigid, less variable phonological system might show an analytic, cautious style of acquisition. If this distinction is valid, then Abby would appear to represent the unanalytic, risk-taking style, whereas Tucker and Aric would represent the analytic, cautious style. A study that includes independent measures of style could evaluate this possibility.

The Sentence Formulation Process: Interdependence or Autonomy?

In light of the complexity of the issues involved, these comments are necessarily speculative and thus should not be taken as "conclusions." Few would disagree that the higher level linguistic components and the lower level speech production components in sentence formulation are anatomically and physiologically distinct. Less clear is how much processing space a child allocates to a particular sentence formulation component and what factors influence allocation decisions. Logically, children have one of two choices: They can either operate within the limits of their processing capabilities or they can exceed these limits and suffer the consequences. The findings from this study lead us to hypothesize that the level of a child's speech, language, and cognitive abilities defines the capacity limits of the sentence formulation process, whereas the extent to which the child tolerates variability in speech determines whether or not these limits are observed or exceeded. This hypothesis predicts that the processes involved in sentence formulation will show different patterns of interaction (ranging from high-

ly interdependent to highly autonomous) within the same child and across different children as a function of speech, language, and cognitive abilities and tolerance for speech variability. One might further hypothesize that in children with comparable speech, language, and cognitive levels, different patterns of interaction will be motivated by differences in the extent to which variability is allowed. Evidence was presented in this study to support both of these hypotheses.

These hypotheses have some intriguing implications. For example, the extent to which a child shows phonological selectivity might be a function of his or her tolerance for speech variability. As suggested earlier, the difference between Waterson's child, who functioned within his processing limits, and Scollon's (1976) subject, who did not, might be in the extent to which these children tolerated variability in their speech. During this early period of development, when speech, language, and cognitive skills are limited, children must show some phonological selectivity in order to function within their processing capabilities. In this case selectivity involves not only choosing which sounds and phonetic shapes to avoid, but also selecting words with an "eye" towards the amount of phonological differentiation possible for each particular sentence type.

These predictions at first seem inconsistent with the findings from the Panagos studies. One possibility is that the group data in the Panagos studies might have obscured individual differences similar to the ones found in this study. It is more likely, however, that disordered children respond in different ways to higher level processing demands than do normal children. Shriberg (1982) has noted that children with phonological disorders rarely show phonological selectivity in their speech. One reason for this reduced selectivity is that the speech, language, and cognitive deficits of these disordered children make them more tolerant of variability in their speech. Normal children who show a high tolerance for variability in their speech, such as Abby, maintain some control over the sentence formulation process because this variability is most prevalent during early stages of language development when utterances are short and contextually redundant. By the time the normal child begins to produce longer utterances, speech, language, and cognitive abilities have progressed sufficiently to keep excursions beyond processing capabilities from significantly impairing intelligibility and other aspects of language performance.

In contrast, most disordered children, because of their limited processing abilities, are often forced to exceed their processing capabilities early in life. Not only do many disordered children continue to exceed their processing limitations as they get older, but the consequences of exceeding processing limitations also become worse as these children begin to use longer utterances and talk about objects and events without contextual support. The result is a highly interactive or interdependent language formulation process, whereby added complexity at one level often adversely affects the output at other levels, just as Panagos and Prelock (1982) have contended.

Deficits in speech, language, and/or cognitive abilities thus seem to make the relationship between the processes in sentence formulation a more interdependent one than it often is in normally developing children.

In conclusion, in this study we have attempted to understand better the way in which children's developmental level and tolerance of speech variability influences the management of processing demands. As expected, younger children with less advanced speech, language, and cognitive abilities were found to be more influenced by changes in language complexity than older children with more advanced speech, language, and cognitive abilities. However, performance differences were also found among children at the same developmental language stage. We have suggested that the between-stage differences were primarily caused by differences in developing speech, language, and cognitive abilities, whereas the within-stage differences were primarily caused by differences in the extent to which children tolerated variability in their speech. Based on this contention, some speculations were offered concerning the way in which normal and disordered children manage processing demands.

ACKNOWLEDGMENTS

Portions of this paper were presented at the Midwest Child Phonology Conference, Purdue University, April 1983.

REFERENCES

- BOCK, J. K. (1982). Toward a cognitive psychology of syntax: Information processing contributions to sentence formulation. *Psychological Review*, 89, 1-47.
- CATTS, H., & KAMHI, A. (in press). Simplification of /s/ + stop consonant clusters: A developmental perspective. *Journal of Speech and Hearing Research*.
- CLARK, H., & CLARK, E. (1977). *Psychology of language*. New York: Harcourt Brace Jovanovich.
- CRYSTAL, D., FLETCHER, P., & GARMAN, M. (1976). *The grammatical analysis of language disability*. New York: Elsevier.
- FERGUSON, C. (1979). Phonology as an individual access system. In C. Fillmore, D. Kempler, & W. Wang (Eds.), *Individual differences in language ability and language behavior*. New York: Academic Press.
- FOSS, D., & HAKES, D. (1978). *Psycholinguistics*. Englewood Cliffs, NJ: Prentice-Hall.
- HODSON, B. (1980). *The assessment of phonological processes*. Danville, IL: Interstate Printers & Publishers.
- LEONARD, L., ROWAN, L., MORRIS, B., & FEY, M. (1982). Intra-word phonological variability in young children. *Journal of Child Language*, 9, 55-71.
- LEONARD, L., SCHWARTZ, R., FOLGER, M., & WILCOX, M. (1978). Some aspects of child phonology in imitative and spontaneous speech. *Journal of Child Language*, 5, 403-416.
- MILLER, J. (1981). *Assessing language production in children*. Baltimore: University Park Press.
- MILLER, J., CHAPMAN, R., BRANSTON, M., & REICHLER, J. (1980). Language comprehension in sensorimotor stages V and VI. *Journal of Speech and Hearing Research*, 23, 284-311.
- NELSON, K. (1973). Structure and strategy in learning to talk. *Monographs of the Society for Research in Child Development*, 149.

- PANAGOS, J. (1982). The case against the autonomy of phonological disorders in children. *Seminars in Speech, Language and Hearing*, 3, 172-182.
- PANAGOS, J., & PRELOCK, P. (1982). Phonological constraints on the sentence productions of language-disordered children. *Journal of Speech and Hearing Research*, 25, 171-177.
- PAUL, R., & SHRIBERG, L. (1982). Associations between phonology and syntax in speech-delayed children. *Journal of Speech and Hearing Research*, 25, 536-547.
- SANDER, E. (1972). When are speech sounds learned? *Journal of Speech and Hearing Disorders*, 37, 55-63.
- SCHWARTZ, R., & FOLGER, P. (1977). Sensorimotor development and descriptions of child phonology. *Papers and Reports in Child Language Development*, 13, 8-15.
- SCHWARTZ, R., & PRELOCK, M. (1982). Cognition and phonology. *Seminars in Speech, Language and Hearing*, 3, 149-162.
- SCOLLON, R. (1976). *Conversations with a one-year-old*. Honolulu: University Press of Hawaii.
- SHRIBERG, L. (1982). Programming for the language component in developmental phonological disorders. *Seminars in Speech, Language and Hearing*, 3, 115-127.
- WATERSON, N. (1978). Growth of complexity in phonological development. In N. Waterson & C. Snow (Eds.), *The development of communication*. New York: Wiley & Sons.

Received March 11, 1983

Accepted February 2, 1984

Requests for reprints should be sent to Alan G. Kamhi, Department of Audiology and Speech Pathology, Memphis State University, 807 Jefferson Ave., Memphis, TN 38105.