

The Linearity of the Relationship Between Articulation Errors and Velopharyngeal Incompetence

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The inference can be made from research findings and clinical observations that velopharyngeal incompetence is causally related to the articulation errors of individuals with cleft palates; that is, cleft palate speakers with velopharyngeal incompetence are not able to impound and maintain the intraoral pressure required for the production of most consonant sounds. In light of such a relationship between velopharyngeal incompetence and articulation errors, one would expect to obtain relatively high correlation coefficients between these two variables. Such is not the case. In general, the correlation coefficients range from .08 (4) to .78 (2) with the majority of the coefficients reported in the range of .30 to .50 (1, 6, 7, 8). The wide variation in the coefficient values can perhaps best be accounted for by the equally wide variation in the techniques used to arrive at these correlations: some investigators have used pressure measures to assess velopharyngeal incompetence while others have used radiographic films and a variety of measures of articulation skills have been used.

There are several possible explanations for the lowness of the correlations. a) The relationship is no stronger than has been reported. This would indicate that variables other than velopharyngeal incompetence are important in influencing articulation proficiency. b) The available research tools are not sensitive or reliable enough to provide information that would result in higher coefficients. c) The technique used to assess this relationship has not been appropriate for the existing relationship. In most instances a Pearson product-moment correlation technique which is appropriate only for linear data has been used. Several researchers have suggested that velopharyngeal competence may be dichotomous in its relationship to articulation proficiency or that the relationship between the two variables may be nonlinear. If such were the case, the

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magnitude of the Pearson product-moment correlation coefficient would be depressed. d) The restricted range of the variables used in some of the investigations (such as a four point rating scale for articulation) may serve to decrease the size of the correlation coefficient. e) It is possible that different relationships exist between velopharyngeal opening and the articulation of speech sounds classified according to manner of production. If such differences exist, grouping all speech sounds together may obscure relationships which could be helpful in understanding the effect of velopharyngeal incompetence on articulation proficiency. f) Classifications other than manner of production, such as voiced-voiceless differences, may be important. Again, grouping phonemes without regard to these classifications may obscure differences in their relationship to velopharyngeal incompetence.

The purpose of this investigation was to provide additional information about the strength of the relationship between articulation errors and velopharyngeal incompetence. Specifically, two questions were asked: a) Is the relationship between articulation skills and velopharyngeal opening linear? b) Are there differences in the strength of the relationship between velopharyngeal opening and the articulation of speech sounds classified in several ways?

Procedure

SUBJECTS. Sixty-two children with cleft lips and palates were selected for study. The 21 females and 41 males ranged in age from seven to 16.5 years with a mean age of 11 years. Mean IQ (WISC Full Scale) was 98.55 with scores ranging from 80 to 132. None of the subjects had hearing losses. Forty-seven subjects had clefts of both lip and palate, the remaining 15 had clefts of the palate only. None of the subjects had clefts of the lip only and children who had open clefts or management other than surgical repair were not included.

ARTICULATION TESTS. An articulation test containing 109 elements was used as the measure of articulation proficiency. Three subdivisions were made of the 109-element test: a 43-element test of fricatives and affricates, a 34-element test of plosives, and a 32-element test of nasals and glides. Distinctions were not made between elements produced in singles or in blends, or between voiced and voiceless cognates in any of the three tests. Each element was recorded as correct or incorrect; the subject's score was the number of elements he produced incorrectly.

VELOPHARYNGEAL MEASURES. On the same day that the articulation test was administered, still lateral head x-ray films were taken of each subject during the phonation of the vowel /u/ and the consonant /s/. Direct measurements were made on each x-ray film to the nearest .5 mm of the distance between the posterior border of the soft palate and the anterior margin of the posterior pharyngeal wall at the point of closest approximation of contact. Measurements were not transformed to life

size since the primary interest of this study was in relationships, not in absolute values.

Results

MEASUREMENTS FOR THE TOTAL SUBJECT GROUP.

Articulation Skills. Scores on the fricative and plosive tests ranged from zero (all elements correct) to 43 and 34, respectively (no elements correct). Although some subjects correctly produced all elements on the nasal/glide test, no subject made errors on all elements on this test, and hence not on the total articulation test. The number of errors on the nasal/glide test were generally few, while the mean number of fricative errors was 48.77% of the total possible errors on that test. The mean number of plosive errors was 29.32% of the total possible, or approximately 20% fewer errors than on the fricative test.

Velopharyngeal Opening. Ranges and mean openings for the group were zero to 20.0 and 6.48 and zero to 17.5 and 6.05 for /s/ and /u/, respectively. Twenty-two subjects showed identical openings for /u/ and /s/. Of that 22, 16 had no opening and six had identical amounts of opening on both films. The remaining 40 subjects showed different amounts of opening for the two conditions. Twenty-one subjects showed openings for /s/ that were greater than for /u/, with mean openings of 12.81 mm and 8.24 mm for /s/ and /u/, respectively. Nineteen subjects showed openings on /u/ that were greater than for /s/, with mean openings of 4.29 mm and 6.95 mm for /s/ and /u/, respectively. These differences indicate that the measurement on the /s/ film was smaller than that on the /u/ film if the subject had a small amount of opening and that the measurement was larger on /s/ than /u/ if the subject had a large amount of opening.

When these differences were plotted graphically, it was apparent that the measurements on /s/ were larger than /u/ for speakers with openings of about 8.0 mm and that the differences between the measurements for /s/ and /u/ increased as the amount of opening on /s/ increased. These trends were evident in the differences between the mean openings for /s/ and /u/ for these two subgroups. Inferences based on these differences, however, must be made with care since smaller amounts of variability for smaller absolute openings may have more effect on speech than greater variability associated with larger absolute openings.

Five subjects achieved closure (or had no opening) on /s/ but not on /u/; none achieved closure on /u/ but not on /s/. This finding suggests that if a subject achieves closure on one of these two sounds under these conditions, it will be on /s/.

RELATIONSHIPS.

Strength. The Pearson product-moment correlation coefficients between the articulation tests and velopharyngeal measurements are reported in Table 1. The correlation coefficients for the plosive, fricative, and total

TABLE 1. Correlation coefficients and ratios and F ratios, for the relationships between articulation errors and measurements of velopharyngeal opening. The significant F is asterisked.

Articulation Measure	Velopharyngeal Measure	r	r^2	η^2	F
Total.....	/u/	.60	.3600	.5603	.7860
	/s/	.54	.2916	.5982	1.0680
Fricative.....	/u/	.61	.3721	.5781	.8451
	/s/	.59	.3481	.6266	1.0444
Plosive.....	/u/	.59	.3481	.6902	1.9209*
	/s/	.50	.2500	.6650	1.7370
Nasal/glide.....	/u/	.06			
	/s/	.01			

articulation tests are relatively comparable but the correlations for the nasal/glide test are considerably lower than those for the other three tests. The correlations of the four articulation tests with the measurements on /u/ are consistently higher than with /s/, although the differences in the strengths of the relationships are very small.

Linearity. It was hypothesized that one factor which may serve to decrease the value of r is the use of a linear correlation technique for data which reflect nonlinear relationships. The square of the statistic *eta* (η^2) was employed to obtain a general notion of goodness of fit of some undetermined hypothetical nonlinear function (\mathcal{S}); the obtained values are presented in Table 1, and the values were all nonsignificant except for the relationship between the plosive test and /u/. For the other five relationships, then, the hypothesis of nonlinearity must be rejected and the inference can be made that the relationships are linear.

Discussion

ARTICULATION MEASURES. One hypothesis advanced in this investigation was that the 'true' relationship between articulation errors and velopharyngeal incompetence might be obscured by the practice of combining all types of speech sounds into a single category (that is, a single articulation test). Findings reported here, however, indicate that the relationships between fricative and plosive subtests and total test and amount of velopharyngeal opening are similar in strength. Only the relationship between velopharyngeal opening and the nasal/glide subtest was different from the other three; that relationship was very low. The implications of these findings are that one can combine fricative and plosive test items in investigating the relationship between articulation skills and velopharyngeal opening and that, further, adding nasal/glide

items to such a test does not influence the overall relationship significantly.

At least two additional possibilities for articulation tests are suggested for research such as this. The first has to do with examining differences in relationship to velopharyngeal opening in articulation test items classified according to presentation as singles or in blends, as voiced-voiceless cognates, and as elements within a specific manner of production category but differing in place of articulation.

A second suggestion has to do with scoring technique. This investigation considered only right-wrong judgments. Another technique might take into account the type of error. One might expect that relationships may be higher between velopharyngeal opening and articulation errors characterized by nasal emission than that relationship between velopharyngeal opening and errors which are judged to be essentially 'oral' in nature. A second technique might be one which involved scaling the relative adequacy of the production of individual speech sounds. Such a technique might be very helpful in investigations of this kind, particularly if one assumes that listeners could reflect in their use of scaling technique gradations in adequacy of articulation associated with gradations in velopharyngeal opening.

VELOPHARYNGEAL INCOMPETENCE. Some interesting differences were noted between the measurements on /u/ and /s/. Perhaps part of these differences may be attributable to problems with the still x-ray film technique. It is not possible to sample more than one moment in time with this procedure, and it is not possible to specify which moment in time is being observed. Therefore, the use of cinefluorographic techniques would be helpful in further investigations of the relationship between articulation errors and velopharyngeal incompetence, since those techniques provide better sampling of the behavior being studied.

RELATIONSHIPS BETWEEN THE TWO VARIABLES. The correlation coefficients obtained in this study are generally comparable to those obtained in similar investigations (1, 2, 6, 7, 8), although Subtelny and Subtelny (7) report much lower coefficients between velopharyngeal opening and fricatives. They used older subjects than those used in the present research, and correlated all articulation measures to x-ray measures for /u/. In addition, a 48-item nonsense-syllable articulation test was used in which each sound was presented four times and the correlations were obtained for six cognate pairs. Each correlation, then, was based on an eight-item articulation test consisting of four samples each of the cognate pairs.

Two characteristics of their data may have led to the depressed coefficients for fricatives in that study. The first has to do with the restricted number of observations (eight) from each subject for each articulation test. That condition should, however, serve to depress coefficients

for plosives as well as for fricatives and so does not explain the disparity between those findings and the ones reported here. The second consideration to be made is that the range of errors (that is, the scores) for fricatives may have been more restricted than for plosives (for example, the majority of subjects may have made errors on the majority of fricative items or vice versa). Such a restricted range of scores could serve to depress the correlation coefficient. Although Subtelny and Subtelny report average number of errors for each consonant pair, and the mean number of errors for the pair /s/—/z/ was significantly greater than any of the other four pairs, there are no data in that report concerning the range of errors.

The results of the statistical analysis reported here do not support the hypothesis that the relationship between velopharyngeal incompetence and articulation errors is a nonlinear one, with the exception of the relationship between incompetence and plosives. There are no indications from the present data regarding the type of nonlinear relationship that exists between plosives and /u/. Since a nonlinear relationship cannot, for the most part, be demonstrated, it does not appear feasible to conclude that velopharyngeal opening is dichotomous in its relationship with articulation skills; that is, that there is a point of velopharyngeal opening beyond which further opening would not affect the number of articulation errors. It would appear plausible, then, to conclude that as velopharyngeal opening increases, the number of articulation errors increases in a proportional or perhaps linear manner.

In the same way, these results do not support the hypothesis that the low correlations reported previously in the literature could be accounted for by the inappropriate use of a linear correlation technique on nonlinear data. Since the results of this investigation indicate that the strength of the relationship between velopharyngeal opening and articulation errors is on the order of .50, indications are that other variables must contribute greatly to the relationship. Further research is needed for the identification of those variables.

Subsequent to the completion of this investigation, Shelton, Brooks, and Youngstrom (5) reported data which are contradictory to the findings reported here. They correlated measures of velopharyngeal closure and articulation skill for 31 individuals who had either surgically repaired cleft palates or 'palatal inadequacies' (noncleft). A Pearson r of .52 was obtained which is comparable to the r 's reported here. Their data indicated, however, that the hypothesis of linearity of that relationship must be rejected.

Two explanations of the difference in findings seem plausible. The first is that the two measures of velopharyngeal opening are not similar. In this investigation, measures of opening were taken from a single observation: a still x-ray film taken during /s/ or /u/. Shelton and his asso-

ciates used a mean of measurements of opening for every film frame taken while the subject repeated three sentences, seven phonemes in isolation, four nonsense syllables, and while he counted from *one* to *six*. Their measure, then, took into account openings on a variety of vowels and consonants in several contexts. The differences in speech samples employed in the two studies could account for differences in results.

The second explanation is that the two subject groups differ in amount of velopharyngeal opening per se and that that difference influences the linearity of the relationships observed; that is, different sections of the curve showing the relationship were investigated. The subject group studied by Shelton and his associates typically showed, by their measure, small velopharyngeal openings: 24 of 31 subjects had openings smaller than 2.00 mm and openings ranged from .08 mm to 9.40 mm. In contrast, the subjects studied in this investigation had relatively large velopharyngeal openings as shown by the measure employed: only 18 of 60 subjects had openings smaller than 2.00 mm and openings ranged from zero to 17.5 mm. Indeed, 21 of 62 subjects had openings larger than 9.00 mm, the largest opening observed for any subject in Shelton's group. The possibility exists, then, that the kind of relationship between velopharyngeal opening and articulation skills depends, at least in part, on the range and extent of opening which is considered for investigation.

Summary

Sixty-two subjects between the ages of seven years and 16.5 years with normal intelligence and with no hearing losses were given articulation tests. In addition, lateral head x-ray films were taken during phonation of /u/ and /s/. The 109-element articulation test was subdivided into a 43-element fricative test, a 34-element plosive test, and a 32-element nasal/glide test. Pearson product-moment correlation coefficients were obtained between each of the four articulation tests and each of the two types of lateral x-ray films. The coefficients ranged from .50 to .60 for all conditions except for the nasal/glide test for which virtually no relationship was found. The results of the *F* tests of nonlinearity showed that the hypothesis of a nonlinear relationship is not acceptable for any combination of articulation errors and velopharyngeal opening except for plosives and the amount of opening on /u/.

It was noted that subjects who were able to achieve closure during phonation on only one sound achieved it during /s/; there were no subjects who achieved closure on /u/ but not on /s/. Subjects with any amount of opening made a greater percentage of errors on the fricative test than on the plosive test.

It was suggested that subsequent research include analysis of type of error and that cinefluorographic techniques yield data which might be

beneficial in further study of the relationship between velopharyngeal incompetence and articulation errors.

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