Oral Stereognosis in Normal and Cleft Palate Individuals

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The tactile discrimination of form without the aid of vision is referred to as stereognosis. This psychoneurological ability has long been recognized by neurologists as an important indicator of central nervous system integrity, and simple tests of this function are usually included in neurological evaluation. An impairment of this capacity, astereognosis, indicates a lesion of the central nervous system in the presence of otherwise intact primary sensory modalities. The lesion appears to affect primarily the post-central gyrus of the parietal lobe (*1, 2, 4, 8, 10*), although subcortical involvement has been cited as well (*8, 10*).

The determination of stereognostic function during neurological examination requires the patient to close his eyes and to identify a familiar object such as a pencil, key, coin, etc., by manipulating it with his hand. In the normal individual, recognition of common objects usually proceeds rapidly and is relatively invariant. Demonstration of a deficiency in this ability is of clinical neurological significance in that it usually indicates central nervous system disturbance in which position sensation and two-point discrimination are usually impaired as well (*8, 10*).

A fundamental concern with the sensory-motor functions involved during the production of speech, coupled with a general interest in oral sensation and perception, has led several investigators to extend the exploration of tactile perception of form intraorally (oral stereognosis). Although measures of oral stereognosis have been obtained with a variety of different geometric objects and have involved different perceptual tasks, certain findings and tendencies have been demonstrated rather consistently by the investigations. Persons with cerebral palsy and other neurological impairments were found to demonstrate inferior ability in oral stereognosis than did normal subjects (*3, 5, 11*). Stutterers and individuals with articulation defects have also been reported to be less able to perceive orally various stimuli than were normal individuals (*3, 6*). In addition, oral stereognosis has been found to be dependent primarily on the anterior

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surfaces of the tongue (*5*). McDonald (*7*) and his students have been engaged in a series of studies along several lines of inquiry in an attempt to arrive at specific procedures to measure oral form perception, and to establish normative data as a function of age.

The results reported in the above investigations indicate that an investigation of oral streognosis among cleft palate individuals would be fruitful in order to extend the present knowledge in this area. This study was designed for that purpose.

Method

Subjects. Thirty normal and twelve cleft palate adults participated in the study. The normal subjects were seven males and 23 females, ranging in age from 19 to 46 years, with a mean age of 25 years. All had acceptable articulation and did not exhibit symptoms of any physical disability. The cleft palate group consisted of three males and nine females, ranging in age from 13 to 50 years, with a mean age of 34 years. The latter group was obtained on the basis of their availability to participate in the study and represented a heterogeneous sample with respect to age, type of cleft, extent of cleft, type of management, speech proficiency, and other associated disabilities. Seven of the twelve cleft palate individuals wore prosthetic appliances which covered the entire hard and soft palate; in the remaining cases, the prosthesis covered the anterior one-half of the hard palate which was judged to be adequately covered for the perceptual task required.

Development of Stereognostic Forms. Preliminary considerations in the development of oral stereognostic stimuli involved an attempt to determine the relative sensory acuity of various intraoral areas, utilizing two-point discrimination threshold measures. The purposes of this preliminary procedure were to be able to relate oral sensitivity to oral stereognosis and to determine the contribution of each oral sensory area to oral form perception. During the administration of this phase of the study, using ten young normal adult subjects, several variables were noted which precluded the completion of this procedure; these included factors such as (a) an inability to locate the precise area of stimulation on repeated occasions, (b) a lack of consistent application of pressure, and (c) an overlapping of oral structures involved in subsequent measures of oral stereognosis. That part of the study was abandoned.

Regarding development of the stereognostic forms, it was desirable to construct forms that would be of sufficient size to preclude the influence of object size upon stereognostic performance. To accomplish this objective, difference thresholds between a cube and a sphere were obtained from ten young normal adults. A series of cubes and spheres, graduated in size from less than $\frac{1}{16}$ to $\frac{1}{4}$ inches in diameter, was presented three times to each subject. By the time threshold was approached for even 50% of the subjects, the object was too small to be easily manipulated, either manually or orally. All subjects were able to identify correctly a $\frac{1}{16}''$ cube or sphere at least 90% of the time.

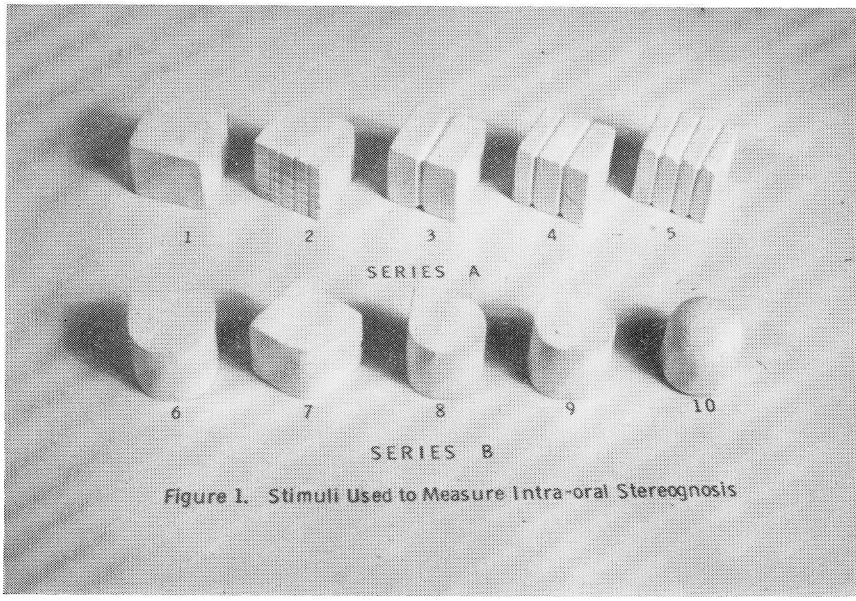

FIGURE 1. Test stimuli to measure oral stereognosis. Series A included five cubes that were progressively modified to represent varying degrees of surface alteration: cube 1 has unaltered surfaces and is completely smooth, cube 2 has one of its surfaces altered by numerous vertical and horizontal grooves; and cubes 3, 4, and 5 have one, two, and three grooves, respectively, running along four of the six surfaces. Series B included five cubes that were progressively modified to represent varying degrees of shape alteration. In this series, the edges and corners of the cubes were progressively eliminated (rounded) to alter the basic shape of each cube. The surfaces for all cubes in series B are smooth.

Figure 1 illustrates the forms which were finally constructed. In series A, there are five forms developed to represent varying degrees of surface alteration. The forms in series B represent varying alterations in basic shape. Thus, two tasks of oral perception were involved: surface and shape modification. Test stimuli were made from the original 5 mm cubes, constructed of base metal alloy with a specific gravity approximating that of gold.

The volume of each cube varied somewhat; however, at least one 5 mm dimension always remained. For reference purposes, plaster duplicates of the forms were constructed in a size which was approximately five times as large as the originals.

Procedure

Each subject was oriented concerning the nature of the experimental procedure, utilizing the three-dimensional duplicate forms for reference. To minimize the possible influence of unaccountable factors that might reduce a subject's ability to relate the oral stimulus to the reference duplicate, each subject was permitted to manipulate the reference forms manually during this preliminary orientation. All stimuli to be used orally were out of the subject's view at all times.

During the testing session the examiner placed each stimulus on the subject's tongue and instructed him to manipulate it with his tongue against the roof of the mouth. The subject was instructed to avoid placing the object between the teeth at any time, since it had been observed previously that tooth-to-tooth contact facilitated identification. As soon as the subject indicated that he had identified the object orally, he was instructed to point to the corresponding reference duplicate, all ten of which were in constant view. Three random sequences of ten trials per sequence were administered to normal subjects, each form being assessed three times. Because several cleft palate subjects fatigued readily, all three sequences could not be administered to all subjects, particularly in cases which required responses with and without prosthetic appliances. A maximum of thirty seconds was allotted for identification of each form. Prior to and following each testing session, the forms were cleansed appropriately.

Results

Each subject's performance was based upon the percentage of correct responses obtained in the single most accurate sequence of ten trials. Because several of the cleft palate subjects with prostheses were able to complete only two of three sequences for a given oral condition (that is, two complete sequences of ten trials each with prosthesis and two sequences without prosthesis), the first two completed sequences were considered for data analysis for all subjects in order to increase comparability of subject performance. Table 1 presents the mean percentage of correct responses of the most accurate of the two sequences for normal and cleft palate subjects for series A and B and for the two series combined. The Mann-Whitney U test was used to test for significance of differences between the two groups. The obtained values of U were transformed into z scores, as suggested by Siegel (*9*, p. 121), to determine the significance of an observed value of U. The z scores presented in Table 1 were all significant at the 2.5% level (for a one-tailed test). Normal subjects demonstrated significantly superior ability than did cleft palate subjects in perceiving surface (series A) and shape (series B) alterations of cubes. The

TABLE 1. Mean percentage of correct responses of the most accurate of two sequences for normal and cleft palate subjects, for Series A (surface alteration), for Series B (shape alteration), and for series combined. Values which are asterisked are significant.

series	*normal*	*cleft palate*	*z*
A	.43	.23	4.17*
B	.43	.27	2.61*
Combined	.86	.50	4.15*

TABLE 2. Mean percentage of correct responses of the most accurate of two sequences for seven cleft palate subjects with and without prostheses, for series A, B, and series combined. Values which are asterisked are significant.

condition	*series A*	*series B*	*combined*
with prosthesis	.26	.33*	.59*
without prosthesis	.23	.24	.47

mean values indicate that normal subjects perceived both series equally well, whereas cleft palate subjects found series A slightly more difficult to perceive than series B.

The Wilcoxin matched-pairs signed-ranks test (*9*) was used to compare the seven prosthetically managed cleft palate subjects for the individual and for the combined series. The mean percent correct responses of the most accurate of the sequences are presented in Table 2. The results indicate that subjects with prostheses in place were able to perceive alteration of shape (series B) and the combined series of stimuli to a significantly greater extent than they were without their prostheses. Although not significant, a similar tendency was observed for series A as well. To determine the effect of age upon oral perception of form, the Wilcoxin test was used to determine significance of differences between two pairs of subjects: the eight oldest normal subjects (30 to 46 years, mean 37.3 and the eight oldest cleft palate subjects, (31 to 49 years, mean 36.7) and the five youngest (13 to 32 years, mean 24.6) and the five oldest (38 to 50 years, mean 47.8) cleft palate subjects. The oldest normal subjects demonstrated significantly superior ability in oral stereognosis for the individual and for the combined series of stimuli than did the cleft palate subgroup. The younger cleft palate subjects were significantly superior to the older cleft palate subgroup on series B and on the combined series, but not on A.

Analyses of stimulus-response confusions for the combined series were conducted for normal, cleft palate, and prosthetic cleft palate subjects and are presented as confusion matrices in Tables 3, 4, and 5, respectively. In Table 3, of 600 possible responses, normal subjects demonstrated a total of 117 confusions (19.5%), with 72 confusions (12%) in series A and 45 confusions (7.5%) in series B. Virtually all response errors were made within a given series, although certain exceptions were observed. Items 1, 2, and 5 from series A were confused with items 7, 7, and 8 respectively, from series B, and item 7 from series B was confused with items 1 and 5 from series A. In all, there were seven inter-series confusions. The items confused most frequently were forms 5, 4, 2, and 6; those most readily perceived correctly were forms 3, 9, and 10. In general, stimuli were confused largely with adjacent or neighboring items in the series.

Table 4 displays the confusion matrix for the cleft palate subjects. This group made 122 errors (51%) of 240 possible responses, 67 (28%) of which

TABLE 3. Confusion matrix for stimulus-response errors made by normal subjects on ten stimulus items for the combined series. Entries are response errors for a given item and are interpreted by comparing the stimulus, along the vertical dimension, with response, along the horizontal dimension. The total number of confusions for each stimulus item are presented in the column at the extreme right of the table. For example, reference to this table indicates that form 1 was identified incorrectly (or confused for) as form 2 four times and as form 7 only once, a total of five erroneous responses. The figures are presented in Figure 1.

stimulus	*response*										
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*total*
1		4					1				5
2	16		2				1				19
3				2	1						3
4	1	8	4		8						21
5		10	2	11				1			24
6							13	5			18
7	3				1	5		4			13
8						2	2	2			6
9						1		1		2	4
10						1		1	2		4

were in series A and 55 (23%) were in series B. Both the normal and the cleft palate subjects found series A more difficult than series B, but the cleft palate subjects manifested a greater proportion and variety of response confusions in both series than did normal subjects. In addition, a greater number of inter-series confusions were noted for cleft palate subjects than for normal subjects, although intra-series responses still predominated. Forms 2, 5, 6, and 4 appeared to be most easily confused; how-

TABLE 4. Confusion matrix for stimulus-response errors made by cleft palate subjects on ten stimulus items for the combined series. See legend, Figure 3, for explanation of entries.

stimulus	*response*										
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*total*
1		1	2		1	2	3		1		10
2	5		1	2	1	2	8		1		21
3	1			1	1			1			4
4		7	2		4	1		1			15
5	2	10		3			1		1		17
6	2	1					2	6		3	14
7	3		1			3		5	1		13
8		1	1			3	2		3		10
9		1				1		2	1	3	7
10						3	1	2	5		11

TABLE 5. Stimulus-response matrix for errors made by prosthetically-managed cleft palate subjects on ten stimulus items for two pooled sequences. See legend, Figure 3, for explanation of entries.

stimulus	*response*										
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*total*
1		1	1	1			1	1			5
2	3		3	1		2	1				10
3		1				1					2
4		1	3		4			1			9
5		6	1	3							10
6	1		1				1	5			8
7	1							3	1	1	6
8						1	3		5	1	10
9								2		1	3
10						1		2			3

ever, extensive errors were observed for items 7, 8, 10, and 1. Forms 3 and 9 were the most readily perceptible, but were confused over a wider range of items than were normal confusions.

The stimulus-response confusions for prosthetically managed cleft palate subjects are presented in Table 5. These subjects demonstrated 36 errors (26%) in series A and 30 errors (22%) in series B, making a total of 66 errors (48%) out of a possible 140 responses. Intra-series confusions dominated, although responses again were distributed over a fairly wide range of items for a given stimulus. Forms 2, 5, and 8 were confused most readily and with equal frequency, whereas items 3, 9, and 10 were most easily identified correctly.

A tendency for reciprocal inter-item confusions was observed. In Table 3, for example, item 4 was confused with item 5 eight times, and item 5 confused with item 4 eleven times. Item 6 was confused with item 7 thirteen times, and item 7 was confused with item 6 five times. Less substantial reciprocal relationships were noted for several other pairs of forms, such as 1 and 2, and 7 and 8. In Table 4, results for items 4 and 5, 6 and 10, and 9 and 10 suggested this tendency for cleft palate subjects. In Table 5, items 4 and 5 indicated reciprocity for prosthetic cleft palate subjects.

The relative degree of response accuracy for each stimulus was ranked across the three subject groups and is presented in Table 6. Spearman rank-order correlation coefficients were computed to ascertain the degree of correspondence of the ranked stimuli. The following coefficients were obtained: normal and cleft palate (.95), normal and prosthetic cleft palate (.91) and cleft palate and prosthetic cleft palate (.88). All were significant. It can be seen from Table 6 that all three groups found forms 5, 2, and 4 relatively difficult to perceive, forms 3 and 9 comparatively easy, and forms 1, 6, and 7 of intermediate difficulty.

TABLE 6. Rank order (*1*, most difficult; *10*, least difficult) of the ten stimulus items for relative degree of response accuracy for normal, cleft palate, and prosthetic cleft palate subjects. Each tied rank, signified by a decimal, was assigned the average of the ranks which would have been assigned had no ties occurred.

form	*rank orders*		
	normal	*cleft palate*	*prosthetic cleft palate*
1	7	7.5	7
2	3	1	2
3	10	10	10
4	2	3	4
5	1	2	2
6	4	4	5
7	5	5	6
8	6	7.5	2
9	8.5	9	8.5
10	8.5	6	8.5

Discussion

According to these findings, individuals with cleft palate demonstrate inferior ability to orally perceive alterations of surface and alterations of shape of cubes than do normal individuals, as judged by their highest level of performance. The mean values in Table 1 indicate a slight, but non-significant, difference in favor of series B for cleft palate subjects, with no such difference observed for normal subjects. The subjective reports of virtually all subjects indicated that forms which represented altered shape (series B) were more readily perceptible than those of altered surface. Reference to the stimulus-response confusion matrices support these subjective impressions: series B evoked fewer response errors for all subjects than did series A. In this connection, it should be pointed out that the mean values reported in Table 1 represent only the single most accurate of two sequences which does not take into account all of the errors manifested by subjects. In contrast, the confusion matrices present all possible errors that occurred.

When oral stereognostic measures were compared as a function of the presence or absence of prosthetic appliances for seven cleft palate subjects, significant differences were observed in favor of prosthetic palatal covering for shape alteration (series B) and for the combined series. A similar, but non-significant, difference was noted for series A (surface alteration). The data confirms the reports of these prosthetically managed individuals that the presence of appliances offered them a feeling of oral facility and provided an apparent greater ease in oral perception of form.

The factor of age is an important variable in interpreting the results. A significant difference was found between the oldest normal subjects who were approximated for age with a comparable group of cleft palate subjects. Younger cleft palate subjects were significantly superior to older cleft palate individuals in perception of shape alteration and when stimuli were combined. Thus, age may be a significant variable among cleft palate subjects, for this kind of task, but the findings indicate that for comparable ages, normals are superior to cleft palate in stereognosis.

Virtually all subjects reported that oral stereognosis was dependent primarily on the tongue, and that the palate functioned mainly as a rigid surface against which the tongue could manipulate the object. This generalization agrees with the report by Grossman (5) who found that lingual anesthesia reduced oral stereognosis considerably. If we assume that lingual receptors in cleft palate individuals are intact, oral stereognosis should not be expected to deteriorate since it appears to depend on the acuity derived from the tongue. That it did in the present investigation raises a question that deserves consideration. It would seem that an explanation might be derived from among the following possibilities: (a) because palatal 'completeness' was absent, it did not afford adequate surface area against which the tongue could manipulate forms easily; (b) increased palatal vault may have resulted in the tongue's making greater than normal excursions of which it was not capable; (c) post-surgical sequelae may have reduced oral sensitivity in general; (d) diffuse oral sensitivity may not have been apparent; (e) unknown sensory-motor deficits accompanying cleft palate; (f) manipulation of forms against the alveolar ridge, as opposed to the hard palate, may have provided an insufficient area; and (g) unknown sub-clinical factors.

In comparing the forms in series A and B relative to the respective perceptual task involved, it appears that recognition of an object's surface is a more subtle oral task than the perception of the alteration of an object's basic form. The relative complexity of each task apparently plays an important role in oral perception. The stimuli in series A (see Figure 1) require two distinct identifications, an initial one in which the basic form is discerned, followed by a more refined recognition of the type of surface involved. In series B, however, only the basic shape of the object requires recognition. It was shown that forms 3, 9, and 10 were consistently among the test stimuli most readily perceptible to all subjects, whereas forms 2, 4, and 5 were among those most difficult to perceive. A comparison of these groups of forms reveals that the former group is characterized by two forms (9 and 10) which are quite different in shape from the remaining stimuli, that is, they are cylindrical rather than cuboidal (see Figure 1). Form 3 is characterized by one outstanding irregularity, a single groove running along four surfaces on otherwise smooth surfaces, which the tongue apparently was able to detect with considerable facility. On the other hand, forms 4 and 5 are characterized by two and three grooves, respectively, running along four surfaces, which may be a rather difficult distinction to make with the tongue. It is noteworthy to mention that the higher the number of grooves along a surface, the more likely it will resemble perceptual smoothness, rather than surface irregularity, a phenomenon supported by the inter-confusions of forms 2, 4, and 5. This observation also seems to explain the confusion between forms 1 and 2. The extensive alteration of the one surface of form 2 increased its similarity to form 1. Another possible explanation for the confusion between these two items stems from the inability to discover lingually the single altered surface among the six surfaces as the object was manipulated in the mouth. It is entirely conceivable that one or more surfaces were missed by the tongue during manipulation.

The prosthetic cleft palate group found form 8 considerably more difficult to perceive than did the remaining subject groups. Reference to Table 5 shows that it was confused primarily with its adjacent forms, 7 and 9, a consistently observed tendency. No explanation seems available.

Summary

Two aspects of oral stereognosis were measured in thirty normal and twelve cleft palate adult subjects: oral perception of surface alteration and shape modification. Two series of metal alloy cubes were developed to represent varying degrees of surface and shape alteration. The responses of three groups of subjects were compared and statistically analyzed on the basis of their most accurate sequence of responses: normal, cleft palate, and, within the cleft palate group, seven subjects with prostheses. The obtained results permit the following conclusions. a) Cleft palate individuals demonstrate significantly inferior oral stereognostic ability than do normal individuals, as judged by their most accurate level of performance. b) According to the stimulus-response confusions demonstrated, both normal and cleft palate individuals are able to differentiate more readily alterations of object shape than alterations of object surface. c) The presence of prosthetic appliances in cleft palate individuals appears to facilitate oral stereognosis, particularly the perception of shape alteration.

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