Motor difficulty and order of sound acquisition

Gayle Stone Fulton

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MOTOR DIFFICULTY AND ORDER OF
SOUND ACQUISITION

By

Gayle Stone Fulton
B.A., Tulane University, 1965

Presented in partial fulfillment of
the requirements for the degree of

Master of Arts
UNIVERSITY OF MONTANA
1975

Approved by:

[Signature]
Chairman, Board of Examiners

[Signature]
Dean, Graduate School

Date Aug 8, 1975

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Motor Difficulty and Order of Sound Acquisition (48 pp.)

Director: Dr. Evan P. Jordan

This study investigated the relationship between motor difficulty of sound production and speech sound development. Since acquisition schedules indicate that children generally learn terminal sounds later than their initial counterparts, another major purpose of this study was to contrast the motor difficulty of initial and terminal sound production.

Forty-five adults scaled motor difficulty of syllable-initiating and syllable-terminating consonantal sounds. The psychological scaling method used was direct magnitude estimation. Mean scale values were derived from the motor difficulty ratings and were correlated with initial and terminal speech sound acquisition schedules. These values were also utilized in a two-way analysis of variance and a table contrasting initial and terminal motor difficulty.

Findings indicate that motor difficulty as rated by adults is more strongly related to initial sound acquisition than to terminal sound acquisition (r=0.66, initial sounds; r=0.39, terminal sounds) and that, in general, terminal sound production is motorically more difficult than initial sound production.
ACKNOWLEDGMENTS

First and foremost I wish to thank my parents and sons who have made sacrifices so that I might attain this goal. Secondly, I wish to express heartfelt appreciation to Dr. Jordan for unselfishly giving of his time in guidance and encouragement. I greatly appreciate the time given me by all committee members, Dr. Robert Anderson, Ms. Sarah McClain, M.A. and Ms. Barbara Bain, M.A. A special thanks also to Winnie Will, for being a wonderful and a most needed listener.
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CHAPTER I

INTRODUCTION

Investigations of meaningful speech sound acquisition by children have shown that some sounds are mastered by a greater percentage of children earlier than other sounds. Though individual children master sounds at differing rates and perhaps in differing sequences, group acquisition schedules appear to be interpretable in terms of a rank order of difficulty or a general developmental order. The later learned sounds have been assumed to be more difficult to learn in some aspect than the earlier learned sounds. Early theorists have attempted to account for this general developmental order on the basis of physiological constraints or motor difficulty of articulation (Fritz Schultz 1880, as quoted by Jakobson), later theorists on the basis of auditory limitations or perceptual difficulty (Olmsted 1966).

Different models of speech production and perception differentially stress the importance of auditory and motor skills in the development and maintenance of adequate articulation. These models also serve to illustrate the intricate and complex interdependence between the two skills. A motor theory of speech perception has been formulated by Liberman...
et al. (1957) after an unsuccessful search for invariant distinguishing acoustic cues in the acoustic spectra of speech sounds. Liberman et al. posit motor mediation of speech sound perception, perception based on reference to articulatory patterns. This theory implies that motor production precedes, guides, and limits auditory perception. Fairbanks (1954), in his servomechanistic theory, includes the auditory channel, traditionally thought to be primarily a receiving component, as an active component of speech production. He describes the auditory and oral somesthetic channels as carrying feedback signals automatically used by the speaker to regulate and correct his speech production. According to this theoretical model, auditory perceptual skills guide and control speech motor activity.

Those believing speech sound acquisition to be primarily related to auditory perceptual skills point to the seemingly parallel growth and maturation of auditory discrimination and articulatory skills (Templin 1957 and Tikofsky and McInish 1969). Correlational and group comparison studies exploring the auditory perceptual-articulation relationship do suggest that depressed auditory perceptual skills and deviant articulation co-occur. However, these studies have not succeeded in revealing a cause-effect relationship and have been criticized on the basis that: (1) some children with normal articulation perform poorly on speech discrimination tasks.
(suggesting that perhaps some skills needed for speech discrimination tasks are not important for articulation learning); and (2) that it is not shown that the sounds misperceived are the sounds misarticulated (Locke and Goldstein 1971). Studies concerned with the perception and production of specific sounds by preschool children have revealed only a very mild relationship between these skills and have uncovered some empirical data which question the adequacy of perception to account for the child's acquisition of phonemes. Locke and Goldstein (1971) found that children misarticulating specific sounds had a greater probability of also misperceiving these sounds than did children who correctly produced these sounds. However, this probability was only slightly greater and the relationship was not a perfect one. The misarticulating children frequently perceived the sounds correctly while the children with correct articulation of these sounds often misperceived them. Graham and House (1971) found that the contrast pairs p-m and p-t, phonemes accurately and consistently produced by three-year-olds, were two of the eleven contrast pairs that generated high error rates by three to four and one-half year old children on a discrimination task. In addition, it should be stressed that findings of perceptual studies with young children are viewed with caution because of methodological considerations. It is uncertain that young children comprehend the necessary concepts needed to execute their perceptual judgments.
Articulation is obviously a motor skill in some part and, as motor skills tend to be developmental in nature, some feel that physiological restraints and constraints are the important determiners of articulation development. Studies (Clark 1959; Prins 1962; and Jenkins and Lohr 1964) have linked deviant articulation with inferior gross and fine motor skills and with motor tasks specific to the oral mechanism (such as diadochokinetic rates). Perkell's (1969) physiological model of speech production suggests that the developmental differentiation and refinement of extrinsic and intrinsic tongue muscle control is involved in regulating articulation development and determines the early acquisition of vowels and diphthongs and the, generally, later acquisition of consonant sounds requiring more difficult, intrinsic muscle adjustments.

Although few studies have explored the relationship between speech sound acquisition and motor difficulty, a recent study which has studied it is that of John Locke (1972). Locke obtained a correlation of 0.66 between adult muscular ease ratings of initial consonant production and three-year-old phonemic acquisition data (Templin 1957); he found a much lower correlation of 0.07 between perceptual data (Koenigsknecht 1970) and phonemic acquisition data (Templin 1957). These data lead Locke to suggest that motoric ease may well be more important than perceptual ease in determining the acquisition schedule for specific phonemes. However, Locke's data relat-
ing motor difficulty and acquisition was limited to initial consonants and it is widely known that, in general, terminal consonant sounds are acquired later than initial.

Motor considerations of consonant position have been explored by Briere (as quoted in Hirsch and Panagos 1972), who found that American English speakers capable of pronouncing /ŋ/ and /ʒ/ in their native postvocalic position required training to produce these sounds in the non-English prevocalic position. Hirsch and Panagos (1972) investigated positional transference of newly acquired initial sounds by adults. They found that trial responses were needed before the sound was produced correctly in the terminal position. Hirsch and Panagos felt these trials were needed for articulator reordering.

Survey of the literature would seem to indicate, then, that:

(1) Auditory perception and articulation are related.
(2) Motor skills and articulation are related.
(3) As currently measured, level of auditory perceptual skills does not appear to account for the developmental order of initial consonant acquisition.
(4) A measure of motor difficulty of sound production relates much better to the initial sound developmental order than a measure of perceptual difficulty.
There is a question then as to whether the terminal sound acquisition schedule is as closely related to motor difficulty as the initial acquisition schedule. Further, differences and similarities in the motoric difficulty of initial and terminal sounds is data of high potential usefulness in modification of articulatory behavior.

It was of particular interest in this study to determine whether motor difficulty is correlated with and can, therefore, be considered related to the terminal consonant acquisition schedule of children.

The present study explored the relationship between motor difficulty of sound production and the child's phoneme acquisition schedule and contrasted motor difficulty of initial and terminal sound production. Data were adult ratings of muscular difficulty of consonant production utilizing direct magnitude estimation to obtain a ratio scale. Statistical analyses include correlations between adult initial and terminal consonant difficulty ratings and three-year-old initial and terminal consonant acquisition (Prather et al. 1974). An analysis of variance procedure was used to explore effects of muscular difficulty, syllabic position and individual consonant. It was felt that obtained relationships between motor difficulty data and the child's consonant acquisition schedules and between motor difficulty data and syllable position would strongly support the hypothesis that motor difficulty is the
primary governing factor of initial and terminal speech sound acquisition.
CHAPTER II

PROCEDURE

Major Purposes

The major purposes of this study were:

(1) to explore the relationship between motor difficulty of sound production and the child's phoneme acquisition schedule;

(2) to contrast motor difficulty of initial and terminal sound production.

Stimuli were consonant-initial and consonant-terminal syllables. These were randomized and the list was recorded as described below. Subjects were asked to produce the stimulus syllables and to scale them according to amount of muscular difficulty involved in their production. To increase the probability that the desired syllable was produced and scaled, the syllable list was presented both auditorily and orthographically.

Rationale for Sounds Scaled

One of the major purposes of this study was to contrast motor ease of initial and terminal sound production. Therefore it was deemed advantageous to include all possible con-
sonant phonemes in both initial and terminal syllabic positions. Irregularities necessitated by this consideration were:

(1) classification of glides and liquids as consonants; and

(2) inclusion of sounds in syllabic positions not ordinarily occurring in English: initial /ŋ/ and /z/ and terminal /hw/, /h/, /j/, and /w/. Initial /ŋ/ and terminal /hw/ were eliminated on the basis that they were not readily produced by phonetically naive adults. Syllable terminal /h/, /w/, and /j/ were elicited in the syllables /ah:/, /au/, and /ai/ respectively. That these syllables incorporated the nearest equivalents to initial /h/, /w/, and /j/ was decided on the articulatory bases of tongue position and movement. It should be noted that a similar classification of these diphthongs is utilized in the Laradon Articulation Test (1963) and that Bloch and Trager (1941) suggested that terminal diphthongs in stressed syllables be considered not as unit phonemes but as combination of a vowel phoneme with a following offglide. They argued that the principle of complementary distribution as well as obvious phonetic resemblance supports this view. An additional rationale for including these sounds is that, though they may not occur word-initially or word-terminally in the formal linguistic structure of standard English, they may occur as syllable initiators and terminators in running speech with close juncture.

The experimenter is aware that the above phonemic classi-
fications are controversial and that some of the sound pairs may not be acceptable to all. The data are analyzed in such a manner that specific consonant data can be easily identified and included or excluded from consideration as the reader desires.

Experimental Tapes

Each consonant phoneme of standard English (Salus, 1969) (with the above-mentioned exceptions of /ŋ/ and /hw/ which are utilized only in their normally occurring positions) was combined with the /a/ vowel to form both a consonant-vowel (CV) and a vowel-consonant (VC) syllable. Thus each consonant (excepting /ŋ/ and /hw/) occurred twice, once in the syllable-initial and once in the syllable-terminal position. To provide some means for evaluating reliability and possible order and/or fatigue effects, the first twenty syllables of the randomly ordered syllable list were duplicated and placed at the end of the list so that they were the first and the last syllable items to be scaled. Thus the entire list of syllables was sixty-eight syllables in length, the last twenty syllables duplicating the first twenty. The orthographic syllable list was presented as two separate lists of thirty-four syllables each in order to obscure the fact that the list contained duplicated syllables.

An adult female speaker of General American recorded
the randomized syllable list on a Uher 4000 Report-L recorder using the Uher M516 microphone and tape of good quality. Tape speed was \(7\frac{1}{2}\) inches per second. Syllables were numbered and were presented at five second intervals. Peak level of \(+2\ dB\) was maintained as monitored by a VU meter.

The parallel orthographic presentation of random syllables can be found in Appendix A.

Subjects

The scaling task was administered to two groups of subjects at different times. Group 1 consisted of twenty-two college students enrolled in education courses at the University of Montana. Group 2 consisted of twenty-three non-university adults from a local church. All subjects were native-born, normal speaking, normal hearing, and naive to the theoretical implications of the task. They all spoke General American dialect. It was assumed that sex and individual variations in pitch and intensity would have no influence on perceived muscular difficulty of sound production and thus Group 1 contained ten males and twelve females; Group 2 contained seven males and sixteen females.

The two separate administrations of the scaling task differed slightly in three respects: (1) hearing assessment procedures; (2) prescaling training; and (3) task directions. Hearing assessment differed in that Group 1 received an audio-
metric hearing screening; Group 2 was asked to indicate on the questionnaire if they were currently experiencing any difficulty hearing and/or understanding speech. The difference in prescaling training was in number of comparative needle-threading tasks. Group 1 received three needles with contrasting eye sizes; Group 2 received two. Instructions differed in elaboration. Since a large percent of subjects in Group 1 used limited number ranges for scaling, Group 2 received instructions encouraging sensitivity to the broad range of motor difficulty present in the syllable list and encouraging the use of a broader range of numbers to reflect these differences. The elaborated set of instructions given to Group 2 did produce the desired results; this group did use a broader range of numbers than Group 1.

The questionnaire below was answered by the subjects in Group 1 two days before the scaling session. This served to determine some of the above subject qualifications and to direct the experimenter's attention to subjects with possible limitations for muscular difficulty scaling.

Name:_______________________________________________________
Place of birth:______________________________________________
First language spoken:________________________________________
Any dental appliances:________________________________________
Self evaluation of your current speech:________________________
Past speech problem?_____ If so, identify as best you can:________________________
Speech, voice and dentition of Group 1 were assessed by the experimenter during the hearing screening. Hearing was screened in the language laboratory with five freshly calibrated portable Beltone 10-C audiometers and trained testers the day before the scaling. An H. H. Scott sound level meter Model No. 450 was used to measure ambient noise levels. The A scale was chosen as an approximation to octave band analysis of the three frequencies measured. Ambient noise levels were below criteria levels 50, 58 and 76 dB (Chaiklin et al. 1975) as evidenced by an A scale reading of 32 dB on the H. H. Scott Model No. 450 sound level meter. (Hearing within 20 dB HL [ANSI, 1969] at 1000 and 2000 Hz and 25 dB at 4000 Hz was considered within the normal range and adequate for the scaling procedures.)

The questionnaire answered by Group 2 was as above with the two following additions:

Are you aware of any current hearing loss?_________
Do you currently have difficulty understanding speech?_________________________________________

Prescaling Training

Subjects were given practice in assigning numbers to the continuum of muscular difficulty through the use of graded tasks with needle and thread. Tasks were graded through use of different sized needle eyes. Large-eyed
needles were raffia straw needles No. 14, small-eyed needles were thin bead needles No. 10, and medium-eyed needles were bead needles No. 16. Thread size 50 was used for all threading tasks. Subjects in Group 1 were instructed to thread first the large-eyed needles, next the small-eyed needles, last, the medium-eyed needles. Subjects in Group 2 were instructed to thread first the small-eyed needles, then the large-eyed needles. Immediately following each trial subjects were told to scale the muscular difficulty of each threading task. Exact instructions were:

Thread each of the needles when told to do so. After threading each needle assign the task a number proportional to its muscular difficulty.

To clarify the scaling procedure, the experimenter drew a straight, horizontal line representing a continuum on a chalkboard at the front of the room. One end was labeled "extreme difficulty," the opposite end "little difficulty." Subjects were instructed to assign numbers to the perceived muscular difficulty of each trial designating its approximate place on the continuum. As recommended by Stevens (1966), subjects were informed concerning the availability of negative as well as positive numbers for scaling.

**Scaling Session**

Scaling was done in a language laboratory equipped with a reel-to-reel Rheem Califone 904-SR console and forty booths with individual headphones of various makes, loudness controls,
and cassette recorders. The room was not sound treated but the seals of the headphones were considered adequate to ensure proper listening conditions with insignificant interference from listener to listener. The experimental tape was presented at a comfortable listening level, centering around 65 dB SPL, at the console. Hearing level was not a major issue and subjects were asked to adjust the loudness level of their headphones so they could hear comfortably.

A sample of seven syllables, representing the speech range in terms of acoustic frequency components, was presented through the headphones as subjects made their loudness adjustments.

Subjects were given a printed copy of the instructions and were asked to read silently as they listened to the taped instructions through earphones. The instructions given to Group 1 and paraphrased from Stevens, were as follows:

You will hear a list of nonsense syllables which you can also see on the attached sheets of paper. Your task is to repeat aloud the syllable you hear and decide the amount of muscular difficulty needed to say the syllable. Give each syllable a number proportional to its apparent difficulty.

Instructions given to Group 2 were:

You will hear a list of nonsense syllables which you can also see on the attached sheets of paper. These syllables cover a broad range of motor difficulty, from very easy to very difficult. Be sensitive to this range. Your task is to repeat aloud the syllable you hear and decide the amount of muscular difficulty needed to
say the syllable. Assign the first syllable any number of your choosing which represents, to you, the amount of difficulty needed to say the syllable; do the same for all subsequent syllables. If a following syllable is twice as difficult as an earlier one, assign it a number twice as large. If a following syllable is half as difficult, give it a number half as large, and so on.

Time was then allowed for clarification of any questions concerning the task. Subjects were told to turn to the printed, randomly-arranged lists and were informed that they would hear the syllables in that exact order. The voicing distinction and orthographic denotation of the /ʃ/, /θ/ cognates and the desired production of /hw/ were explained. Subjects were asked to write the scale number in the blank opposite the printed syllable. The range of each individual rater was adjusted to agree with the largest range used. This was done by multiplying each value by a suitable multiplier. As a consequence, all ratings were henceforth on the same scale.

Nine randomly chosen subjects were monitored via cassette tape recorders to determine the extent to which they were correctly producing the experimental syllables.

Statistical Design

Mean scale values of the experimental syllables were computed for Group 1 and Group 2 separately. These values were correlated to obtain an inter-group reliability co-
efficient. A test-retest intra-group reliability coefficient was computed for the twenty duplicated syllables. Mean scale values were computed for the first judgments of the twenty repeated syllables and correlated with the mean scale values for the second judgments. The value for a reliability coefficient of 0.90 or above was considered an adequate level of reliability and is in line with reliability coefficients obtained with other scaling studies (Prather 1960).

Syllable production of nine randomly chosen subjects had been recorded. Their syllable production was checked to determine the percentage of syllables erroneously produced.

To examine the relationship between muscular difficulty and speech sound development, two Pearson r's were computed relating perceived muscular difficulty data and percent-correct-articulation-by-three-year-olds data from Prather's study (Prather et al. 1975). Correlations were run separately for initial and terminal sound data. For purposes of computing the Pearson r's mean scale values of difficulty ratings were obtained and these were correlated with percentage correct production of each sound by three-year-olds. The experimenter chose to use sound acquisition data of three-year-olds because this age appeared to best reflect the relative difficulty of specific sound elements and sound position. In general, investigation of children's speech sound acquisi-
tion schedules indicate that while the three-year-old has mastered vowels, diphthongs, and the consonants /p/, /m/, /h/, /n/, and /w/, he is still in the process of mastering /k/, /g/, /d/, /b/, and /t/, is just beginning to acquire /f/ and /j/, and has yet to acquire even later learned sounds. Sound production at age three, then, was viewed as providing a relatively sensitive index of sound acquisition.

Relationships between muscular difficulty of production, syllabic position, and identity of individual sound were explored by means of an analysis of variance utilizing a treatment by treatment by subjects design (Lindquist 1953:237, 238). Scheffe' contrasts were used to assess the effects of manner, place, and syllable position.
CHAPTER III

RESULTS AND DISCUSSION

Introduction

A syllable list was constructed which contained sounds having consonantal function in English in both syllable-initial and syllable-terminal position but including four controversial sounds (vowel lengthening for terminal /ah/, /ai/ for terminal /aj/, /au/ for terminal /aw/, and syllable-initial /aj/). Each sound was scaled on the attribute of motor difficulty. Scaling was done by two separate groups of listeners at different times. Mean scale values were calculated for each syllable within each of the two groups of listeners. Statistical analyses were performed on the motor difficulty scale values to explore the possibility of a relationship between motor difficulty and sound acquisition by children and to evaluate the relationships between motor difficulty, identity of the individual sound, and syllable position of each sound. The statistical analyses include correlations, a two-way analysis of variance, and Scheffe' contrasts.

Reliability

The first twenty of the forty-eight syllables were
duplicated as the last twenty syllables in order to enable a measure of intra-group reliability. Verbal and written subjective responses of the subjects indicated that the subjects became more comfortable with the scaling task as they progressed through the syllable list. On the basis of these reactions, it was decided to accept the scale value of the last twenty of the twenty duplicated syllables rather than the first twenty as the experimental values for those syllables.

In order to obtain the advantage of a larger sample of listeners, the 48 mean motor difficulty values for the experimental syllables from Group 1 data were correlated with the 48 mean scale values of Group 2. The resulting $r$ of 0.91 was considered large enough to justify combining Group 1 with Group 2 and an N of 45 was thus obtained.

Mean scale values from the combined group for the first twenty and last twenty duplicated syllables were derived and correlated with one another. The obtained test-retest, intra-subject reliability coefficient was 0.96 which met the previously-set criterion of 0.90 or above and the mean scale values were consequently viewed as highly reliable.

**Subject Syllable Production**

As previously stated, the syllable utterances of nine randomly-chosen subjects were taped to sample whether sub-
jects were correctly producing the experimental syllables. These tapes revealed that none of the nine subjects produced anything other than the target syllables and this evidence was taken as strongly indicative that the entire group of listeners produced few if any syllables deviating from the experimental targets. It was concluded, therefore, that the listeners were scaling the appropriate sounds with associated sensory-motor feedback from production of those sounds.

**Relationship Between Motor Difficulty and Acquisition**

Correlations between mean scale values of adult-perceived motor difficulty of the experimental sounds and percent-correct-articulation-by-three-year-olds of the same sounds (Prather et al. 1975) for initial and terminal sound data resulted in an \( r \) of 0.66 for initial sound data and an \( r \) of 0.39 for terminal sound data. These correlations relating motor difficulty and three-year-old sound acquisition data indicate that motor difficulty as rated by adults is more strongly related to initial sound acquisition than to terminal sound acquisition. Results of this study suggest that motor difficulty may account for approximately 44 percent of the variance in initial sound acquisition while it accounts for only about 15 percent of the variance in terminal sound acquisition. There is, thus, experimental support for the con-
tention that initial sound acquisition may be much more a function of motor difficulty of the individual sound than is terminal sound acquisition. The questions were then asked: (1) Could terminal sound acquisition be predicted by initial sound acquisition; or (2) Could motor difficulty of terminal sounds be predicted by the motor difficulty of initial sounds? Again correlations were utilized to evaluate these relationships. Results suggest that the strength of either of these relationships is only moderate. The correlation between scaled motor difficulty of syllable-initial sounds and scaled motor difficulty of syllable-terminal sounds is 0.73; the correlation between order of acquisition of initial sounds and order of acquisition of those same sounds in the terminal position is 0.68. Both correlations indicate that about 50 percent of the variability in syllable-terminal motor difficulty or acquisition order of sounds is accounted for by variability in the equivalent measure of syllable-initial sounds. It appears, then, that the terminal consonantal sounds may differ importantly from the initial consonantal sounds in several ways: (1) in motor difficulty, (2) in order of acquisition, (3) and in the strength of relatedness of motor difficulty and order of acquisition. These differences suggest that initial sounds and terminal sounds are, indeed, two very different sets of sounds from an articulatory point of view and that research and discussion concerning these
sounds should often consider them as separate and different sets of events.

Findings of this study indicate that 66 percent of the variance in initial sound acquisition and 85 percent of the variance in terminal sound acquisition is not accounted for by motor difficulty. Variance in sound acquisition unaccounted for by motor difficulty may reside in perceptual factors and in the frequency with which the child encounters the sounds. Locke (1972) obtained measures of correlation for these relationships with initial sound acquisition and found that perception may account for only 5 percent of the variance in initial sound acquisition and frequency of occurrence for 16 percent of the variance in initial sound acquisition. Together perception, frequency of occurrence, and motor difficulty (44 percent), then, can account for approximately 65 percent of the variance in the initial sound acquisition schedule. The remaining variance of 35 percent may well be due to the differences in frequency of occurrence experienced by individual children and to the differences in perceived motor difficulty by individual adults, i.e., intra-group variability. These percentages suggest that perhaps motor difficulty is the largest (but definitely not the only) contributing factor in initial sound acquisition. Similar information concerning terminal sounds is not available but would be of considerable interest.
It is of particular interest to note that the correlation obtained in this study between initial-sound motor difficulty and Prather's three-year-old-sound-acquisition data (0.66) agrees exactly with that obtained by Locke (1972) using an initial-sound motor-ease rating scale and Templin's (1957) three-year-old-sound-acquisition data. The repetition in two separate experiments of moderate correlations between measures of motor difficulty and measures of initial-sound acquisition strengthens the conclusion that a high moderate relationship between initial sound acquisition and motor difficulty does, indeed, exist.

The agreement between the various methods of motor difficulty scaling is also of interest. Locke (1972) obtained an r of 0.78 between the scale values produced by two different groups of subjects using two different psychological scaling methods, interval scaling and paired comparisons. Correlations obtained between the motor difficulty scaling method used in this study, direct magnitude estimation, and Locke's methods were 0.71 (interval scaling) and 0.60 (paired comparisons). In each of these cases of moderate agreement there exists both difference in groups of listeners and difference in scaling methods. However, the same scaling method, direct magnitude estimation, with different groups of listeners (this study) produced scale values which related at r=0.91. It appears, then, that the scaling method used has import in
determining scale values in this complex dimension and that a validity study, perhaps one utilizing electromyographic readings, is in order.

Although substantial correlation need not indicate causality and adult motor-difficulty scaling cannot be assumed to be synonomous with scaled motor difficulty as generated by children, this study and Locke's suggest that individual phonemes vary in motor difficulty, that motor difficulty is, in some way, related to acquisition and that this relationship is most importantly true of syllable-initial sounds.

**Differences Among Sounds and Between Sound Positions**

A two-way analysis of variance was utilized to explore the relationships between scaled motor difficulty, identity of the individual sound, and the syllabic position of the sound. As was expected, motor difficulty was shown to be influenced by both identity of individual sound and sound position. Results of the two-way analysis of variance are summarized in Table 1 below.

That motor difficulty of individual sounds varies significantly was an expected finding. So, also, was the finding that motor difficulty varies significantly with syllabic position. However, what are of interest are: (1) which particular sounds are motorically most difficult, and (2) in
TABLE 1

Summary of Analysis of Variance Showing Effects of Individual Sound and Sound Position

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<tr>
<th>Source</th>
<th>Degrees of Freedom</th>
<th>Sums of Squares</th>
<th>Mean Squares</th>
<th>F Ratio</th>
<th>Probability of F</th>
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<td>54728.3</td>
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<tr>
<td>Pos x Sound</td>
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<td>1267.57</td>
<td>5.748</td>
<td>.00000</td>
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<tr>
<td>Pos x Subject</td>
<td>44</td>
<td>29389.9</td>
<td>667.952</td>
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<td>Sound x Subject</td>
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<td>299657</td>
<td>296.104</td>
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<td>Pos x Sound x Ss</td>
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<td>223154</td>
<td>220.508</td>
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<tr>
<td><strong>Total</strong></td>
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<td><strong>3194397.2</strong></td>
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</tbody>
</table>

which syllabic position are they motorically more difficult. Table 2 lists the scale values of the individual sounds in ascending order of perceived motoric difficulty by syllabic position. It was constructed to aid in identification of the syllabic position which is motorically more difficult for each sound. A raw score critical difference between means significant at the 5 percent level was computed. Asterisks mark those differences between terminal and initial means which are significant. The syllable-initial mean scale value is subtracted from the syllable-terminal value in each case.
<table>
<thead>
<tr>
<th>Syllable Initial</th>
<th>Syllable Terminal</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>/m/</td>
<td>41.594</td>
<td>47.331</td>
</tr>
<tr>
<td>/l/</td>
<td>41.908</td>
<td>50.485</td>
</tr>
<tr>
<td>/d/</td>
<td>42.331</td>
<td>51.61</td>
</tr>
<tr>
<td>/b/</td>
<td>43.155</td>
<td>51.585</td>
</tr>
<tr>
<td>/h/</td>
<td>43.314</td>
<td>40.270</td>
</tr>
<tr>
<td>/n/</td>
<td>44.064</td>
<td>47.755</td>
</tr>
<tr>
<td>/t/</td>
<td>44.342</td>
<td>48.808</td>
</tr>
<tr>
<td>/p/</td>
<td>44.810</td>
<td>54.910</td>
</tr>
<tr>
<td>/s/</td>
<td>45.019</td>
<td>58.011</td>
</tr>
<tr>
<td>/f/</td>
<td>45.491</td>
<td>55.997</td>
</tr>
<tr>
<td>/r/</td>
<td>48.299</td>
<td>57.774</td>
</tr>
<tr>
<td>/g/</td>
<td>48.525</td>
<td>58.313</td>
</tr>
<tr>
<td>/w/</td>
<td>50.055</td>
<td>/du/ 61.442</td>
</tr>
<tr>
<td>/k/</td>
<td>50.698</td>
<td>56.356</td>
</tr>
<tr>
<td>/j/</td>
<td>52.048</td>
<td>/di/ 41.005</td>
</tr>
<tr>
<td>/dʒ/</td>
<td>52.196</td>
<td>66.521</td>
</tr>
<tr>
<td>/v/</td>
<td>52.810</td>
<td>51.233</td>
</tr>
<tr>
<td>/z/</td>
<td>52.867</td>
<td>52.463</td>
</tr>
<tr>
<td>/tʃ/</td>
<td>54.485</td>
<td>73.042</td>
</tr>
<tr>
<td>/ʃ/</td>
<td>56.776</td>
<td>71.383</td>
</tr>
<tr>
<td>/θ/</td>
<td>62.826</td>
<td>73.034</td>
</tr>
<tr>
<td>/hw/</td>
<td>64.159</td>
<td>/j/ 81.384</td>
</tr>
<tr>
<td>/x/</td>
<td>65.764</td>
<td>74.849</td>
</tr>
<tr>
<td>/ɣ/</td>
<td>76.766</td>
<td>67.789</td>
</tr>
</tbody>
</table>

* = significant at the 5 percent level.
It should be noted that all but five (/n/, /z/, /v/, /h/, and /t/) of these sounds differ significantly in motor difficulty and that, of the eighteen sounds which differ significantly, only two, /ʒ/ and /ʃ/ (both of which are controversial sets), deviate from the general trend of terminal more difficult than initial.

It is probably no surprise that subjects found syllable-initiating /ŋ/ more difficult than the terminating version of that phoneme since /ŋ/ does not occur word-initial in English. The greater difficulty of initial /ʃ/, on the other hand, is not easily understood. This finding is in agreement with usual clinical experiences. Children often misarticulate /ʃ/ even in the presence of a correctly-articulated offglide /ai/. It may be that, for whatever reasons, children learn the high-front offglide as part of a set of vocalic articulations and the high-front onglide in connection with consonant acquisitions, generally occurring later.

If this reasoning is correct, then a different set of factors must be operating in the sound set /w/ and /au/ since initial /w/ (wa) is considered motorically easier than /au/. Perhaps initial /w/ is produced most importantly as a labial movement (generally rated as motorically easy) where terminal /au/ is produced as a dorsal velar tongue movement, generally rated as more difficult than lip movements.

Similar terminal voiceless segment of a syllabic vowel
(terminal /h/) may well represent primarily a relatively undifferentiated vowel articulation whereas a voiceless prevocalic may well involve a more consonant like adjustment of articulatory postures and coordination of voice onset time.

A reasonable conclusion is that motor difficulty of initial and terminal sounds does differ and that this difference is usually in the direction of initial sounds easier than terminal sounds.

**Differences Among Sounds and Between Sound Positions Analyzed According to Manner and Place**

Scheffe' contrasts were used to assess differences in manner and place categories as sources of the significant variance in motor difficulty due to sound position and the identity of the individual sound.

Manner classifications were taken from Fairbanks (1960), and slightly modified. Modification entailed: (1) the combining of liquids and glides into a single category, and (2) the inclusion of /hw/ in the fricative category. The classifications were as follows: (1) liquids and glides (/j/, /w/, /r/, and /l/); (2) nasals (/m/, /n/, and /ŋ/); (3) fricatives (/s/, /z/, /ʃ/, /ʒ/, /θ/, /ð/, /v/, /f/, /h/, and /hw/; (4) stops (/p/, /t/, /k/, /b/, /d/, and /g/);
and (5) affricates (/tʃ/ and /dʒ/). The controversial /ai/ for terminal /aj/ and /au/ for terminal /aw/ were included in this analysis of these sounds. Results of the Scheffe' contrasts assessing differences in manner of sound production indicate that nasals, fricatives, stops, and affricates are more difficult to produce in the terminal position than in the initial position and that this difference is not significant for the liquid and glide manner category. These results appear to reflect the initial first, terminal later trend in acquisition with the exception of the nasals. Acquisition schedules indicate that nasals are generally learned in both positions about the same time. A look at the scale value means in Table 2 leads one to feel that the large motor difficulty scale value mean for terminal /ŋ/ accounts for this discrepancy.

Place categories were adapted from Walsh (1974) and were as follows: (1) labials (/p/, /b/, /m/, /f/, /v/, and /hw/); (2) interdentals (/θ/ and /ʃ/); (3) tip-alveolars (/t/, /d/, /n/, /l/, /s/, and /z/); (4) blade-palatal (/ʃ/, /ʒ/, /r/, /t/, and /dʒ/); and (5) dorsum-velo-palatal (/k/, /g/, /ŋ/, /h/, /w/, and /j/). Place Scheffe' contrasts show motor difficulty to be significantly greater in terminal position than in initial position for interdentals, tip-alveolars, blade-palatal, and velo-palatal and insignificant for labials. Here again lies agreement between the
results of motor difficulty analysis and acquisition; acquisition studies reveal a general tendency for children to acquire the initial sounds before they acquire the terminal sounds in all place categories other than labials.

Table 3 below lists mean scale values for these five places of production.

TABLE 3
Initial and Terminal Mean Scale Values for Five Places of Production

<table>
<thead>
<tr>
<th>Place</th>
<th>Initial</th>
<th>Terminal</th>
<th>Diff. Sig. at 5% Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>tip-alveolars</td>
<td>45.088</td>
<td>50.885</td>
<td></td>
</tr>
<tr>
<td>labials</td>
<td>48.670</td>
<td>52.511</td>
<td>4.999</td>
</tr>
<tr>
<td>velo-palatal</td>
<td>48.928</td>
<td>56.462</td>
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</tr>
<tr>
<td>blade-palatal</td>
<td>57.704</td>
<td>67.302</td>
<td></td>
</tr>
<tr>
<td>interdentals</td>
<td>64.296</td>
<td>73.942</td>
<td></td>
</tr>
</tbody>
</table>

As Table 3 indicates, in general, tip-alveolars are easier than labials, labials easier than velo-palatal, next are blade-palatal, and most difficult are interdentals. This rank order follows clinical intuition as to place of production.

It should be mentioned that the difficulty order obtained in this study may well be, in part, a function of the /a/ vowel used. The difficulty order may vary when
consonantal sounds are used with other vowels. This data, of course, is yet to be gathered.
CHAPTER IV

SUMMARY AND CONCLUSIONS

Forty-five adults scaled motor difficulty of consonantal sounds occurring in both syllable-initiating and syllable-terminating positions. Correlations were utilized to examine the relationship between motor difficulty and the initial and terminal speech sound acquisition schedules. A two-way analysis of variance was used to contrast the motor difficulty of initial and terminal sound production.

Correlations showed that a moderate relationship exists between the child's sound acquisition schedule and motoric difficulty of sounds as rated by adults and that this relationship is considerably stronger for initial sounds than for terminal. The two-way analysis of variance revealed the expected finding that motor difficulty is affected by the identity of the individual sound and the syllabic position of the sound. Further inspection of mean scale values reveals that, in general, initial sounds are motorically less difficult to produce than are terminal sounds.

These findings would seem to support the need to consider motor factors as an etiology of speech problems, particularly when initial sound deviance is evident. Once motor
factors are established as a component of the speech problem, it is hoped that the data generated by this study, concerning relative motor difficulties of the individual sounds and of the syllabic position of the sounds could be used in planning the goals and steps of remediation.

Need for Further Research

During the course of this study, four related areas of interest for which little or no information is currently available became obvious.

(1) One need, which has been mentioned previously, is for a validity study of the psychological scaling methods for motor difficulty. It has been suggested that an electromyographic measure should prove useful in determining validity of motor difficulty scaling.

(2) A study similar to this one but utilizing children as judges of motor difficulty would be interesting and relevant since it is data regarding children's acquisition that motor difficulty is pertinently related to. Motor difficulty for adults may not be the same as motor difficulty for children.

(3) The relationships between perceptual ease and terminal sound acquisition and between
frequency of occurrence and terminal sound acquisition need to be investigated.

(4) Locke (1972) found eight out of ten common substitutions used by children were rated motorically easier than the target phonemes. This pertains to initial sounds only. A study might be done relating motor difficulty and misarticulations of terminal sounds.
BIBLIOGRAPHY


Tikofsky, R. S. and McInish, J. R. "Consonant Discrimination by Seven Year Olds: A Pilot Study." Psychonomic Science, 10 (1968), 61-62.

APPENDICES
ORTHOGRAPHIC RANDOM SYLLABLE LIST

1. ang ________
2. ak ________
3. az ________
4. za ________
5. ath ________
6. am ________
7. ma ________
8. la ________
9. ash ________
10. ab ________
11. zha ________
12. ga ________
13. da ________
14. ach ________
15. eye ________
16. al ________
17. sha ________
18. ad ________
19. av ________
20. tha ________
21. va ________
22. ash ________
23. na ________
24. ha ________
25. tha ________
26. ar ________
27. an ________
28. at ________
29. wha ________
30. wa ________
31. ja ________
32. af ________
33. ag ________
34. cha ________
35. aj _______            52. za _______
36. ka _______            53. ath _______
37. ra _______            54. am _______
38. pa _______            55. ma _______
39. as _______            56. la _______
40. ta _______            57. ath _______
41. ap _______            58. ab _______
42. fa _______            59. zha _______
43. ya _______            60. ga _______
44. azh _______           61. da _______
45. ow _______            62. ach _______
46. ba _______            63. eye _______
47. ah: _______           64. al _______
48. sa _______            65. sha _______
49. ang_______            66. ad _______
50. ak _______            67. av _______
51. az _______            68. cha _______
ADJUSTED INDIVIDUAL SCALE VALUES

The first ten 6-digit columns present adjusted scale values subject by subject for the sounds in the following order:  (I=initial;  T=terminal).

| I | /j/  | T | /aI/ |
| I | /w/  | T | /aU/ |
| I | /r/  | T | /r/  |
| I | /I/  | T | /I/  |
| I | /m/  | T | /m/  |
| I | /n/  | T | /n/  |
| I | /hw/ | T | /h/  |
| I | /s/  | T | /s/  |
| I | /S/  | T | /S/  |
| I | /z/  | T | /z/  |
| I | /q/  | T | /q/  |
| I | /θ/  | T | /θ/  |
| I | /ʃ/  | T | /ʃ/  |
| I | /v/  | T | /v/  |
| I | /f/5 | T | /f/  |
| I | /h/  | T | /ah:/ |
| I | /p/  | T | /p/  |
| I | /t/  | T | /t/  |
| I | /d/  | T | /d/  |
| I | /k/  | T | /k/  |
| I | /g/  | T | /g/  |
| I | /b/  | T | /b/  |
| I | /tʃ/ | T | /tʃ/ |
| I | /dʒ/ | T | /dʒ/ |

The data for any one subject is presented in five rows, the first four containing ten 6-digit columns, the last one only eight.

In the eleventh column, a 3-digit column, the first two digits identify the subject and the third digit identifies the row of data from that particular subject.

The decimal point follows the third digit.
<p>| | | | | | | |</p>
<table>
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