THOMPSON, Robert Charles, 1935-
THE EFFECTS OF ORAL SENSORY DISRUPTION UPON ORAL STEREOGNOSIS AND ARTICULATION.

The University of Oklahoma, Ph.D., 1968
Speech Pathology

University Microfilms, Inc., Ann Arbor, Michigan

THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE EFFECTS OF ORAL SENSORY DISRUPTION UPON ORAL STEREOGNOSIS AND ARTICULATION

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

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Oklahoma City, Oklahoma

1968

THE EFFECTS OF ORAL SENSORY DISRUPTION UPON

ORAL STEREOGNOSIS AND ARTICULATION

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ACKNOWLEDGMENTS

The writer is deeply indebted to Dr. Bruce R. Pierce, director of this research, for his guidance, counsel, and criticism during the planning and execution of this study.

Thanks are due to Mrs. Margaret F. Shackelford for advice concerning the experimental design and statistical treatment of the data and to Dr. Royal B. Dunkelberg for contributing freely of his time to construct the palatal shields and to administer the intraoral anesthesia required for this study.

TABLE OF CONTENTS

Chapter | Page

LIST OF TABLES

LIST OF FIGURES

THE EFFECTS OF ORAL SENSORY DISRUPTION UPON ORAL STEREOGNOSIS AND ARTICULATION

CHAPTER I

INTRODUCTION

Speech articulation, whether normal or abnormal, is generally viewed as a complex motor phenomenon. With controlled exhalation as a base, the functions of the laryngeal, oral, and nasal cavities are modified by muscular movements to produce the different phonemes of speech. Moreover, motor dysfunctioning is widely recognized as a significant causal factor in deficient articulation, as in, for example, the cerebral palsied and those articulation defectives with "general oral inaccuracy" (29).

The articulatory process, however, also includes a critical sensory component. The muscular movements effected by efferent impulses of the nervous system are instantly followed by afferent impulses which relay information on changes in articulator position and movement, an activity which Fairbanks (11) describes as a "closed cycle system or servo-system." Sensory impulses which reflect the motor responses of speech are fed to the central nervous system through auditory, kinesthetic, and tactile channels, this information is compared to the intended speech act, and an evaluation is placed on the adequacy of the desired act. While introductory texts routinely stress the significance of auditory feedback to articulation development and therapy, Van Riper and Irwin (39), among others, emphasize the importance to articulation learning of the feedback of tactile and kinesthetic information, concluding that, once stabilized, these two monitoring processes ". . . serve as the dominant control for speech," while auditory feedback takes a "secondary role."

In addition, inadequate or abnormal tactile and kinesthetic feedback mechanisms have been recognized as factors in disordered articulation (42, 45). Mecham, Berko, and Berko (25) state that such monitoring deficiencies are frequently present in all types of cerebral palsy and that they are the primary disorders in the ataxic. Moreover, such deficits of feedback may also be present in those persons with speech defects not classifiable as organic. Powers (29), for example, states that tactile and kinesthetic deficiencies may be "predisposing factors" to functional articulation defects.

Investigations of the motor functioning of the oral mechanism may be found throughout the early literature in speech pathology (e.g., 37, 43). Only within the last decade or so, however, have investigators turned extensive attention to oral sensory functioning, primary evaluations of which have included those of two-point discrimination (17, 32), lingual reaction times to tactile stimuli (36), and difference limens for texture (24), touch (17), and weight (24). In addition, investigators have attempted to explore the functioning of oral sensory processes by means of tests of oral stereognosis, the faculty of perceiving the nature of objects on the basis of tactile-kinesthetic sensations from the oral cavity, particularly the tongue. In such tests, the subject manipulates and identifies small forms, varying in such characteristics as shape, weight, texture, and/or edging, placed in his mouth. It appears obvious that oral stereognosis is a perceptual process rather than exclusively a sensory process, that it is dependent upon the integrity not only of the motor and sensory systems of the oral mechanism, but also of those parts of the nervous system necessary for the integration and evaluation of sensory experiences. A subject's successful performance on a test of oral stereognosis indicates the integrity of the oral motor, sensory, and perceptual systems. His failure on such a test, on the other hand, may be attributable to a variety of factors, including problems of motor impulse initiation and control, inadequate sensory end-organ function, deficient sensory impulse transmission, or central disturbances which prevent correct interpretation of the impulses received.

While a variety of geometric forms were utilized in the initial studies of oral stereognosis in the latter 1950's, the greater part of research in this area has been carried out with the forms developed subsequently at the National Institute of Dental Research, or, to a lesser degree, with those designed by Nuttall at Cornell University. Investigations of oral stereognostic abilities have been undertaken to develop normative date (4, 20, 24, 41), to compare normal-speaking and various kinds of speech-defective children and adults (8, 19, 21, 27, 41), to evaluate the relative contributions to oral stereognosis of sensations from the tongue, lips, and palate (16, 19, 24), and to explore the effects of various teaching methods on oral form identification (24).

Attempts have also been made to evaluate oral tactile-kinesthetic behavior through studies of the effects of local anesthesia of the tongue and associated oral structures upon speech articulation. In this respect, investigators have utilized both single-word (22, 40) and conversational speech (18, 31) responses, both topical (31, 33) and nerve block (16, 22, 31, 33, 34, 40) anesthetics, both mandibular (16, 31) and mandibular-infraorbital (24, 31, 33) nerve-blocking procedures, and anesthetization both with and without auditory masking and delayed auditory feedback (18, 40). In addition, two investigators (16, 33) have explored the effects of local anesthesia upon oral form identification.

While there seems to be little question regarding the importance of oral tactile-kinesthetic feedback to speech articulation, an understanding of this acknowledged relationship is yet incomplete. A review of the literature reveals no comparisons of subject performances on separate tests of oral stereognosis and no investigations of the relationships between oral stereognostic and articulation scores under conditions of disrupted oral sensation. This study represents an effort to gather objective data in this respect.

CHAPTER II

REVIEW OF THE LITERATURE

The role of oral taction-kinesthesia in the speech articulation process has been the subject of numerous research efforts in such fields as speech pathology, dentistry, and experimental psychology. Among the principal methods utilized to investigate this relationship have been the assessment of the effects upon articulation of oral anesthesia and the evaluation of the performance of various subject samples on tests of oral stereognosis. The literature pertinent to the present investigation may be reviewed under three principal headings, (a) The Anatomy of Oral Taction-Kinesthesia, (b) Oral Anesthesia and Speech Articulation, and (c) The Assessment of Oral Stereognosis.

The Anatomy of Oral Taction-Kinesthesia

The oral cavity contains the sensory end-organs for one of the four "special" senses, taste, and peripheral nerve endings for all of the superficial (taction, pain, and temperature) and deep (kinesthesia, pressure, and vibration) "general" senses. The integrity of the oral tactile-kinesthetic receptors and pathways are, of course, essential to the functioning of the combined senses of the oral cavity, such as stereognosis, topognosis, barognosis, and graphesthesia.

Oral taction-kinesthesia is served primarily by the maxillary and mandibular branches of the Trigeminal nerve (V). The maxillary branch, which passes through the foramen rotundum of the sphenoid bone and divides to become the zygomatic, sphenopalatine, superior alveolar, and infraorbital nerves, is exclusively sensory. It serves, in addition to the skin of the middle portion of the face, the maxillary teeth and alveoli and the mucous membranes of the soft and hard palates, the upper gums, and the upper lip (14).

The largest branch of the Trigeminal, the mandibular nerve, leaves the skull through the foramen ovale of the sphenoid bone, gives off the recurrent and internal pterygoid nerves, and splits into those branches which provide, in addition to sensation from the skin of the lower portion of the face, the principal tactile-kinesthetic pathways from the oral cavity. The long buccal nerve serves the mucous membranes of the inner cheek and the outer portions of the upper and lower gums. The inferior alveolar nerve serves the mandibular teeth and alveoli and the mucous membrane of the lower lip. The lingual nerve is sensory to the mucous membrane and muscles of the anterior two-thirds of the tongue and the mucous membrane of the inner portions of the lower gums. This nerve, which lies medial to and in front of the inferior alveolar nerve, passes beneath the external pterygoid muscle, runs between the internal pterygoid muscle and the internal surface of the mandibular ramus, courses medially over the superior pharyngeal constrictor and the styloglossus muscle, and ramifies in the anterior two-thirds of the tongue (34). The mandibular nerve also projects a relatively small motor root which serves the tensor tympani, tensor veli palatini, masseter, temporalis, internal and external pterygoid, mylohyoid, and anterior digastricus muscles.

While tactile and kinesthetic sensations from the greater portion of the tongue are provided by the lingual branch of the mandibular nerve, afferent impulses from the tongue are carried by three other cranial nerves. Taste in the anterior two-thirds of the tongue is served by the chorda tympani branch of the Facial nerve (VII). Both sensation and taste from the posterior one-third of the tongue are carried by the lingual branch of the Glossopharyngeal nerve (IX). Sensation from the root of the tongue, surrounding the epiglottis, is provided by the superior laryngeal branch of the Vagus nerve (X).

All efferent impulses to the tongue musculature, except the glossopalatine muscle, which receives motor impulses from the Spinal Accessory nerve (XI), are conducted by the Hypoglossal nerve (XII). After emerging from the skull through the hypoglossal canal of the occipital bone, this nerve extends downward and forward to a level slightly above the hyoid bone, runs deep to the tendon of the digastricus and stylohyoid muscles, and continues forward among the fibers of the geniohyoid muscle as far as the tip of the tongue to provide efferent impulses to the intrinsic musculature of the tongue. It provides efferent impulses to the hyoglossus, genioglossus, chondroglossus, and styloglossus muscles (13).

Oral Anesthesia and Speech Articulation

Studies of sensory feedback are not infrequently approached through observation of the ways in which a subject's responses differ from normal under conditions of modified or eliminated sensation. Visual functions, for example, may be evaluated through the use of blindfolds or darkened rooms, audition by means of masking noises, and taction-kinesthesia through the use of local anesthetization, the elimination of feeling or sensation in a limited part of the body by means of an anesthesia-producing drug. Such an approach has been utilized in investigations of oral taction-kinesthesia, particularly as this kind of sensory input relates to speech articulation.

Either topical or nerve-block anesthetization may be utilized to achieve alteration of tactile sensation; nerve-block anesthetization is necessary to induce loss of kinesthetic sensation. Topical, or surface, anesthetization is produced by spreading or spraying the anesthetic agent on the skin or mucous membrane. Nerve-block anesthetization is accomplished through direct injection of the anesthetic along the course of the nerve, so as to eliminate sensory input from all end-organs served by that nerve.

For well-controlled and stable elimination of tactile and kinesthetic sensation from the oral cavity, without involvement of the motor innervation of the tongue, local anesthetization of the mandibular and/or maxillary nerve is used. Anesthetization of the mandibular nerve involves the intraoral injection of an anesthetizing agent along the interior aspect of the mandibular ramus. This procedure eliminates all sensory stimuli from those areas served by the long buccal, inferior alveolar, and lingual nerves, without involving the motor portion of the Trigeminal or Hypoglossal nerves (33). Elimination of sensation from those areas served by the maxillary nerve is achieved by infraorbital or zygomatic injection (9). Anesthesia of those oral structures not served by the maxillary or mandibular nerves demands anesthetization of the oral branches of the Glossopharyngeal, Vagus, Spinal Accessory, and Hypoglossal nerves.

A widely used anesthetizing agent in studies of oral anesthesia and speech articulation is lidocaine hydrochloride (Xylocaine), a fast-acting (eight to fifteen minutes) drug which ". . . has been found to be the most stable local anesthetic drug presently available" (5). The addition of epinephrine or adrenaline, usually 1:50,000, to the Xylocaine produces a local vaso-constriction which greatly decreases the blood flow through the injected area (1), thereby retarding the absorption of the anesthetic agent and prolonging the duration of the anesthesia up to four hours (9).

Among the earliest investigators to utilize this experimental approach, Guttman (18) studied the effects upon articulation of bilateral nerve blocks of the mandibular nerve using 2 cc of Xylocaine 2% with 1:50,000 epinephrine. Both with and without anesthesia, six adult male subjects read the Rainbow passage under three different conditions: normal auditory feedback, 100 dB of thermal noise, and a .2-second delay. Anesthesia resulted in a significant decrease in the mean number of correctly articulated words under each of the auditory conditions. It is interesting to note that the greatest mean difference between the nonanesthesia and anesthesia conditions occurred under the normal auditory feedback condition.

McCroskey (22) had six subjects read aloud lists of single words following anesthetization of the oral region through bilateral mandibular and infra-orbital nerve blocks employing Xylocaine 2% with 1:50,000 epinephrine. Under the normal condition, an average of 132 of 144 words were correctly articulated; following anesthetization, an average of 117 words were correctly articulated. In a later analysis of this data, McCroskey, Corley, and Jackson (23) reported on the number, type, and place of articulatory errors. No statistical analysis of the data was deemed necessary, ". . . in view of an obviously significant difference between the two groups," but the authors noted that, under anesthesia, substitution and distortion errors predominated, with lingua-rugal sounds most frequently in error.

Weber (40) evaluated the articulation of eight normal young adults reading aloud a twenty-five-item word list under the following experimental conditions: (a) normal, (b) "high-level" air- and bone-conduction auditory masking, (c) bilateral anesthetization of the mandibular nerve and the palatal branches of the infra-orbital nerve, and (d) combined auditory masking and oral anesthesia. Anesthesia was achieved through injections of Xylocaine 2% with 1:100,000 epinephrine. Although no significant difference was found in the mean number of phonemic errors under the normal and auditory masking conditions, significantly more errors were reported under the anesthetization and combined auditory masking and anesthetization conditions. Weber concluded that "non-auditory cues" are of greater importance than auditory cues in the monitoring process of the speech articulation of normal adult speakers. An analysis of type of error indicated that, under the normal and auditory masking conditions, 66 per cent of the phonemic errors were distortions and 33 per cent were omissions, while, under oral anesthetization and oral anesthetization with auditory masking, 50 per cent of the articulatory errors were distortions, 40 per cent substitutions, and 10 per cent omissions.

In a similar study, Ringel and Steer (31) examined the effects of oral topical anesthetization, bilateral mandibular and infra-orbital anesthetization, and auditory masking on the articulation of thirteen female college students in the oral reading of a six-sentence selection.

Six experimental conditions were utilized: (a) normal, (b) binaural masking, (c) topical anesthetization with Xylocaine 4%, (d) bilateral mandibular and infraorbital nerve-block anesthetization employing Xylocaine 2%, (e) simultaneous masking and topical anesthetization, and (f) simultaneous masking and nerve-block anesthetization. The mean number of articulation errors (type and place of error were not reported) under the normal condition was not significantly different than that obtained under topical anesthesia, masking, and simultaneous masking and topical anesthesia, but it was significantly different from that obtained under nerve-block anesthesia and nerve-block anesthesia with masking. These results, like those reported by Weber, support the contention of Van Riper and Irwin that tactile-kinesthetic feedback is more important to speech articulation than auditory feedback.

As part of an extensive study of oral sensation, Grossman (16) included a condition of bilateral mandibular anesthesia achieved with Xylocaine 2% with 1:100,000 epinephrine. The subjects were three teen-agers with athetoid cerebral palsy and thirty normal male and female subjects between ten and forty years of age. In this study, Grossman did not evaluate articulation but, rather, required the subjects to identify with the tongue ten plastic geometric configurations of varied shape. The normal subjects, who were able to identify 70 per cent of the forms under the control conditions, found the forms "indistinguishable" under anesthesia. No data were reported for the three cerebral palsied subjects.

The Assessment of Oral Stereognosis

During the last ten years or so, a number of investigators have attempted to derive information concerning oral sensory functioning by means of tests of oral stereognosis. Such investigations have utilized a variety of tests, subjects, and experimental conditions and, perhaps not surprisingly, have not always concurred in their findings and conclusions.

Many types of forms have been devised to evaluate oral stereognosis. McDonald (24), for example, utilized three-dimensional forms of a sphere, cube, pyramid, cross, and cylinder. Hochberg, Kabcenell, and Silverman (19) designed a series of ten cubes, five of which varied in shape and five in surface molding. Larson (21) used both spheres graduated in dimension and disks with holes in them, Class (8) used a variety of geometric forms of various sizes, and Woodford (44) chose a combination of spheres, disks, and symmetrical and asymmetrical forms. The tests of oral stereognosis, however, which have recently received primary research attention have been those developed by personnel at the National Institute of Dental Research (NIDR) of the National Institutes of Health, and, more recently, by Nuttall at Cornell University. The NIDR test, originally composed of ten forms of varying shapes, was subsequently altered to the test of twenty such forms that has been used by numerous investigators. Nuttall's original test, consisting of nine forms, included three basic shapes, square, circle, and triangle, each of which was distinguished by a different edge, smooth, fluted, and sawtooth. Nuttall subsequently added a fourth shape, a hexagon, and a fourth edge, a small sawtooth, making a total of sixteen forms.

Among the earliest studies of oral stereognosis was that by Larson (21), in 1955, who assessed the ability of children to judge the sizes of objects and holes with the tip of the tongue. Larson's subjects consisted of thirty elementary and junior high school children with functional articulation disorders and an equal number of normal-speaking controls matched in age, sex, intelligence, and economic level. The test materials included eleven plastic spheres of graded size and ten disks containing holes of various dimensions. Larson found no significant difference between the two groups in the lingual identification of spheres but a significant difference in favor of the control group in the discrimination of holes. On the strength of these findings, he concluded that ". . . among elementary and junior high school children with functional disorders of articulation, a significantly greater amount of tactile deficiency is exhibited lingually than among a matched group of normal-speaking children."

Class (8), in another early study of oral stereognosis, compared the ability of twenty normal speakers, twenty cerebral palsied patients, twenty stutterers, and twenty articulation defective subjects to identify six plastic geometric forms--circle, half-oval, square, rhombus, isosceles triangle, and right isosceles triangle--each of seven different sizes. The stimulus forms, mounted on plastic strips, were held stationary as the subject passed his tongue over them. Class found significant differences between group means in the identification of the test forms, with the cerebral palsied speakers inferior to all other groups and the stutterers and speakers with articulation problems inferior to the normal speakers. The cerebral palsied subjects also required significantly more time to complete the task than all the other groups, and the stutterers and subjects with articulation problems required significantly more time than the normal speakers. Class concluded that there is a ". . . possible relationship between speech defects and tactual-kinesthetic perception of form with the tongue."

McDonald and Aungst (24) have reported on a series of unpublished oral form perception studies completed by McDonald and his students at Pennsylvania State University. McDonald and Solomon (24) determined that "children as young as five years of age can differentiate textures, weights, and forms placed in their oral cavities." Texture discrimination was evaluated by means of one-inch buttons varying in surface configuration, while weight was tested by imbedding different amounts of lead shot in identical geometric forms. Five three-dimensional plastic forms--sphere, cube, pyramid, cross, and cylinder--were used in the form test.

Aungst (24) subsequently used these five three-dimensional forms, plus the twenty-form NIDR test, to assess the oral stereognosis of eighty "typical" kindergarten and first-grade children. Each subject received this twenty-five-item test of oral stereognosis, the McDonald Deep Test of Articulation for the /s/, /r/, /l/, and /θ/ phonemes, and a global rating of articulation proficiency based upon the average of four judges' ratings. On the basis of his findings, Aungst concluded that there is a slight association between articulation proficiency and oral stereognosis, although the correct production of some speech sounds (/r/ and /θ/) is more closely related to oral stereognostic ability than that of other speech sounds (/s/ and /l/).

In a later investigation, McDonald and Aungst (24) administered the twenty-five-item test of oral stereognosis to 298 children, approximately thirty in each grade from one through eight and in the eleventh and twelfth grades. Results of administration of the test to forty college students (eighteen to thirty-one years, with a mean age of twenty-one) and twenty-nine geriatric subjects (fifty-two to eighty-nine years, with a mean age of seventy) were included in an analysis of the data. The distribution of the 367 scores revealed an increment in oral stereognostic scores as a function of age in children, a leveling off in the mid-teens and young adults, and a decrease in scores in the geriatric group. An improvement with age in oral stereognosis is also reported by both Hochberg, Kabcenell, and Silverman (19) and Blanchard (4).

Mihacs (24) administered the twenty-five-item test used by McDonald and Aungst to twenty college students with normal speech and dentition. Each subject was tested twice, once with a palatal shield of dental wax and again without the shield; half of the subjects were tested first without the shield. Mean oral stereognostic scores under the two conditions were identical, and Mihacs concluded that sensations from the hard palate made no significant contribution to oral form identification. Using the same test with a similar group of twenty college students, Hollingsworth (24) covered the subjects' lips with dental wax in the experimental condition; her results indicated that labial sensation does not contribute to oral stereognosis. Grossman (16) used ten varied forms, each 0.5 cm in thickness and approximately 1.4 cm in length, to test thirty normal subjects. He found that the subjects were able to identify at least 70 per cent of the forms without the use of their lips and with a prosthesis covering the hard palate.

Carpe, Dalinsky, Ritchie, and Rowland (24) attempted to determine the effects of different teaching methods on oral form identification by first- and second-grade children. Following initial administration of the twenty-form NIDR test to four groups of thirty children each, half of the children in each group received fifteen minutes of teaching with either (a) manual-tactile experience with the forms, (b) simultaneous visual and oral experience, (c) proprioceptive experience, or (d) verbal description accompanying the placement of the forms in the oral cavity. The second half of each group received no training. Each child was then administered the test a second time. Although the number of errors decreased slightly under the second test session, none of these teaching methods had a significant effect on the oral identification of forms.

Wegener (41) administered the twenty-form NIDR test to thirty preadolescent children with "non-organic" articulatory problems and to a matched control group of thirty normal-speaking children. On the basis of the results, he concluded that there is a significant relationship between articulatory defectiveness and oral astereognosis but that there is no correlation between astereognosis and degree of articulatory defectiveness. Although no procedures for evaluating gross or oral motor skills are reported, Wegener suggests that the inferior capabilities of the experimental group in stereognostic ability ". . . may reflect a subtle organic base for some articulation disorders." Wegener assigned children to the articulation-defective group if they scored below 167 on the Templin-Darley Test of Articulation (maximum score: 176) and to the normal-speaking group if they scored above 172 on this test. Variances were not reported, no mention was made of whether the subjects in either group had received speech therapy, and no reliability data were indicated.

Moser, LaGourgue, and Class (27) report the results of a series of unpublished research projects using the NIDR forms with normal, articulation-defective, blind, and deaf subjects conducted by Kile, Class, Levin, and LaGourgue at Ohio State University. Kile (27), comparing the oral stereognostic ability of eight normal-speaking and eight articulation-defective young adults, found no significant differences between the performances of the two groups or between test-retest conditions. Kile and Class (27) presented different sized sets of NIDR forms twice to each of three groups of normal-speaking college students (number unstated); analysis of the results indicated a significant difference on the initial trial between the standard size and the two-thirds and one-half size forms but no differences between sizes on the second trial. Levin (27), using the twenty-form NIDR test to compare the oral stereognostic abilities of twenty-seven aphasic and twenty-seven normal adults, found the aphasics to make approximately three times as many errors as did the normal subjects.

LaGourgue (27) investigated the form perception abilities of forty-nine blind, fifty "deaf-oral", and ten "deaf-manual" subjects between twelve and twenty-one years of age, all screened to insure average intelligence and ". . . freedom from handicaps or abnormalities other than the specific unisensory deficit." Preliminary investigations of the ability of the visually handicapped to match the forms tactually and of the hearing handicapped to match the forms visually, using a criterion of eighteen correct out of twenty responses, reduced the sample to twenty-seven blind, forty-eight "deaf-oral" and ten "deaf-manual" subjects. The mean scores of the three groups on the twenty-form NIDR test did not differ significantly.

Woodford (44) assessed the oral sensory abilities of eighteen children with normal occlusion, twelve children with malocclusion, twelve children with various neurological handicaps, twenty-four adults with dentures, and twelve adults with natural dentition. The tasks involved the oral identification of three spheres, three disks, and six geometric forms. The neurologically-impaired children performed all tasks significantly poorer than the neurologically-normal children, but there were no significant differences between the children with normal occlusion and those with occlusal problems or between the adults with natural dentition and those with dentures.

Schleissser and Coleman (33) studied the effects of oral anesthesia upon the oral stereognosis, speech, and motility of the speech musculature of six adult male subjects. Anesthetization involved a bilateral mandibular nerve block and a nerve block in the area of the incisive foramen of the anterior hard palate employing Xylocaine 2%, and topical anesthesia (agent not indicated) of the palate. Although the subjects could identify all ten of the experimental geometric forms under the normal condition, "virtually total intra-oral tactile insensitivity" occurred under anesthesia. No significant difference in repetitive speech and nonspeech behavior was found under the normal and anesthesia conditions. Recorded samples of the subjects reading forty-two sentences were obtained under four conditions: normal, auditory masking, anesthesia, and combined anesthesia and masking. A panel of listeners rated the speech recorded under combined anesthesia and masking to be approximately twice as defective as that recorded under either of these conditions separately. The speech obtained under all conditions of sensory disruption was judged to be notably more defective than that obtained under the normal condition. Type and number of articulation errors were not evaluated and no reliability data were reported.

Hochberg, Kabcenell, and Silverman (19) compared the oral stereognostic ability of thirty normal and twelve cleft palate subjects, using the previously described ten three-dimensional objects designed by these investigators. The normals ranged in age from nineteen to forty-six years, with a mean age of twenty-five, and the cleft palate subjects ranged from thirteen to fifty years, with a mean age of thirty-four. The cleft palate subjects did significantly poorer than the normals on the identification of both surface and shape. Seven of the cleft palate subjects, administered the oral stereognostic test with and without their prosthetic appliances, obtained significantly higher scores for shape, but not surface, with the appliance in than with the appliance removed. The prosthetic appliance, therefore, facilitated oral stereognosis, at least for perception of shape. An age factor was also noted, with younger cleft palate subjects significantly superior to older cleft palate subjects in the perception of shape; the older normal subjects made significantly better surface and shape scores than did the older cleft palate subjects. The authors conclude 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." It may be speculated that perception of form and perception of surface are separate but related tasks, each involving a different sensory modality--the former, kinesthetic, the latter, tactile.

Nuttall's stereognostic test material, consisting of four geometric forms with four different edges, was designed with this rationale in mind, that shape identification is essentially a kinesthetic function and edge identification primarily a tactile function (20). Nuttall (28), in addition, points out that the rate of tongue movement required for efficiency must also be considered if oral stereognostic skill is to be used as an analogue to speech articulation. For accurate articulation in normal speech, the tongue must move more quickly than when exploring a form from an oral stereognostic test. To examine this premise, several of Nuttall's students used and compared the two scoring procedures initially utilized by Class (8), (a) the length of time required to identify the material and (b) the accuracy of the response.

Kershner (20) administered the nine-item Nuttall test to thirty male college students and obtained time and accuracy scores during three different trials: identification of shape only, identification of edge only, and identification of shape and edge simultaneously. The mean time scores of the group were significantly different for the three shapes but not for the three edges. The greatest number of errors were committed on the composite test, with the edges proving more difficult to identify than the shapes. Kershner suggested that more difficult test material be constructed and that response-time scores be eliminated and accuracy alone used as a measurement of oral stereognosis.

Blanchard (4), using the same material with fifty first-graders and fifty fifth-graders, also measured response time and accuracy. The first-grade subjects had 37 per cent incorrect and the fifth-grade subjects 23 per cent incorrect, a significant difference in favor of the latter. The fifth-grade subjects also completed the identification of the forms in a shorter period of time. Blanchard reports a ". . . highly significant correlation between short correct response times and low number of errors" and suggests that time scoring be eliminated from this task.

CHAPTER III

DESIGN OF THE INVESTIGATION

It was the purpose of the study to determine the effects of oral sensory deprivation, by means of both mandibular-nerve anesthetization and palatal shielding, upon oral stereognosis and speech articulation. In this experiment, two tests of oral stereognosis and two tests of articulation were administered twice to a group of normal adults under each of four conditions: (a) normal, (b) palatal shielding, (c) bilateral mandibular-nerve anesthesia, and (d) combined shielding and anesthesia. The research questions and descriptions of the subjects, materials, and procedures of this study are presented in the following sections.

The Research Questions

The following research questions were formulated for this investigation:

1. What are the relationships among subject performances on two tests of oral stereognosis and two tests of articulation?

2. How are these relationships affected by palatal shielding, bilateral mandibular nerve-block anesthetization, and combined shielding and anesthesia?

3. How reliable are subject performances on the two tests of oral stereognosis and the two tests of articulation under the experimental conditions?

Subjects

The group consisted of seven normal-speaking adults, four males and three females between the ages of twenty-one and thirty, all graduate students in the Department of Communication Disorders at the University of Oklahoma Medical Center. The following criteria were established for subject selection: (a) no history of sensory or motor disorder or of adverse reaction to local anesthetization, (b) normal hearing, as determined by audiometric screening at 15 dB (ISO), and (c) the ability to match visually identical oral stereognostic test forms.

Material

The material used in this investigation included the National Institute of Dental Research and Nuttall tests of oral stereognosis and two tests of articulation, the Templin-Darley Screening Test of Articulation (38) and the first paragraph of the Rainbow passage (12). The NIDR test consists of twenty plastic forms of varying shapes, each three-sixteenth inch in thickness. The Nuttall test, consisting of sixteen plastic forms, each one-eighth inch in thickness, includes four shapes---square, circle, triangle, and hexagon. Each of the four forms of each shape is distinguished by a different edge---smooth, fluted, large sawtooth, and small sawtooth. The NIDR and Nuttall test forms are shown in Figures 1 and 2, respectively (See Appendix). The screening form of the Templin-Darley test is a list of fifty single words which correlates highly with the full-scale Templin-Darley test (37). The first paragraph of the Rainbow passage consists of ninety eight words of connected speech which includes at least one of each of the phonemes of general American speech.

Procedure

The data of this investigation were obtained under four experimental conditions: normal, shield, anesthesia, and anesthesia-shield. The order of conditions was randomized for each subject. After each subject had been tested under all four conditions, the conditions were re-randomized and all tests were repeated under each condition. Under each of the conditions, the two oral stereognosis tests and the two articulation tests were administered in random order.

Each subject was fitted by the participating dental surgeon with a palatal shield of permanent acrylic. The shield intimately covered the mucosal surface within the maxillary arch as far back as the posterior border of the hard palate. When necessary, a commercial dental adhesive was utilized to insure stability of the shield. The shield was worn only by the subjects during the shield and anesthesia-shield conditions.

The nerve-block anesthetic, Xylocaine 2% with 1:50,000 epinephrine, was administered through bilateral intraoral injections to the mandibular branch of the Trigeminal nerve. All anesthetization was done by a practicing dental surgeon at the Dental Clinic of the Veteran's Administration Hospital, Oklahoma City. Allowing approximately ten minutes for the anesthetic to take effect, the degree of anesthesia of the anterior two-thirds of the tongue and associated mandibular structures was determined by both the dental surgeon and the experimenter according to standard dental clinical procedures. Anesthesia was judged to be complete on the basis of both the subject's report of loss of sensation and his consistent failure to identify tactile, thermal, and pain-producing stimuli. Such assessment was undertaken at least once during and at the completion of each testing session.

All oral stereognostic testing was conducted in a private clinical room furnished with a large table and two chairs. During testing, the subject was seated with his back to the table so that he could observe neither the test materials nor the examiner's activities. Following cleansing of the test forms, their order of presentation was randomized and they were placed on a clean, dry mat on the table. Each testing session began with the investigator reading the following directions to the subject:

> You are already familiar with the forms of the two tests of oral stereognosis. This procedure requires you to identify the forms of each test, without being able to see them, as they are placed one at a time on your tongue. After a form has been placed in your mouth, manipulate it with your tongue to determine its characteristics. Keep the form behind your teeth and do not touch it with your lips or cheeks.
>
> The forms of the first of the two tests are affixed to the placard in front of you. When you feel that you know which form is in your mouth, point to the form on the placard that is identical to it. Accuracy is more important than speed, but make your identification of each form without unnecessary delay. When you have made your choice, I will record your response and remove the form from your mouth. Some of the forms may be presented for your identification more than once. When you finish this first test, we will go directly on to the second test. Have you any questions regarding the procedure or what is expected of you?

The investigator used one hand to manipulate the test form and the other to shield the form from view as it was placed in or removed from the subject's mouth. A ten-inch loop of dental floss, passed through the edge of each form, was held by the subject to insure he did not swallow the form. Caution was exercised during the entire procedure to insure that each subject complied with the directions.

The subject's responses on the single-word and conversational speech articulation tests were recorded in a single-walled sound room (IAC, 40CT) with an Electrovoice microphone (Model 636) and an Ampex magnetic tape recorder (Model 601). The material was read without practice by the subject following the investigator's reading of these directions:

> I am going to record your reading of a short paragraph and a list of fifty familiar words. Read both in a normal

> conversational manner, and please pause briefly after each item on the word list. Have you any questions regarding this procedure?

The recorded speech samples were played back in a sound controlled environment on the Ampex tape recorder through an Ampex amplifier-speaker (Model 602) for purposes of evaluation.

Incorrect responses on the NIDR test were scored on the basis of one point per item, for a maximum error score of twenty. Each item of the sixteen-form Nuttall test, however, required two identifications and incorrect responses were scored one point for shape and one point for edge. The maximum error score on the Nuttall test, therefore, was thirty-two points. The fifty-word Templin-Darley and ninety-eight word Rainbow passage tests of articulation were scored on the basis of the number of words in which at least one phoneme was in error.

CHAPTER IV

RESULTS

The data obtained under the four experimental conditions were subjected to both statistical and descriptive analysis. Spearman rank correlation coefficients (35) were computed to evaluate the reliability of each test under each condition. The Wilcoxon matched-pairs signed-ranks test (35) was used for the following comparisons: normal versus shield, anesthesia versus anesthesia-shield, and combined nonanesthesia versus combined anesthesia.[1] Spearman rank correlation coefficients were also used to determine the relationship, under each condition, between the two measures of oral stereognosis, between the two measures of articulation, and between each measure of oral stereognosis and each measure of articulation. A .05 confidence level for a one-tailed test was selected for all statistics computed.

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[1]The experiment was taken to be analagous to the situation in parametric statistical methodology where four treatment means will provide no more than three independent comparisons among pairs of means. In this sense, it was determined that an appropriate orthogonal set of comparisons could be interpreted.

Tests of Oral Stereognosis

The NIDR Test

Reliability. The twenty-point NIDR test of oral stereognosis was administered to each subject twice (Sessions A and B) under each of the four experimental conditions. The error scores and ranks for each subject and the mean error scores and standard deviations for the group on the two tests under each condition are presented in Table 1. Inspection of these figures reveals that, for each condition, the mean error score for Session B was smaller than that for Session A and that the differences between the Session A and Session B means were small and quite similar, never exceeding two errors. The difference between the standard deviations for Session A and Session B were also small and comparable in size and direction for each of the conditions.

An evaluation of the differences in Session A-Session B error scores of the individual subjects is also critical to an understanding of the test-retest reliability of the NIDR test. It can be seen in Table 1 that these error score differences were, with few exceptions, small and similar in size under each of the four conditions. Under the normal condition, for example, six of the seven subjects made changes of two errors or less from Session A to Session B. Differences greater than two errors were made by only two subjects under both the shield and the anesthesia-shield conditions, and three subjects each

TABLE 1.

SESSION A AND SESSION B ERROR SCORES, RANKS, MEANS, AND STANDARD DEVIATIONS FOR THE NIDR TEST.

Conditions	Session		Subjects 1	2	3	4	5	6	7	$\bar{x}$	σ
Normal	A	score	4	4	4	2	2	4	9	4.14	2.17
		rank	($4\frac{1}{2}$)	($4\frac{1}{2}$)	($4\frac{1}{2}$)	($1\frac{1}{2}$)	($1\frac{1}{2}$)	($4\frac{1}{2}$)	(7)		
	B	score	3	3	2	4	0	3	5	2.86	1.46
		rank	(4)	(4)	(2)	(6)	(1)	(4)	(7)		
Shield	A	score	1	3	4	0	0	5	9	3.14	2.99
		rank	(3)	(4)	(5)	($1\frac{1}{2}$)	($1\frac{1}{2}$)	(6)	(7)		
	B	score	2	2	1	2	1	3	3	2.00	.75
		rank	(4)	(4)	($1\frac{1}{2}$)	(4)	($1\frac{1}{2}$)	($6\frac{1}{2}$)	($6\frac{1}{2}$)		
Anes.	A	score	16	13	6	15	3	11	13	11.00	4.44
		rank	(7)	($4\frac{1}{2}$)	(2)	(6)	(1)	(3)	($4\frac{1}{2}$)		
	B	score	15	8	3	15	6	5	11	9.00	4.44
		rank	($6\frac{1}{2}$)	(4)	(1)	($6\frac{1}{2}$)	(3)	(2)	(5)		
Anes.-Shield	A	score	20	18	5	20	18	12	10	14.71	5.36
		rank	($6\frac{1}{2}$)	($4\frac{1}{2}$)	(1)	($6\frac{1}{2}$)	($4\frac{1}{2}$)	(3)	(2)		
	B	score	17	15	5	20	18	10	11	13.71	4.89
		rank	(5)	(4)	(1)	(7)	(6)	(2)	(3)		

earned identical scores in both Sessions A and B under the latter condition. Under the anesthesia condition, five of the seven subjects had inter-session differences of three errors or less. Of the twenty-eight individual Session A-Session B difference scores under the four conditions, only four exceeded three errors. No single subject had a Session A-Session B score difference greater than two errors on more than two conditions.

The direction of individual error score differences was, in general, that indicated by the relationship between the Session A and Session B means. Individual Session B error scores were lower than those for Session A for six subjects under the normal condition, four under the shield condition, five under the anesthesia condition, and three under the anesthesia-shield condition.

Spearman rank correlation coefficients were also computed to estimate the group's test-retest reliability, with the following results for each condition: normal, .51; shield, .64; anesthesia, .88; and anesthesia-shield, .88. Since, for seven pairs of ranks, a <u>rho</u> of .71 is required for significance at the .05 level, it is evident that only the coefficients for the anesthesia and anesthesia-shield conditions were significant. The small scores and ranges of scores for the normal and shield conditions appear to be primarily accountable for the lower Session A-Session B correlations derived for these two conditions. Scores and ranges of this magnitude allow relatively small score differences between the two sessions to result in relatively large rank differences. Under the normal condition, for example, Subject Four had a Session A-Session B difference of two errors, which caused a rank difference of four and one-half ranks. In contrast, under the anesthesia condition, Subject Six had scores for Sessions A and B which differed by six errors, yet the rank difference was only one rank.

Among Conditions. The sum of each subject's error scores on the two NIDR tests (Sessions A and B) under each condition was taken as representative of his performance on that test under that condition. These scores and ranks and the group means and standard deviations are displayed in Table 2.

Under the normal condition, individual errors ranged from two to fourteen, out of a possible forty, with a mean of 7.00 and a standard deviation of 3.30. Somewhat surprisingly, six of the seven subjects made fewer errors under the palatal shield condition than under the normal condition, with a resultant mean error score of 5.14 and a standard deviation of 3.81. Five of the seven subjects had scores under the shield condition that were within two errors or less of their scores under the normal condition. It can also be seen that the two subjects who were at the extremes of the error score range under the normal condition were in those positions under the shield condition. A Wilcoxon matched-pairs signed-ranks test of the difference between the two sets of scores was significant.

TABLE 2

SUMMED SESSION A-SESSION B ERROR SCORES, RANKS, MEANS, AND STANDARD DEVIATIONS FOR THE NIDR TEST.

Condition		Subjects							$\bar{x}$	σ
		1	2	3	4	5	6	7		
Normal	score	7	7	6	6	2	7	14	7.00	3.30
	rank	(5)	(5)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	(1)	(5)	(7)		
Shield	score	3	5	5	2	1	8	12	5.14	3.81
	rank	(3)	($4\frac{1}{2}$)	($4\frac{1}{2}$)	(2)	(1)	(6)	(7)		
Anes.	score	31	21	9	30	9	16	24	20.00	8.07
	rank	(7)	(4)	($1\frac{1}{2}$)	(6)	($1\frac{1}{2}$)	(3)	(5)		
Anes.-Shield	score	37	33	10	40	36	22	21	28.43	9.42
	rank	(6)	(4)	(1)	(7)	(5)	(3)	(2)		

The subject's error scores under the anesthesia and anesthesia-shield conditions were, on the average, three to four times greater than those obtained under the normal condition; a Wilcoxon test of the difference between the pooled normal and shield scores and the pooled anesthesia and anesthesia-shield scores was significant. Individual error scores ranged from nine to thirty-one, with a mean of 20.00 and a standard deviation of 8.07, under the anesthesia condition and from ten to forty, with a mean of 28.43 and a standard deviation of 9.42, under the anesthesia-shield condition. Even greater differences are evident, of course, when the mean error score of the palatal shield condition is compared with those derived under the anesthesia and anesthesia-shield conditions.

Six of the seven subjects made a greater number of errors under the anesthesia-shield condition than under the anesthesia condition; these differences ranged from one to twenty-seven errors. The direction of these score differences is in contrast to that of the differences observed between the scores for the normal and shield conditions, in which the mean error score and six of the seven individual error scores decreased with placement of the palatal shield. Subjects who were at the extremes of the range of errors under the anesthesia condition tended to be in those same positions under the anesthesia-shield contition. A Wilcoxon test of the difference between the anesthesia and anesthesia-shield scores was significant.

The Nuttall Test

Reliability. The thirty-two-point Nuttall test of oral stereognosis was administered twice (Sessions A and B) to each subject under each experimental condition. Table 3 presents the test-retest error scores and ranks for each subject and the group mean error scores and standard deviations.

Examination of this table reveals figures that are similar in pattern to those derived with the NIDR test. For each condition, the mean error score for Session B was smaller than that for Session A, and the difference between the Session A and Session B means never exceeded two errors under any condition. The differences between the Session A-Session B standard deviations for each of the four conditions were also small and quite similar.

Differences in Session A-Session B error scores of individual subjects were generally smaller for the normal and shield conditions than for the anesthesia and anesthesia-shield conditions. It can be seen in Table 3 that changes of more than three errors from Session A to Session B were made by no subjects under the normal condition and by only two subjects under the shield condition. Changes of this magnitude, however, were made by four subjects under the anesthesia condition and three under the anesthesia-shield condition.

The direction of change in error score for individual subjects was only in general that indicated by the relationship between the mean

TABLE 3

SESSION A AND SESSION B ERROR SCORES, RANKS, MEANS, AND STANDARD DEVIATIONS FOR THE NUTTALL TEST.

Conditions	Session		Subjects 1	2	3	4	5	6	7	$\overline{X}$	σ
Normal	A	score	2	2	2	3	5	0	5	2.71	1.67
		rank	(3)	(3)	(3)	(5)	($6\frac{1}{2}$)	(1)	($6\frac{1}{2}$)		
	B	score	1	0	0	0	3	0	2	.86	1.06
		rank	(5)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	(7)	($2\frac{1}{2}$)	(6)		
Shield	A	score	2	4	2	1	0	0	4	1.86	1.55
		rank	($4\frac{1}{2}$)	($6\frac{1}{2}$)	($4\frac{1}{2}$)	(3)	($1\frac{1}{2}$)	($1\frac{1}{2}$)	($6\frac{1}{2}$)		
	B	score	1	0	0	0	4	1	4	1.43	1.68
		rank	($4\frac{1}{2}$)	(2)	(2)	(2)	($6\frac{1}{2}$)	($4\frac{1}{2}$)	($6\frac{1}{2}$)		
Anes.	A	score	8	12	5	19	19	6	14	11.86	5.38
		rank	(3)	(4)	(1)	($6\frac{1}{2}$)	($6\frac{1}{2}$)	(2)	(5)		
	B	score	10	17	10	16	12	9	6	11.43	3.62
		rank	($3\frac{1}{2}$)	(7)	($3\frac{1}{2}$)	(6)	(5)	(2)	(1)		
Anes.-Shield	A	score	16	20	2	22	21	9	8	14.00	7.15
		rank	(4)	(5)	(1)	(7)	(6)	(3)	(2)		
	B	score	8	14	4	22	18	11	12	12.71	5.57
		rank	(2)	(5)	(1)	(7)	(6)	(3)	(4)		

error scores for Sessions A and B under each condition. Session B error scores were lower than those for Session A for six subjects under the normal condition and four under the shield condition. Under the anesthesia and anesthesia-shield conditions, on the other hand, even though the mean scores were lower for Session B than for Session A in both instances, only three of the seven subjects had lower Session B scores.

Estimation of the group's test-retest reliability by means of Spearman rank correlation coefficients resulted in the following _rhos_: normal, .76; shield, -.10; anesthesia, .39; and anesthesia-shield, .85. Only the coefficients for the normal and anesthesia-shield conditions were significant. The _rho_ of -.10 for the shield condition appears to be attributable to the low error scores, the small error score range, and the marked shift in rank between Sessions A and B of Subjects Two and Five. Despite relatively large error scores and greater score ranges on the two sessions of the anesthesia condition, Subjects Two and Seven shifted ranks sufficiently to depress the rank correlation below the experimental confidence level.

Among Conditions. The sum of each subject's error scores on the two Nuttall tests under each condition was taken as representative of his performance under that condition. These scores and ranks and the group means and standard deviations are presented in Table 4.

It can be seen that the figures for the normal and shield conditions were highly similar, with ranges of zero to eight and one to eight,

TABLE 4

SUMMED SESSION A-SESSION B ERROR SCORES, RANKS, MEANS, AND STANDARD DEVIATIONS FOR THE NUTTALL TEST.

Condition		Subjects							$\bar{x}$	σ
		1	2	3	4	5	6	7		
Normal	score	3	2	2	3	8	0	7	3.57	2.66
	rank	(4½)	(2½)	(2½)	(4½)	(7)	(1)	(6)		
Shield	score	3	4	2	1	4	1	8	3.29	2.25
	rank	(4)	(5½)	(3)	(1½)	(5½)	(1½)	(7)		
Anes.	score	18	29	15	35	31	15	20	23.29	7.61
	rank	(3)	(5)	(1½)	(7)	(6)	(1½)	(4)		
Anes.-Shield	score	24	34	6	44	39	20	20	26.71	12.12
	rank	(4)	(5)	(1)	(7)	(6)	(2½)	(2½)		

means of 3.57 and 3.29, and standard deviations of 2.66 and 2.25, respectively. Only one subject had a score difference between the two conditions of more than two errors, and the direction of error score differences between the normal and shield condition was about equally divided. A Wilcoxon test of the difference between the two sets of scores was not significant.

The mean error scores under the anesthesia and anesthesia-shield conditions were six to seven times larger than those obtained under the normal and shield conditions; a Wilcoxon test of the difference between the pooled normal and shield scores and the pooled anesthesia and anesthesia-shield scores was significant. Individual error scores ranged from fifteen to thirty-five, with a mean of 23.29 and a standard deviation of 7.61, under the anesthesia condition and from six to forty-four, with a mean of 26.71 and a standard deviation of 12.12, under the anesthesia-shield condition. Five of the seven subjects made a greater number of errors under the anesthesia-shield condition than under the anesthesia condition, and the subjects who were at the extremes of the error score range under the former condition were in those positions under the latter. Despite the magnitude of the changes in error score, subjects did not change ranks between the two conditions sufficiently to result in a significant Wilcoxon.

Relationships between the NIDR and Nuttall Tests

The summed Session A-Session B scores and ranks for each subject on the NIDR and Nuttall tests of oral stereognosis are presented in Table 5. It is evident that, despite the difference in possible error score on the two tests (forty for the NIDR, sixty-four for the Nuttall), subjects made a greater number of errors on the NIDR test under three of the four conditions.

Under the normal condition error scores ranged from two to fourteen, with a mean of 7.00, on the NIDR test and from zero to eight, with a mean of 3.57, on the Nuttall test. Six of the seven subjects made from three to seven more errors on the former than on the latter; only Subject Five had a lower score, by six errors, on the NIDR test.

A similar trend can be seen in the scores under the shield condition. Individual error scores ranged from one to twelve and from one to eight for the NIDR and Nuttall tests, respectively, with means of 5.14 and 3.29. Five of the seven subjects made from one to seven more errors on the NIDR than on the Nuttall test. Subject One had identical scores on the two tests, and only Subject Five had a lower score on the NIDR test.

Subject scores under the anesthesia condition were, on the average, higher on the Nuttall than on NIDR test, with ranges of fifteen to thirty-five and nine to thirty-one and means of 23.29 and 20.00, respectively. Three subjects' scores were higher and four lower on the

TABLE 5

SUMMED SESSION A-SESSION B ERROR SCORES, RANKS, MEANS, AND STANDARD DEVIATIONS FOR THE NIDR AND NUTTALL TESTS.

Condition	Test		Subjects							$\bar{x}$	σ
			1	2	3	4	5	6	7		
Normal	NIDR	score	7	7	6	6	2	7	14	7.00	3.30
		rank	(5)	(5)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	(1)	(5)	(7)		
	Nuttall	score	3	2	2	3	8	0	7	3.57	2.66
		rank	($4\frac{1}{2}$)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	($4\frac{1}{2}$)	(7)	(1)	(6)		
Shield	NIDR	score	3	5	5	2	1	8	12	5.14	3.81
		rank	(3)	($4\frac{1}{2}$)	($4\frac{1}{2}$)	(2)	(1)	(6)	(7)		
	Nuttall	score	3	4	2	1	4	1	8	3.29	2.25
		rank	(4)	($5\frac{1}{2}$)	(3)	($1\frac{1}{2}$)	($5\frac{1}{2}$)	($1\frac{1}{2}$)	(7)		
Anes.	NIDR	score	31	21	9	30	9	16	24	20.00	8.07
		rank	(7)	(4)	($1\frac{1}{2}$)	(6)	($1\frac{1}{2}$)	(3)	(5)		
	Nuttall	score	18	29	15	35	31	15	20	23.29	7.61
		rank	(3)	(5)	($1\frac{1}{2}$)	(7)	(6)	($1\frac{1}{2}$)	(4)		
Anes.-Shield	NIDR	score	37	33	10	40	36	22	21	28.43	9.42
		rank	(6)	(4)	(1)	(7)	(5)	(3)	(2)		
	Nuttall	score	24	34	6	44	39	20	20	26.71	12.12
		rank	(4)	(5)	(1)	(7)	(6)	($2\frac{1}{2}$)	($2\frac{1}{2}$)		

NIDR than on the Nuttall test. While error score differences between the two tests under this condition were generally comparable in magnitude to the intertest differences under the other conditions, two subjects had differences as great as thirteen and twenty-two points.

Under the anesthesia-shield condition, error scores ranged from ten to forty, with a mean of 28.43, on the NIDR test and from six to forty-four with a mean of 26.71, on the Nuttall test. Four of the seven subjects made larger error scores on the former than on the latter. Only Subject One had an error score difference that was remarkably different from that of the other subjects under this condition.

Spearman rank correlation coefficients between the NIDR and Nuttall scores under each condition were: normal, -.13; shield, .20; anesthesia, .26; and anesthesia-shield, .88. While only the latter _rho_ was significant at the experimental confidence level, differences of more than two ranks were made by only three subjects under the normal condition and by two subjects under each of the shield and anesthesia conditions. Examination of the individual subject rank differences between the two tests again illustrates the fact that, with an N of 7, changes of several ranks by several subjects are sufficient to depress the rank correlation between the two sets of scores.

Tests of Articulation

The Templin-Darley Test

Reliability. Each subject was administered the fifty-word Templin-Darley articulation test twice (Sessions A and B) under each condition. These articulation error scores and ranks and the group means and standard deviations are presented in Table 6.

The majority of subjects made no articulation errors during either session under the normal and shield conditions. Under the normal condition, no subjects made errors during Session A and only one subject made one error during Session B. Under the shield condition, one subject made one error during Session A and three subjects made one error each during Session B.

At least six of the seven subjects made articulation errors during one of the sessions under the anesthesia and anesthesia-shield conditions. The mean error scores and standard deviations for Session B were smaller than those for Session A in both instances. Differences between Session A-Session B scores for individual subjects exceeded two errors for only two subjects under each condition. Five of the seven subjects made fewer articulation errors during Session B than during Session A under the anesthesia condition. Only two subjects had a lower Session B than Session A score under the anesthesia-shield condition, but the magnitude of these differences was sufficient to result in a lower Session B mean.

TABLE 6

SESSION A AND SESSION B ERROR SCORES, RANKS, MEANS, AND STANDARD DEVIATIONS FOR THE TEMPLIN-DARLEY TEST.

Condition	Session		Subjects 1	2	3	4	5	6	7	$\bar{x}$	σ
Normal	A	score	0	0	0	0	0	0	0	.00	.00
		rank	(4)	(4)	(4)	(4)	(4)	(4)	(4)		
	B	score	0	0	0	0	0	0	1	.14	.35
		rank	(3½)	(3½)	(3½)	(3½)	(3½)	(3½)	(7)		
Shield	A	score	0	0	0	0	0	0	1	.14	.35
		rank	(3½)	(3½)	(3½)	(3½)	(3½)	(3½)	(7)		
	B	score	0	0	1	0	0	1	1	.43	.53
		rank	(2½)	(2½)	(6)	(2½)	(2½)	(6)	(6)		
Anes.	A	score	2	2	4	5	6	2	2	3.29	1.74
		rank	(2½)	(2½)	(5)	(6)	(7)	(2½)	(2½)		
	B	score	3	0	1	1	4	4	1	2.00	1.51
		rank	(5)	(1)	(3)	(3)	(6½)	(6½)	(3)		
Anes.-Shield	A	score	7	2	14	10	5	3	0	5.86	4.79
		rank	(5)	(2)	(7)	(6)	(4)	(3)	(1)		
	B	score	2	4	0	11	6	5	2	4.29	3.33
		rank	(2½)	(4)	(1)	(7)	(6)	(5)	(2½)		

Neither the *rho* for the anesthesia condition, .32, nor that for the anesthesia-shield condition, -.03, was significant. Session A-Session B differences greater than two ranks can be seen for three subjects under the anesthesia condition and for two subjects under the anesthesia-shield condition. The rank differences of Subject Six under the former condition and Subject Three under the latter, were particularly influential in decreasing the correlation coefficients. *Rhos* were not computed for the normal and shield conditions because of the large number of zero scores and low error scores.

Among Conditions. Each subject's summed Session A-Session B error scores on the Templin-Darley test, their ranks, and the group means and standard deviations are presented in Table 7. It can be seen that only one subject made one error under the normal condition and that three subjects made a total of four errors under the shield condition. Means were .14 and .57 and standard deviations .35 and .78 for the two conditions, respectively. No individual score difference between the two conditions exceeded one error.

Each subject made two or more articulation errors under the anesthesia and anesthesia-shield conditions, and the group means were, of course, considerably greater than those for the normal and shield conditions. A Wilcoxon test of the difference between the pooled normal and shield scores and the pooled anesthesia and anesthesia-shield scores was significant. Individual error scores ranged from two to

TABLE 7

SUMMED SESSION A-SESSION B ERROR SCORES, RANKS, MEANS, AND STANDARD DEVIATIONS FOR THE TEMPLIN-DARLEY TEST.

Condition		Subjects							$\bar{x}$	σ
		1	2	3	4	5	6	7		
Normal	score	0	0	0	0	0	0	1	.14	.35
	rank	(3½)	(3½)	(3½)	(3½)	(3½)	(3½)	(7)		
Shield	score	0	0	1	0	0	1	2	.57	.78
	rank	(2½)	(2½)	(5½)	(2½)	(2½)	(5½)	(7)		
Anes.	score	5	2	5	6	10	6	3	5.29	2.42
	rank	(3½)	(1)	(3½)	(5½)	(7)	(5½)	(2)		
Anes.-Shield	score	9	6	14	21	11	8	2	10.14	5.64
	rank	(4)	(2)	(6)	(7)	(5)	(3)	(1)		

ten, with a mean of 5.29 and a standard deviation of 2.42, under the anesthesia condition and from two to twenty-one, with a mean of 10.14 and a standard deviation of 5.64, under the anesthesia-shield condition. Six of the seven subjects made a greater number of errors under the anesthesia-shield than under the anesthesia condition; the magnitude of score differences between the two conditions was two or less for only three of the seven subjects. A Wilcoxon test of the difference between the two sets of scores was significant.

The Rainbow Passage

Reliability. The ninety-eight-word Rainbow passage was recorded twice (Sessions A and B) by each subject under each experimental condition. The number of words in which articulation errors occurred for each subject and the means and standard deviations for the group on the two tests under each condition are presented in Table 8.

It can be seen that a majority of the subjects made no articulation errors during Sessions A or B under either the normal or shield conditions and that the number of individual errors under the anesthesia and anesthesia-shield conditions never exceeded 10 per cent of the possible number of errors on this articulation passage. Except for the normal condition, for which the means were identical, the mean error scores for Session B were again smaller than those for Session A. The differences between the Session A-Session B means were only .15,

TABLE 8

SESSION A AND SESSION B ERROR SCORES, RANKS, MEANS, AND STANDARD DEVIATIONS FOR THE RAINBOW PASSAGE TEST.

Conditions	Session		Subjects							$\bar{x}$	σ
			1	2	3	4	5	6	7		
Normal	A	score	0	1	0	0	0	0	1	.29	.45
		rank	(3)	($6\frac{1}{2}$)	(3)	(3)	(3)	(3)	($6\frac{1}{2}$)		
	B	score	0	0	0	0	0	0	2	.29	.70
		rank	($3\frac{1}{2}$)	($3\frac{1}{2}$)	($3\frac{1}{2}$)	($3\frac{1}{2}$)	($3\frac{1}{2}$)	($3\frac{1}{2}$)	(7)		
Shield	A	score	4	0	0	0	0	1	1	.86	1.35
		rank	(7)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	($5\frac{1}{2}$)	($5\frac{1}{2}$)		
	B	score	0	0	0	0	1	1	3	.71	1.03
		rank	($2\frac{1}{2}$)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	($5\frac{1}{2}$)	($5\frac{1}{2}$)	(7)		
Anes.	A	score	5	3	0	6	3	4	2	3.28	1.83
		rank	(6)	($3\frac{1}{2}$)	(1)	(7)	($3\frac{1}{2}$)	(5)	(2)		
	B	score	4	4	0	4	5	3	2	3.14	1.64
		rank	(5)	(5)	(1)	(5)	(6)	(3)	(2)		
Anes.-Shield	A	score	5	5	7	9	3	8	2	5.57	2.38
		rank	($3\frac{1}{2}$)	($3\frac{1}{2}$)	(5)	(7)	(2)	(6)	(1)		
	B	score	5	2	4	6	7	3	1	4.00	2.00
		rank	(5)	(2)	(4)	(6)	(7)	(3)	(1)		

.14, and 1.57 for the shield, anesthesia, and anesthesia-shield conditions, respectively.

The differences in Session A-Session B scores for individual subjects were also generally small and quite comparable for the four conditions. While only Subjects Two and Seven each made an articulation error during Session A under the normal condition, only the latter subject had an error score during Session B. Intersession differences of greater than two errors occurred for only one subject under the shield condition and for none of the subjects under the anesthesia condition. Four of the seven subjects had a Session A-Session B difference of greater than two misarticulations under the anesthesia-shield condition. The direction of change in individual scores from Session A to Session B was generally divided equally for the normal, shield, and anesthesia conditions, but five of the seven subjects made fewer misarticulations on Session B than on Session A under the anesthesia-shield condition.

Spearman rank correlation coefficients were not computed between the session scores for the normal and shield conditions, because of the large number of zero scores and the low error scores. Rhos of .69 and .28 for the anesthesia and anesthesia-shield conditions, respectively, were not significant, although the former approached the correlation coefficient of .71 required for significance at the .05 level. It can be seen, under the anesthesia condition, that only Subject Five had a Session A-Session B rank difference greater than two ranks. Although five of the seven subjects had differences of one and one-half ranks or less under the anesthesia-shield condition, rank differences of five and three by Subjects Five and Six, respectively, were sufficient with this number of subjects to depress the rank correlation.

Among Conditions. Each subject's summed Session A-Session B articulation errors on the Rainbow passage, their ranks, and the group means and standard deviations under each condition are displayed in Table 9. Inspection of these figures reveals that only two subjects made articulation errors during the normal condition, as compared to four during the shield condition. Means were .57 and 1.57 and standard deviations 1.05 and 1.68 for the two conditions, respectively. Only one individual score difference between the two conditions exceeded two errors. Four of the five subjects who made articulation errors under either or both of the two conditions made a greater number of errors under the shield condition.

The group's mean articulation error scores under the anesthesia and anesthesia-shield conditions can be seen to be remarkably greater than those for the normal and shield conditions. A Wilcoxon matched-pairs signed-ranks test of the difference between the pooled normal and shield scores and the pooled anesthesia and anesthesia-shield scores was significant. Under the anesthesia condition, individual error scores ranged from zero to ten, with a mean of 6.43 and a standard deviation of

TABLE 9

SUMMED SESSION A-SESSION B ERROR SCORES, RANKS, MEANS, AND STANDARD DEVIATIONS FOR THE RAINBOW PASSAGE TEST.

Condition		Subjects 1	2	3	4	5	6	7	$\bar{x}$	σ
Normal	score	0	1	0	0	0	0	3	.57	1.05
	rank	(3)	(6)	(3)	(3)	(3)	(3)	(7)		
Shield	score	4	0	0	0	1	2	4	1.57	1.68
	rank	(6½)	(2)	(2)	(2)	(4)	(5)	(6½)		
Anes.	score	9	7	0	10	8	7	4	6.43	3.16
	rank	(6)	(3½)	(1)	(7)	(5)	(3½)	(2)		
Anes.-Shield	score	10	7	11	15	10	11	3	9.57	3.46
	rank	(3½)	(2)	(5½)	(7)	(3½)	(5½)	(1)		

3. 16; under the anesthesia-shield condition, the range was from three to fifteen, with a mean of 9. 57 and a standard deviation of 3. 46. Five of the seven subjects made a greater number of errors under the anesthesia-shield condition than under the anesthesia condition. The magnitude of the differences between the two conditions was less than two errors for four subjects but, for one subject, was as high as eleven. A Wilcoxon test of the difference between the two sets of scores was not significant.

Relationship between the Templin-Darley and Rainbow Tests

Each subject's summed Session A-Session B error scores and their ranks on the two tests of articulation are compared in Table 10. It can be seen that, despite the difference between the two tests in the number of possible errors (ninety-eight for the Rainbow passage, fifty for the Templin-Darley), subject scores were, on the average, very similar on the two tests under each condition.

Under the normal condition, only one subject made a single error on the Templin-Darley test and only two subjects made a total of four errors on the Rainbow passage. Means were . 14 and . 57 for the two tests, respectively. Under the shield condition, four subjects made no errors on the Templin-Darley and the remaining three made one or two each; on the Rainbow test, three subjects made no errors and the scores of the other four subjects ranged from one to four errors. Means were . 57 and 1. 57 for the two tests, respectively.

TABLE 10

SUMMED SESSION A-SESSION B ERROR SCORES, RANKS, MEANS, AND STANDARD DEVIATIONS FOR THE TEMPLIN-DARLEY AND RAINBOW PASSAGE TESTS.

Condition	Test		Subjects 1	2	3	4	5	6	7	$\bar{x}$	σ
Normal	Templin-Darley	score	0	0	0	0	0	0	1	.14	.35
		rank	($3\frac{1}{2}$)	($3\frac{1}{2}$)	($3\frac{1}{2}$)	($3\frac{1}{2}$)	($3\frac{1}{2}$)	($3\frac{1}{2}$)	(7)		
	Rainbow	score	0	1	0	0	0	0	3	.57	1.05
		rank	(3)	(6)	(3)	(3)	(3)	(3)	(7)		
Shield	Templin-Darley	score	0	0	1	0	0	1	2	.57	.78
		rank	($2\frac{1}{2}$)	($2\frac{1}{2}$)	($5\frac{1}{2}$)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	($5\frac{1}{2}$)	(7)		
	Rainbow	score	4	0	0	0	1	2	4	1.57	1.68
		rank	($6\frac{1}{2}$)	(2)	(2)	(2)	(4)	(5)	($6\frac{1}{2}$)		
Anes.	Templin-Darley	score	5	2	5	6	10	6	3	5.29	2.42
		rank	($3\frac{1}{2}$)	(1)	($3\frac{1}{2}$)	($5\frac{1}{2}$)	(7)	($5\frac{1}{2}$)	(2)		
	Rainbow	score	9	7	0	10	8	7	4	6.43	3.16
		rank	(6)	($3\frac{1}{2}$)	(1)	(7)	(5)	($3\frac{1}{2}$)	(2)		
Anes.-Shield	Templin-Darley	score	9	6	14	21	11	8	2	10.14	5.64
		rank	(4)	(2)	(6)	(7)	(5)	(3)	(1)		
	Rainbow	score	10	7	11	15	10	11	3	9.57	3.46
		rank	($3\frac{1}{2}$)	(2)	($5\frac{1}{2}$)	(7)	($3\frac{1}{2}$)	($5\frac{1}{2}$)	(1)		

Subject scores under the anesthesia condition were generally higher on the Rainbow than on the Templin-Darley test, with ranges of two to ten and zero to ten and means of 6.43 and 5.29, respectively. Five subjects's scores were higher on the Rainbow than on the Templin-Darley test. The magnitude of score differences for the seven subjects ranged from zero to five.

Under the anesthesia-shield condition, articulation errors ranged from two to twenty-one, with a mean of 10.14, on the Templin-Darley test and from three to fifteen, with a mean of 9.57, on the Rainbow test. Four of the seven subjects made greater error scores on the Rainbow than on the Templin-Darley test, all of three errors or less, but the large differences between the two tests in the opposite direction for Subjects Three and Four resulted in a lower group mean for the Rainbow passage.

Spearman rank correlaticn coefficients were not computed between the subject scores under the normal and shield conditions because of the small error scores and the large number of tied scores. Rhos of .48 and .82 were obtained between the two tests under the anesthesia and anesthesia-shield conditions, respectively; only the latter was statistically significant. Although under the anesthesia condition three subjects had Session A-Session B differences of two and one-half ranks, no subject exceeded this difference. Under the anesthesia-shield condition, three subjects had differences from one-half to one and one-half ranks, and three subjects each had identical ranks between the two tests.

Relationships between the Tests of Oral Stereognosis and the Tests of Articulation

Subject scores and ranks on the NIDR and Nuttall tests of oral stereognosis may be compared with those on the Templin-Darley and Rainbow passage tests of articulation in Table 11. Inspection of this table reveals that, with the exception of the tests of oral stereognosis under the shield condition, the mean error scores for all four tests increased over conditions of increasing sensory deprivation. Under the normal condition, the mean for the NIDR test was 7.00, that for the Nuttall test was 3.57, and those for the Templin-Darley and Rainbow tests were .14 and .57, respectively. Under the shield condition, the means for both measures of oral stereognosis decreased, to 5.14 for the NIDR test and 3.29 for the Nuttall test, and those for the single-word and paragraph tests of articulation increased, to .57 and 1.57, respectively. The mean error scores for all four tests increased markedly under the anesthesia condition, although greater proportionately for the two tests of articulation. The NIDR and Nuttall means under this condition were 20.00 and 23.29, respectively, while the mean for the Templin-Darley test was 5.29 and that for the Rainbow test was 6.43. All four mean error scores also increased under the anesthesia-shield condition, but again disproportionately. The mean

TABLE 11

SUMMED SESSION A-SESSION B ERROR SCORES, RANKS, MEANS, AND STANDARD DEVIATIONS FOR THE NIDR, NUTTALL, TEMPLIN-DARLEY, AND RAINBOW TESTS.

Condition	Test		Subjects							$\bar{x}$	σ
			1	2	3	4	5	6	7		
Normal	NIDR	score	7	7	6	6	2	7	14	7.00	3.30
		rank	(5)	(5)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	(1)	(5)	(7)		
	Templin-Darley	score	0	0	0	0	0	0	1	.14	.35
		rank	($3\frac{1}{2}$)	($3\frac{1}{2}$)	($3\frac{1}{2}$)	($3\frac{1}{2}$)	($3\frac{1}{2}$)	($3\frac{1}{2}$)	(7)		
	Rainbow	score	0	1	0	0	0	0	3	.57	1.05
		rank	(3)	(6)	(3)	(3)	(3)	(3)	(7)		
	Nuttall	score	3	2	2	3	8	0	7	3.57	2.66
		rank	($4\frac{1}{2}$)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	($4\frac{1}{2}$)	(7)	(1)	(6)		
Shield	NIDR	score	3	5	5	2	1	8	12	5.14	3.81
		rank	(3)	($4\frac{1}{2}$)	($4\frac{1}{2}$)	(2)	(1)	(6)	(7)		
	Templin-Darley	score	0	0	1	0	0	1	2	.57	.78
		rank	($2\frac{1}{2}$)	($2\frac{1}{2}$)	($5\frac{1}{2}$)	($2\frac{1}{2}$)	($2\frac{1}{2}$)	($5\frac{1}{2}$)	(7)		
	Rainbow	score	4	0	0	0	1	2	4	1.57	1.68
		rank	($6\frac{1}{2}$)	(2)	(2)	(2)	(4)	(5)	($6\frac{1}{2}$)		
	Nuttall	score	3	4	2	1	4	1	8	3.29	2.25
		rank	(4)	($5\frac{1}{2}$)	(3)	($1\frac{1}{2}$)	($5\frac{1}{2}$)	($1\frac{1}{2}$)	(7)		

TABLE 11 - CONTINUED.

Condition	Test		Subjects 1	2	3	4	5	6	7	$\bar{x}$	σ
Anes.	NIDR	score	31	21	9	30	9	16	24	20.00	8.07
		rank	(7)	(4)	(1½)	(6)	(1½)	(3)	(5)		
	Templin-Darley	score	5	2	5	6	10	6	3	5.29	2.42
		rank	(3½)	(1)	(3½)	(5½)	(7)	(5½)	(2)		
	Rainbow	score	9	7	0	10	8	7	4	6.43	3.16
		rank	(6)	(3½)	(1)	(7)	(5)	(3½)	(2)		
	Nuttall	score	18	29	15	35	31	15	20	23.29	7.61
		rank	(3)	(5)	(1½)	(7)	(6)	(1½)	(4)		
Anes.-Shield	NIDR	score	37	33	10	40	36	22	21	28.43	9.42
		rank	(6)	(4)	(1)	(7)	(5)	(3)	(2)		
	Templin-Darley	score	9	6	14	21	11	8	2	10.14	5.64
		rank	(4)	(2)	(6)	(7)	(5)	(3)	(1)		
	Rainbow	score	10	7	11	15	10	11	3	9.57	3.46
		rank	(3½)	(2)	(5½)	(7)	(3½)	(5½)	(1)		
	Nuttall	score	24	34	6	44	39	20	20	26.71	12.12
		rank	(4)	(5)	(1)	(7)	(6)	(2½)	(2½)		

for the NIDR test increased by more than one-third, to 28.43, but that for the Nuttall test by only one-eighth, to 26.71. The mean for the Templin-Darley test almost doubled, to 10.14, and that for the Rainbow passage increased by approximately one-half, to 9.57.

The low error scores and large number of tied scores on the tests of articulation under the normal and shield conditions precluded meaningful statistical analysis of the relationships between these tests and the tests of oral stereognosis under these conditions. It can be seen, however, under the normal condition, that the rank differences between each test of oral stereognosis and each test of articulation were small and similar in magnitude. Differences greater than two ranks were obtained by only one subject between the NIDR and Templin-Darley tests, by no subjects between the NIDR and Rainbow tests, and by two subjects each between the Nuttall and Templin-Darley and the Nuttall and Rainbow tests. Rank differences under the shield condition tended to be somewhat higher than those under the normal condition. Although no subject's rank difference between the NIDR and Templin-Darley tests was greater than two ranks, four subjects had rank differences greater than two between the NIDR and Rainbow tests, four between the Nuttall and Templin-Darley tests, and three between the Nuttall and Rainbow tests.

Under the anesthesia condition, extensive rank differences were evident between the NIDR and Templin-Darley tests, with only one subject presenting a rank difference of less than two; the Spearman rank correlation coefficient of -.27 was not significant. Differences in rank between the NIDR and Rainbow tests were relatively small. Five of the seven subjects had differences of one rank or less, but Subjects Five and Seven had differences of three ranks or more, and the rho of .57 was not significant. Similar rank relationships were evident in a comparison of the Nuttall test with the two tests of articulation. Only two subjects exceeded a rank difference of two between the Nuttall and Templin-Darley tests and only one subject between the Nuttall and Rainbow tests, but neither of the respective coefficients of .22 and .63 was significant.

Differences in rank between each test of oral stereognosis and each test of articulation were similar under the anesthesia-shield condition. Three subjects obtained identical intertest ranks and three had differences of two ranks or less between the NIDR and Templin-Darley tests. Subject Three, however, had a difference of five ranks, and the rho between the two tests was only .39. Rank differences between the NIDR and Rainbow tests were two or less for four subjects and two and one-half for each of two other subjects. Subject Three again had the largest difference, four and one-half ranks, and the correlation coefficient of .29 was not significant. Five subjects had rank differences of one and one-half or less between the Nuttall and Templin-Darley tests, but one subject had a difference of three ranks and another (Subject Three) a difference of five ranks, and the rho of .33 was not significant. Rank differences between the Nuttall and Rainbow tests in excess of two ranks were presented by four subjects, with a resultant rho of .13.

Examination of Table 11 reveals only few patterns of consistency of error score and/or rank by individual subjects on the four tests under the four conditions. Particularly notable, however, are the contrasts in score and rank performances by Subjects Four and Seven under the nonanesthesia and anesthesia conditions. Subject Four made no errors on either articulation test and relatively few errors on the tests of oral stereognosis under the normal and shield conditions, with ranks on the four tests under the two conditions ranging from one and one-half to four and one-half. This subjects's error scores increased greatly under the anesthesia and anesthesia-shield conditions, however, such that, with only two exceptions, he ranked seventh on all four tests under these conditions. Subject Seven, on the other hand, had ranks of six to seven on the four tests under the normal and shield conditions but, with two exceptions, ranks of one or two under the anesthesia and anesthesia-shield conditions. While this subject's oral stereognostic errors did increase under the two anesthesia conditions, his articulation scores were remarkably similar under each of the four conditions. It is apparent that Subject Seven's change in ranks between the nonanesthesia and anesthesia conditions is attributable to the fact that the other subjects made relatively fewer errors under the former conditions and relatively more errors under the latter.

CHAPTER V

DISCUSSION

Tests of Oral Stereognosis

Reliability

The data presented in Chapter IV indicate that the test-retest reliability of both the NIDR and Nuttall tests of oral stereognosis is relatively high. Under each condition, the mean error scores for Session A and Session B were quite similar, the difference between them never exceeding two errors. The Session A-Session B differences for the majority of individual subjects were generally two or less for the NIDR test and three or less for the Nuttall test under each condition.

Significant correlation coefficients were obtained for the Nuttall test under the normal and anesthesia-shield conditions and for the NIDR test under the anesthesia and anesthesia-shield conditions. The *rhos* computed for the Nuttall test under the shield and anesthesia conditions and for the NIDR test under the normal and shield conditions were -.10, .39, .51, and .64, respectively, with the latter approaching the .05 level of confidence. These lower coefficients appear to be primarily attributable to limited ranges of errors, low error scores, and/or marked shifts in rank by one or two subjects.

While the differences between the Session A and Session B means were small, the Session B means for both the Nuttall and NIDR tests were lower than those for Session A under each condition, suggesting the presence of a practice effect. Under the normal condition, six of the seven subjects had lower Session B than Session A error scores on both tests. Under the shield, anesthesia, and anesthesia-shield conditions, however, approximately half of the subjects obtained either identical scores during Session A and Session B or made more errors during Session B. It is evident that the lower Session B means for these latter three conditions were due to the performances of only half the subjects.

The improvement in NIDR identification under the normal condition is in agreement with the findings of Carpe, Dalinsky, Ritchie, and Rowland (24), who utilized the same material in two tests of thirty primary school children. Although their investigation was designed to determine the effects of teaching upon oral stereognosis following an initial test session, the test-retest data reported indicate an improvement in mean score from first to second test session of between one and two errors. Other previous studies have not reported test-retest performances, suggesting that the findings of such researchers as McDonald and Aungst (24), Grossman (16), Wegener (41), Hochberg *et al*, (19), and Blanchard (4), may be open to reinterpretation in light of this apparent learning effect. Perhaps the degree of test-retest reliability of tests of oral stereognosis varies with such factors as the age, intelligence, oral sensory integrity, sophistication, and articulation abilities of the subjects.

Among Conditions

The results of this study indicate that the subjects performed similarly on the two tests of oral stereognosis under the experimental conditions, although the pattern of mean scores over the four conditions suggests that the twenty-point NIDR test was more difficult than the thirty-two point Nuttall test. It may be speculated that fewer errors were made on the Nuttall test because its items are larger and present grosser differences among a limited number of shapes and edges than those on the NIDR test. The ratio of edge errors to shape errors on the Nuttall test was approximately three to one under each condition. Under the normal and shield conditions, a majority of the errors made on the Nuttall test occurred on identification of the large sawtooth edge of Items D, H, L, and P (See Figure 2, Appendix). On the NIDR test, a majority of the errors made were on items which were similar in shape, such as Items Three and Four, Nine and Ten, and Fourteen, Fifteen, and Twenty (See Figure 1, Appendix). Under the anesthesia and anesthesia-shield conditions, no patterns of relatively greater identification error were evident for any shape on the NIDR test or for any shape or edge on the Nuttall test.

The mean error scores for both the NIDR and Nuttall tests were lower under the shield condition than under the normal condition, although the decrease for the Nuttall test was smaller and not significant. The direction of this error difference was unexpected, since logic would seem to dictate that placement of the shield would have an adverse rather than a beneficial effect upon item identification. The reasons underlying this improvement in oral stereognosis with placement of the palatal shield are difficult to explain; perhaps the shield altered the subjects' perceptual field sufficiently to cause them to focus more intently upon lingual sensation than under the normal condition. In any event, these data indicate that the tongue functions with equal or greater facility in the identification of oral stereognostic forms with or without sensory assistance from the palate.

The results noted here for the NIDR test do not support those of Mihacs (24), who reported no difference in the oral stereognosis of twenty college students required to identify the twenty NIDR forms, plus five three-dimensional items, under normal and shield conditions. This contradiction may be due to differences between the two studies in the size of the samples, variations in shielding techniques, or subject sampling. On the other hand, these findings do agree with those of Hochberg, Kabcenell, and Silverman (19), who used cubes of various size and surface molding to test seven cleft palate subjects ranging in age from thirteen to fifty years. These investigators found significantly lower error scores for shape and a trend to lower error scores for surface identification following the placement of the subjects' prosthetic appliances in contrast to a condition with the appliance removed. They suggested that perhaps this difference occurred because the surgically-repaired palates of these subjects presented abnormalities which hinder item identification and which were overcome by the palatal prosthesis, giving them " . . . a feeling of oral facility."

The mean error scores on both tests of oral stereognosis were remarkably higher under the anesthesia condition than under the normal condition, underscoring the critical role that lingual taction-kinesthesia plays in oral stereognosis. That the error score difference between the two conditions was both absolutely and proportionately larger for the Nuttall test suggests that it is more sensitive to lingual sensory deprivation and/or less sensitive to palatal taction than the NIDR test.

In light of the findings of Grossman (16), whose subjects found ten varied stereognostic forms "indistinguishable" under bilateral mandibular-nerve anesthesia, it might have been anticipated that most items on the NIDR and Nuttall tests would be incorrectly identified under such a condition in this investigation. This was not the case, however, for an average of 50 per cent of the NIDR and 63 per cent of the Nuttall identifications were correct under the anesthesia condition. Since the same type of anesthetization technique was used in the two studies, the difference in results appears to be due primarily to test materials and subject selection.

The mean error scores for both the NIDR and Nuttall tests were higher under the anesthesia-shield than under the anesthesia condition, although proportionately more so for the former test. Identification of the NIDR items, therefore, seemed to be more adversely affected than identification of the Nuttall items by palatal shielding. Since, it will be recalled, error scores on both tests were lower under the shield than under the normal condition, it is evident that the effects upon oral stereognosis of the deprivation of palatal taction is dependent on the presence of lingual sensitivity.

The results of this study show that subjects varied in their performance on the tests of oral stereognosis over the experimental conditions. For example, Subject Four had few errors under the normal and shield conditions, but was among those subjects with the most errors under the two conditions utilizing anesthesia. Subject Seven, on the other hand, performed in a contradictory manner, making the most errors under the normal and shield conditions but improving in performance, in relation to other subjects, as oral sensory disruption increased. Considering the homogeneity of subjects and experimental procedures of this investigation, it may be speculated that these variations were due to subtle differences in such factors as the subjects' neurological integrity, ability to use minimal sensations, and intrinsic motivation.

Tests of Articulation

Reliability

Both the Templin-Darley and Rainbow tests of articulation proved to be reliable under each of the experimental conditions. As expected, a majority of the subjects made no errors on either test during Session A or Session B under the normal condition and over half of the subjects made no errors on either test under the shield condition. Both the individual and mean intersession differences attest to the similarity of the subjects' performance during the two sessions under these conditions. While a greater number of articulation errors occurred for all subjects under the anesthesia and anesthesia-shield conditions, the mean error scores for Session A and Session B differed only by approximately one and one-half errors or less for both the Templin-Darley and the Rainbow tests. Intersession differences for individual subjects under both conditions were also small for both tests. Although the Session B means were slightly lower than those for Session A for both tests under the anesthesia and anesthesia-shield conditions and for the Rainbow passage under the shield condition, the low individual and mean error scores and even smaller individual and mean score differences between sessions make it difficult to determine whether or not a true practice effect existed.

Among Conditions

Since these subjects presented normal articulation, it was not surprising that only few errors were made on both the Templin-Darley and Rainbow tests under the normal condition. Among the errors was the substitution of /ŋ/ for the medial /n/ in onion and the omission of /d/ in legend, both considered pronunciation differences since these phonemic problems were not present in other words. The placement of the palatal shield resulted in a few distortions on sibilant phonemes by several subjects, but the elimination of palatal taction, in the presence of intact lingual feedback, did not seem to have a significant effect on articulation skills as measured by these two tests.

The increase in articulation errors under the two conditions utilizing anesthesia agrees with the findings reported by Guttman (18), Weber (40), Ringel and Steer (31), and Schleisser and Coleman (33). These results offer further support to the contention of Van Riper and Irwin (39) that oral taction-kinesthesia plays an important and critical role in the monitoring of speech articulation in adults. The present study, in addition, made it possible to compare articulation following bilateral mandibular anesthesia both with and without intact palatal taction. The increase in articulation errors on both tests from the anesthesia to the anesthesia-shield condition suggests that palatal taction does contribute to the monitoring of articulation skills if lingual sensations are eliminated. Under the anesthesia and anesthesia-shield conditions, a majority of the misarticulations were either distortions of sibilant phonemes or final omissions.

Individual subjects varied in their articulatory ability across the four conditions, suggesting that some individuals compensate far more adequately than others under conditions of oral sensory deprivation. Subject Seven, for example, presented essentially the same number of articulation errors on both tests under each of the four conditions, while Subject Four made no errors on either test under the normal and shield conditions but was among those with the greatest number of errors on both tests under the two anesthesia conditions.

Relationships between the Tests of Oral Stereognosis and the Tests of Articulation

A comparison of the performances of the subjects on the oral stereognostic and articulation tests under conditions of increasing oral sensory deprivation indicates a generally positive relationship between speech articulation and oral stereognostic skills. The low error scores under the normal and shield conditions on both the Templin-Darley and Rainbow tests makes it difficult to compare either meaningfully with the two tests of oral stereognosis. It is apparent, however, that subjects with normal articulation are not able to identify correctly all forms on either the Nuttall or NIDR tests. The placement of the palatal shield resulted in less oral stereognostic errors but more articulation errors indicating that the elimination of palatal taction effects these skills differently if lingual sensory feedback is intact.

It was evident that lingual sensation does contribute significantly to both articulation and oral stereognosis, since the number of errors on both kinds of tests increased markedly under anesthesia. The additional increase in errors on all tests from the anesthesia to anesthesia-shield condition suggests that palatal taction does contribute sensory cues both for the monitoring of articulation and for the identification of oral stereognostic forms.

While these results indicate that articulation and oral stereognosis are affected similarly by increasing oral sensory deprivation, the nonsignificant rhos obtained for the comparison of each test of oral stereognosis with each test of articulation shows that the rank correlation between the subjects' performances on these tests is not high. In several instances, to be sure, individual subjects performed remarkably similarly on the two tests of oral stereognosis and on the two tests of articulation over the four conditions, as in the previously discussed examples of Subjects Four and Seven. Generally, however, a subject's performance on either of the tests of oral stereognosis was not specifically predictive of his performance on either test of articulation.

Sources of Possible Error and Suggestions for Further Research

The results of this experiment must, of course, be interpreted in the light of factors, over which the investigator had no control, which may have influenced subject performances in speech articulation and/or oral stereognosis.

The effectiveness of anesthetization of the mandibular nerve to eliminate lingual taction-kinesthesia may not be equivalent for all subjects. Although all subjects in this study were completely anesthetized according to clinical dental standards, it can be speculated that the effects of bilateral mandibular-nerve anesthetization vary sufficiently to allow some subjects to profit more than others from sensory cues from ancillary musculature and structures. Moreover, although the anesthetization technique used in this investigation should not interfere with the motor functioning of the tongue and mandible, the possibility of minimal neuromotor disturbances in certain subjects cannot be completely discounted. Additional controls over the extent and degree of oral sensory deprivation and the motor functioning of the oral musculature should be considered in future studies of this kind.

Variations in the height and width of the palatal vault among the subjects may also have affected item identification. Some of the forms from each of the tests of oral stereognosis could be manipulated by some subjects in the maxillary arch in such a manner as to provide clues about shape; other subjects were unable to do this, however, because of limitations in palatal conformation. A study of the contour of the palate as a variable in oral form identification under mandibular anesthesia may be warranted.

The highly selective population used in this experiment may have had a significant effect upon the results obtained. All subjects had completed at least one year of graduate study in speech pathology or audiology and had more than average knowledge of the motor and sensory functioning of the speech mechanism. This may have contributed to their skill in utilizing minimal cues for the experimental tasks over the conditions of increasing sensory deprivation. It may be speculated that greater error scores in both articulation and oral stereognosis, and perhaps different relationships between these tests, would be obtained with less sophisticated adult subjects.

The use of an N of 7 appears to be another factor affecting results. With this small a sample, the performance of one or two subjects was sufficient to depress the rank correlation coefficients, so as to suggest a lack of relationship between two sets of scores which were otherwise similar.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The contribution of oral sensory feedback to speech articulation has received increasing research attention in recent years, primarily through investigations of the oral stereognostic abilities of various subject samples and evaluations of articulation under conditions of oral anesthesia. These studies suggest that oral stereognosis is deficient in speech-handicapped subjects and that articulation skills diminish under oral anesthesia. Information on subject performances on different tests of oral stereognosis, however, and on the effects of oral anesthesia on oral stereognosis, and on the relationships between oral stereognostic and articulatory skills under conditions of increasing sensory deprivation is lacking. The present experiment was designed to provide objective data regarding these factors.

Seven adults, four males and three females between the ages of twenty-one and thirty years, all with normal hearing and speech and negative neurological histories, served as subjects in this study. Each subject was administered, on two separate occasions, the National Institute of Dental Research (NIDR) and Nuttall tests of oral stereognosis and the Templin-Darley Screening and Rainbow passage tests of articulation under four experimental conditions: normal, shield, anesthesia, and anesthesia-shield. Subjects wore a permanent acrylic palatal shield under the shield and anesthesia-shield conditions; anesthesia was achieved by means of bilateral intraoral injections of Xylocaine 2% to the mandibular branches of the Trigeminal nerve. Subject performance was quantified on the basis of the number of incorrect form identifications on each test of oral stereognosis and of the number of words which contained one or more incorrect phonemes on each recorded test of articulation.

The test-retest results of this investigation indicated a relatively high temporal reliability for both tests of oral stereognosis and both tests of articulation under each of the four experimental conditions. Differences between the mean error scores for Session A and Session B in no instance exceeded two errors for any test, and intersession score differences for individual subjects, while variable, were generally small on all tests under all conditions. Spearman rank correlation coefficients were also used to estimate the test-retest reliability of the tests of oral stereognosis under all conditions and the tests of articulation under the two anesthesia conditions; correlations were not computed for the two articulation tests under the nonanesthesia conditions because of the large number of zero scores. Coefficients were significant for the NIDR test under the anesthesia and anesthesia-shield conditions. The remaining <u>rhos</u>, with only two exceptions, were positive but did not achieve significance, apparently because of the small error scores and ranges. On the tests of oral stereognosis, the group error score means for Session B were lower than those for Session A under each of the four conditions, suggesting the presence of a practice effect. This relationship was also evident between the Session A-Session B means for the two tests of articulation, except for the Rainbow passage under the normal condition and the Templin-Darley test under the normal and shield conditions, on which only few articulation errors occurred.

This study also reveals that the scores on the two tests of oral stereognosis were similar in magnitude and pattern under the four experimental conditions. The means obtained for both the NIDR and Nuttall tests under the shield condition were smaller than those obtained under the normal condition, suggesting that deprivation of palatal taction results in improved oral stereognosis when lingual sensation is intact. The mean error scores on both the NIDR and Nuttall tests under the anesthesia conditions were significantly higher than those under the nonanesthesia conditions, clearly indicating the role of oral sensory feedback in oral stereognosis. Individual and mean scores on both tests were also notably higher under the anesthesia-shield than under the anesthesia condition. The elimination of palatal taction in the presence of mandibular-nerve anesthesia, therefore, had a detrimental effect upon oral stereognosis, in contrast to that evident in the comparison of the scores for the normal and shield conditions. Somewhat surprisingly, under both anesthesia conditions, most subjects were able to identify more than one-third of the items on both tests of oral stereognosis, suggesting the use of ancillary sensory cues in oral form identification.

A majority of the subjects made no articulation errors on the Templin-Darley and Rainbow passage tests under the normal and shield conditions. A greater number of articulation errors occurred on both tests under the latter condition, however, and palatal shielding was judged to have a detrimental effect upon articulation while lingual sensation was intact. With the introduction of mandibular anesthesia, both individual and mean error scores increased significantly on both tests of articulation. A further increase in error scores occurred on both tests with the addition of palatal shielding to anesthesia, suggesting that palatal taction contributes to the maintainence of speech articulation when lingual sensory feedback is absent.

Because of the high number of zero scores on the Templin-Darley and Rainbow tests under the normal and shield conditions, a comparison of subject performance on the tests of articulation and tests of oral stereognosis under these conditions was not undertaken. Under the anesthesia and anesthesia-shield conditions, however, individual and mean error scores increased similarly for all four tests. No rank correlation coefficient computed between either test of oral stereognosis and either test of articulation under these two conditions was significant.

In light of the results of this investigation, the following conclusions appear warranted:

1. The test-retest reliability of tests of oral stereognosis and tests of articulation under conditions of increasing oral sensory deprivation is generally high.

2. The elimination of palatal taction appears to improve oral stereognosis but to have a detrimental effect upon speech articulation if lingual feedback is intact.

3. The elimination of palatal taction in the presence of lingual anesthesia, however, causes an increase in both oral stereognostic and articulation errors.

4. Lingual sensory feedback plays a major role in both oral form identification and speech articulation. The deprivation of sensory feedback from the tongue both without and with palatal taction causes a marked increase in errors on both tests of oral stereognosis and articulation.

5. Although errors of both oral stereognosis and articulation increase under conditions of oral sensory deprivation, a subject's performance on either test of oral stereognosis does not appear to be predictive of his performance on either test of articulation.

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APPENDIX

Figure 1.---The National Institute of Dental Research (NIDR) Test of Oral Stereognosis

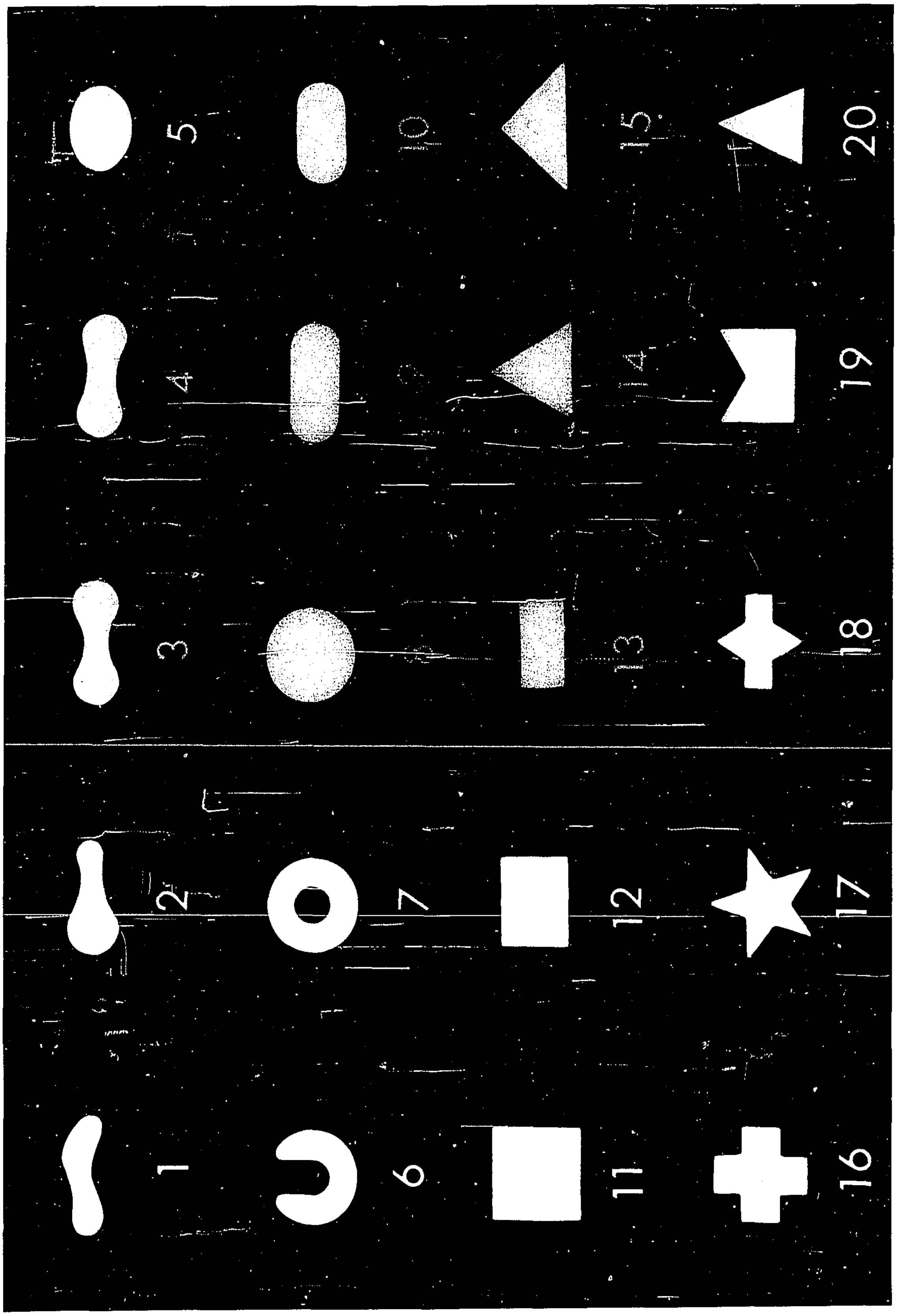
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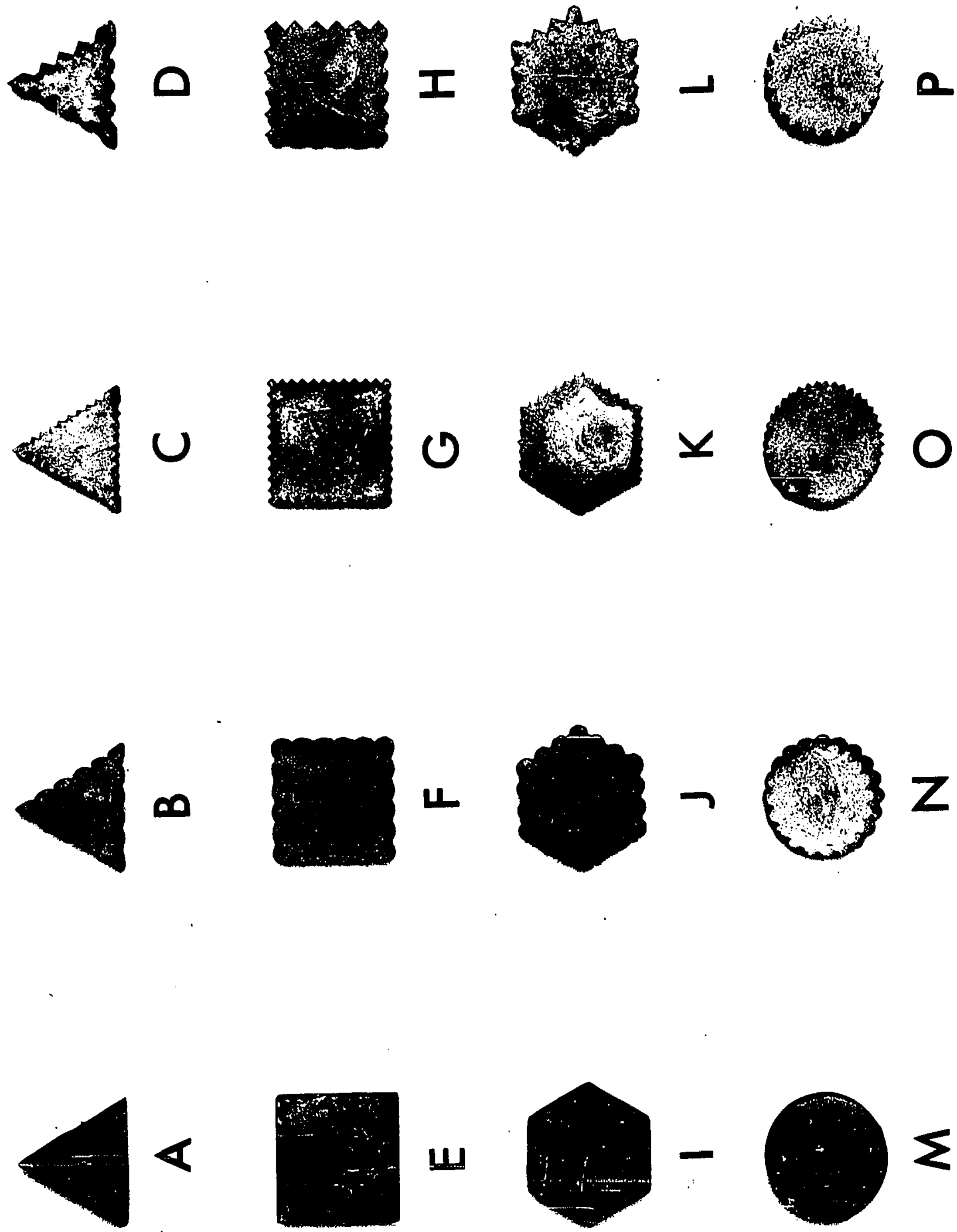
Figure 2.---The Nuttall Test of Oral Stereognosis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