

A COMPARISON OF METHODS
FOR TESTING ORAL STEREOGNOSIS

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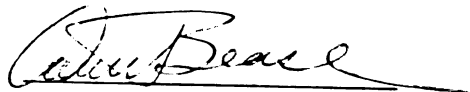


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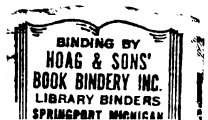
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ABSTRACT

A COMPARISON OF METHODS FOR TESTING ORAL STEREOGNOSIS

By

Ida Annie Torrans

A recent method of studying oral sensory phenomena has been through the use of plastic geometric forms for determining recognition of shape, or oral stereognosis.

This study compared three aspects of testing oral stereognosis; form set, form retention time, and response type. Four sets of forms were compared: (1) 20 geometric shapes developed by the National Institute of Dental Research (NIDR); (2) ten forms selected from the NIDR 20 by McDonald and Aungst; (3) ten forms selected from the NIDR 20 by Ringel and associates; and (4) five forms developed at Pennsylvania State University. Two form retention times were compared: (1) a five second limit on the time the subject retained the form in his mouth and, (2) unlimited time. Two answer types were compared: (1) matching a form in the mouth to a chart containing an outline of all forms in a set and, (2) making a same-different judgment on successively presented pairs. Forty young adults with normal articulation, language abilities, and hearing were presented the 16 possible

experimental conditions. Eight combinations involved the point to outline response. For these, each form of a set was presented individually. Subjects matched the form to an outline on a chart containing outlines of all forms in the set being used. Eight combinations involved a same-difference judgment on a pair of forms presented successively. For each form set, every form was combined with itself and every other form. For each of the two ten-form sets this gave 55 pairings. For each of those two sets, ten of the 55 pairings were repeated, giving a total of 65 pairs presented. For the set containing 20 forms, 210 pairings were possible. Fifty-five of these were randomly selected for presentation. Ten of these 55 were repeated, giving a total of 65 pairs presented. For the five form set 15 pairings were possible; five were repeated, giving a total of 20 pairs presented.

Results indicated significant differences in percentage of errors ($p < 0.0005$) for the factors of form set and answer type. Significant interactions were found for the combinations of form set and answer type ($p < 0.0005$) and form set, answer type, and form retention time ($p < 0.029$). The four Penn State form combinations proved to be easiest. The four most difficult combinations were the two Ringel and the two NIDR 20 sets when combined with the point to outline response and either time limit.

For the Ringel form set, the shorter of the two flat-edged ovals was the most difficult single presentation; the

two biconcaves were the most difficult pair. For the McDonald and Aungst form set, the cross with the two pointed and two rectangular arms and the standard cross were the most difficult single presentations; the pair composed of these two forms was the most difficult pair. For the NIDR form set, the longer of the two flat-sided ovals was the most difficult single presentation; and the two biconcaves were the most difficult pair.

It was concluded that previous findings of correlation or no correlation between oral stereognostic test results and other measures of oral sensation or of articulation may have been the result of interactions between factors involved in testing and may have to be reconsidered. It was also concluded that since the defining attributes of oral sensory categories are not known, further research on sensory bases for categorization is needed before valid conclusions can be drawn about comparisons within and across categories.

The four combinations of factors with the greatest potential for current clinical application were discussed.

Accepted by the faculty of the Department of Audiology and Speech Sciences, College of Communication Arts, Michigan State University, in partial fulfillment of the requirements for the Doctor of Philosophy degree.

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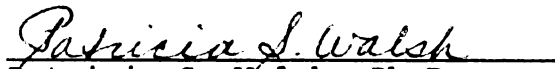
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CHAPTER I

INTRODUCTION

Recent studies of human oral sensory functions have used a wide variety of methods to test specific sensory abilities. The most common testing method has been to ask a subject to identify the shape of a plastic geometric form placed in his mouth. To date however, there has been very little agreement among researchers concerning the number and kind of geometric shapes to be used, the presence or absence of time limits, or the type of response requested from the subject (see Table 1). This study sought to determine whether or not any significant difference existed in the number of errors made by normal adult subjects when each subject responded to four different sets of forms, two time conditions, and two answer conditions, in all possible combinations.

Relevance to Speech Pathology

One of the ways in which speech pathologists have traditionally described the sounds of a language has been in terms of the physiological processes necessary to produce them. The study of the anatomy, physiology, and neurology

Table 1. Methodologies in testing oral stereognosis with geometric forms. (NA = Not applicable; NG = Not given)

Study	Form Set	Attachment	Time	Manipulation	Response	Size	Answer	Subjects
Class (1956)	Penn State		No limit	No manipulation	Same-different	Match outline	Match picture	Told correct or not
	NIDR 10	With			Match drawing	Match object	Constant	Not told
Woodford (1964)	NIDR 20	Without	Time in mouth limited	Manipulation	Match 1 of 5 outlines	Varied		
	Other	Flows or thread	Time between pairs limited					
Augst (1965)								20 each cer. pal. artic. stutter, normal
								17 nor., 18 malocclusion teenagers, 12 neuro. hand., 24 adults with dentures, 24 normal teeth
								80 K and 1st grade
								athetoid c.p.
Solomon (1965)								42 cleft pal. 6-45 yrs.
Mason (1967)	I							30 normal 2 types anesth.
	II							normal and disordered teens
Moser et al. (1967)		NA						normal 18-35 years
		NA						25 aphasics
								61 oral deaf 10 manual deaf 46 blind
								20 21-42 years
Shelton, Arndt, Heatherington, (1967)								20 adults
								10 grad stu. 26 1st 66 3rd
								76 5-8 yr. old
								20 nor., 20 artic. adults
Locke (1968b and 1969)								30 1st gr., 30 3rd., 30 adult
Ringel, Burk, and Scott (1968 and 1970)								100 9 yrs., 100 adults
Arndt et al. (1970)								
Arndt, Elbert, and Shelton (1970)								

continued

Table 1--continued

Study	Form Set	Attach- ment	Time	Manipu- lation	Response	Size	Answer Feedback	Subjects
	Penn State							
Henkin (1970)	x	x	x	x	x	x	Not told	50 normal adult, 16 chronic diseases
McDonald and Aungst (1970a)	x	x	x	x	x	x	x	50 each, K-3rd
McDonald and Aungst (1970b)	x	x	x	x	x	x	x	1 spastic quadriplegic
Ringel, et al. (1970)	x	x	x	x	x	x	x	60 nor., 60 funct. artic children
Weinberg, Liss, and Hillis (1970)	x	x	x	x	x	x	x	34 /r/ defective jr. and sr. hi
Weinberg, Lyons, and Liss (1970)	x	x	x	x	x	x	x	40 elem. sch., 35 jr. hi, 36 univ. students
Williams and LaPointe (1970a)	x	x	x	x	x	x	x	40 normal 20-59 yrs.
Williams and LaPointe (1970b)	x	x	x	x	x	x	x	25 nor., 21-47 yrs.
Fucci and Robertson (1971)	x	x	x	x	x	x	x	10 nor., 10 funct. artic., teen agers
Lass et al. (1971)	x	x	x	x	x	x	x	30 adults
LaPointe and Williams (1971)	x	x	x	x	x	x	x	12 normal adults
Lass et al. (1972)	x	x	x	x	x	x	x	30 adults
II	x	x	x	x	x	x	x	11 adults
III	x	x	x	x	x	x	x	30 adults
IV	x	x	x	x	x	x	x	25 adults
Lass and Hammed (1972)	x	x	x	x	x	x	x	30 adults
LaPointe and Williams (1972)	x	x	x	x	x	x	x	15 aphasic males, 20-79
Ringel, House, and Bishop (1972)	x	x	x	x	x	x	x	18 manual deaf, 18 normal, high school

of the speech and language mechanism has been considered basic to the study of speech pathology. It is, in fact, required information for the Certificate of Clinical Competence awarded by the American Speech and Hearing Association. Certain texts in speech and hearing science, such as those by Zemlin (1968) and Penfield and Roberts (1959) have dealt solely with these areas. Introductory speech pathology texts such as those by Perkins (1971), Eisenson and Ogilvie (1971), and Egland (1970) begin with discussions of the speech mechanism and the process of producing sounds. More specialized texts such as those by Johnson, Darley, and Spriestersbach (1963), Lenneberg (1967), Berry (1969), Kantner and West (1960), Gray and Wise (1959), and Eisenson, Auer, and Erwin (1963) begin with a discussion, more or less detailed depending on the nature of the text, of the anatomy, physiology, and neurology of the speech mechanism and of the production of sounds. All make some reference to the sensory processes involved in speech production.

Although the act of producing a sound or a sequence of sounds yields an acoustic signal, the act itself is a physiological phenomenon. One aspect of that physiological mechanism which has only recently received concentrated experimental study is the oral sensory process. However, further investigation is needed in order to provide a more complete understanding of its relationship to human communication. It is also possible that such research may lead to a clinically

useful test of differential diagnosis of individuals with articulation disorders.

Sensory and Motor Innervation of the Oral Cavity

As a physiological act, sound production has both motor and sensory components. The motor behavior of the oral cavity is based upon the activity of the facial, vagus, hypoglossal, and accessory nerves and the mandibular division of the trigeminal nerve (Hollinshead, 1968; Chusid, 1970; and Kaplan, 1971).¹

According to Hollinshead (1968), sensory innervation of the buccal gingival mucosa is chiefly the responsibility of the maxillary nerve with some innervation from the mandibular nerve. Innervation for the nasal mucosa is provided by the ophthalmic and maxillary divisions of the trigeminal nerve (Chusid, 1970).

The sensory innervation of the palate has not been satisfactorily determined, but according to Hollinshead (1968) the trigeminal nerve is mainly responsible, with some

¹When describing oral sensory innervation some authors refer to the mandibular and maxillary nerves, some to the maxillary and mandibular divisions of the trigeminal nerve, and some to the maxillary, mandibular, and ophthalmic branches of the sensory division of the trigeminal nerve. Each author is cited here in the terminology which he preferred to use in his writing.

aid from fibers of the facial, maxillary, and posterior cranial or upper spinal nerves. Chusid (1970) assigned this innervation to the ophthalmic division of the trigeminal nerve.

Hollinshead (1968) assigned the afferent supply of the mucous membrane of the anterior two-thirds of the tongue to the lingual nerve and the posterior one-third to the glossopharyngeal nerve. He noted that both of these nerves contain some fibers of general sensation, i.e., touch, pain, and temperature. He assigned general sensation of the tongue primarily to the trigeminal nerve.

The maxillary division of the trigeminal nerve provides sensory innervation for the upper jaw, upper teeth, and upper lip, while the mandibular division innervates the lower jaw, lower teeth, and lower lip (Chusid, 1970). The facial nerve has some proprioceptive fibers which carry deep pressure and position information from the facial muscles (Chusid, 1970).

Terminology of Sensory Investigation

The literature on sensory investigation has been confounded with conflicting terminology. Different terms have been used by different writers to mean the same thing; the same terms have been used to mean different things. There has not been even complete agreement on what constitutes a sense or how many senses exist. Because of this conflict, some of the more common terms are defined and discussed below.

Senses

According to Neff (1960), one of the earliest attempts at classifying the human senses was Aristotle's definition of the human senses as consisting of vision, hearing, touch, taste, and smell. Since that time other investigators have at one time or another considered kinesthesia, pressure, muscle sense, temperature, pain, prickly pain, and strain or deep pressure to be separate senses (Gibson, 1967).

Sensation versus Perception

The separation of sensation and perception mentioned by Gibson (1967) has been reflected in both terminology and methodology. Up to about 1930 sensations were considered to be the information carried from the sensory receptors through the central nervous system, and perceptions were considered to be the knowledge of the environment based on these sensations (Gibson, 1967). Writers with a neurological orientation such as Penfield (1960), Rose and Mountcastle (1960), and Chusid (1970) have used definitions of sensation and perception as related primarily to the neural message.

Tuber (1960) argued strongly against making such a distinction between sensation and perception. He considered this distinction to be arbitrary and historical rather than logical or experimentally useful. Neff (1960), Ruch (1951), and Grossman and Hattis (1967) seemed basically in agreement with Tuber, that a sensation-perception dichotomy is not the best way to describe the sensory process. Tuber (1960)

considered this artificial distinction to be one of the major reasons why neither a clear theory of perception nor a complete knowledge of the sensory and/or perceptual processes is yet available.

Gibson (1967) attempted to avoid the entire sensation-perception controversy by coining a different term. He considered the ability of an individual to sense, or be aware of, the world adjacent to his body as "haptic perception" and called the entire perceptual system used in this sensing "the haptic system". The mouth, with its membranes and structures, was considered to be a part of this system.

Proprioception versus Kinesthesia

The ability of the body to sense its position in space, including sensations of equilibrium, balance, and muscular sensations, has been classified by some writers as proprioception (Chusid, 1970; Gray and Wise, 1959; and Dittman, 1955). Proprioception was considered to be the result of impulses from nerve endings which are located mainly in the Golgi tendon organs and muscle spindles and which were termed proprioceptors.

Rose and Mountcastle (1960), Shelton, Arndt, and Heatherington (1967), and Class (1956) labeled the conscious perception of position and movement as kinesthesia rather than proprioception. Rose and Mountcastle (1960) further differentiated between kinesthesia, which is concerned with

deep sensations, and tactition, which is concerned with surface sensations.

Somesthesis

Another common term used in the study of sensation and perception is somesthesis. Dittman (1955) included the exteroceptive, proprioceptive, and interoceptive sensibilities under this rubric, in reference to bodily feeling and sensation. She discussed somesthesis in terms of the receptors involved rather than the input from those receptors. She credited sensory receptors collectively with representing the body sense or general somesthetic sensibility. Included in somesthetic sensibility were the receptors for touch, pressure, pain, temperature, sense of movement and position, and visceral sense, plus the organs of the special senses of smell, taste, sight, hearing, and head position and movement (Dittman, 1955).

Neff (1960) viewed somesthesis as consisting of touch, temperature, pain, and possibly light touch, deep pressure, and warmth. He suggested that somesthetic sensations arise from the same receptor endings stimulated by different kinds of stimuli.

Stereognosis

Chusid (1970) defined stereognosis as the recognition and naming of familiar objects placed in the hand and as the capacity to recognize forms, sizes, and weights of objects.

Paine (1967) contended that stereognosis literally means recognition of shape, and that asternognosis is the absence of ability to recognize shapes by palpation of objects, either totally or partially. Semmes (1967) proposed that disturbances of manual stereognosis depend on at least two factors, a sensory factor specific to the affected hand and a general spatial factor which enters into performance of both hands and into performances regulated by other modalities as well.

Arndt, Gauer, Shelton, Crary, and Chisum (1970) used the term oral stereognosis in much the same way as stereognosis has been defined. They used the term to refer to the ability to identify objects using oral exploration. The term was defined by Woodford (1964) as the ability to perceive and identify the shapes of objects orally.

Oral Stereognostic Forms

Geometric shapes or forms made of various materials have been devised as one means for testing oral stereognosis. There are several different sets of forms which have been used. Listed below are four of the most common sets.¹

- (1) The Penn State Forms--This set of five three-dimensional forms (see Figure 1) was developed by McDonald and Solomon (1962) at the Pennsylvania

¹For addresses of firms from which the first three sets are available see Appendix A.

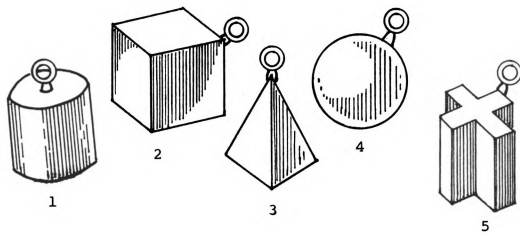


Figure 1. The five oral stereognosis forms developed at Pennsylvania State University.

State University. These forms are truly three-dimensional, i.e., a cube, a sphere, etc.

- (2) The NIDR 20 Forms--The Oral and Pharyngeal Development and Function section of the National Institute of Dental Research of the National Institutes of Health developed a set of 20 three-dimensional plastic forms for testing oral stereognosis (Aungst, 1965). These forms are three-dimensional, but unlike the Penn State forms, they are plane figures, i.e., a circle, square, star, etc., cut from plastic with enough thickness to give them depth (see Figure 2).
- (3) The McDonald and Aungst Forms--This is a selection of ten of the 20 forms of the NIDR set chosen by McDonald and Aungst (1970a) in an attempt to shorten the time involved in testing (see Figure 3).
- (4) The Ringel Forms--Ringel and associates (cited individually later) developed a set of ten forms based on the NIDR designs. These forms were of a different material, slightly smaller and thinner than the NIDR forms, and handleless (see Figure 4). These are not available commercially, although they have been used frequently for research and clinical purposes.

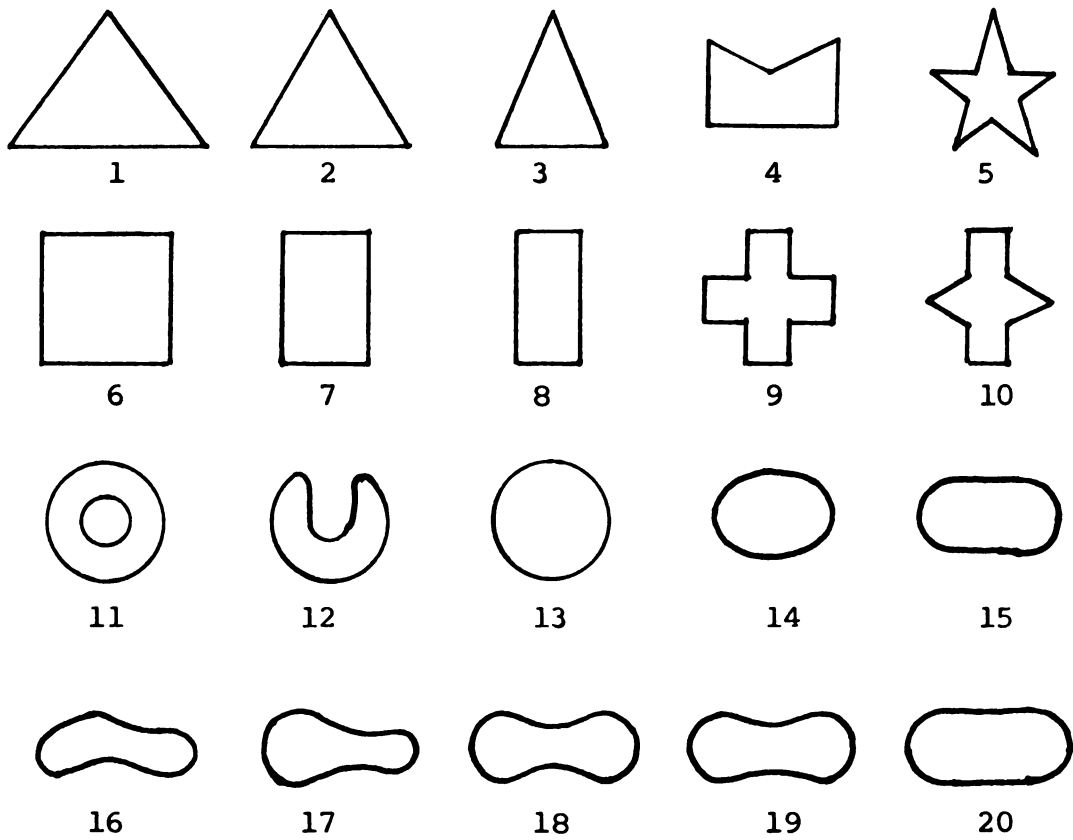


Figure 2. The twenty NIH forms as arranged for response in the LaGourgue study, Moser et al. (1967).

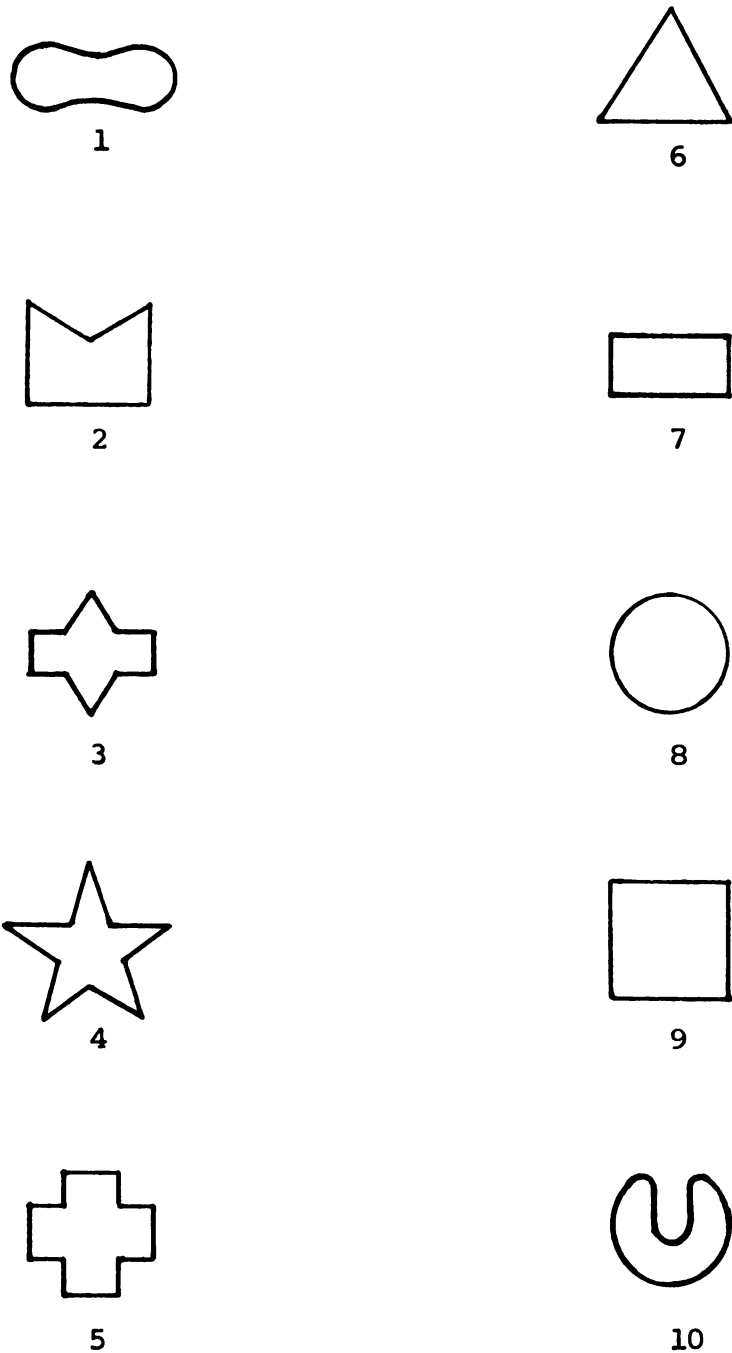


Figure 3. Outlines of items used for short test of oral stereognosis (McDonald and Aungst, 1970a).

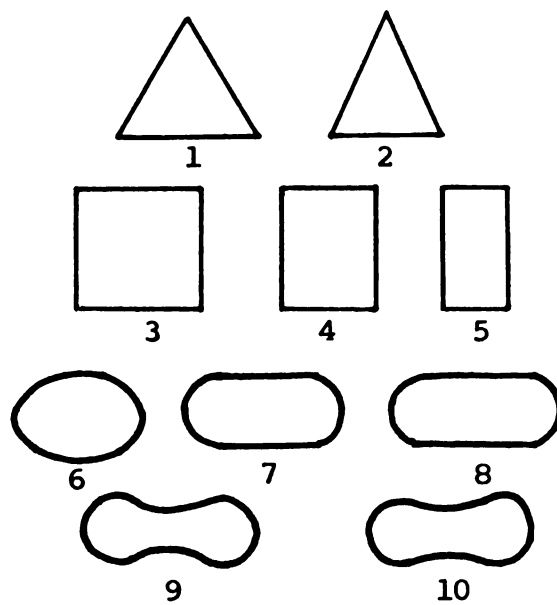


Figure 4. Outlines of the ten forms selected from the NIDR 20 by Ringel and associates.

Theories of Speech Production

Various theories of speech production relate the sensations and perceptions of the oral cavity to the auditory system and to the motor acts of articulation and speech production. Proprioceptive or kinesthetic feedback is a major component of several of these theories.

Peterson (1968) presented a schematic of the process of speech communication (see Figure 5) which included proprioceptive and tactile feedback. He suggested that phonetics is basic to any description of the phonological aspect of a spoken language. Tactile and proprioceptive fibers transmit information about the movements and positions of the mouth during speech, but the relative importance of this information during either speech learning or speech production has not been studied in detail (Peterson, 1968). He noted that auditory, proprioceptive, and kinesthetic feedback must be more closely studied. In particular, he urged that the physiological formations which are associated with phonetic symbols be explicitly designated and incorporated into phonetic theory (Peterson, 1968).

Catford (1968) classified human speech into six phases for analysis and discussion. He listed the neuro-muscular, organic, aerodynamic, acoustic, neuro-receptive, and perceptual phases, subdividing the perceptual phase further into auditory and kinesthetic.

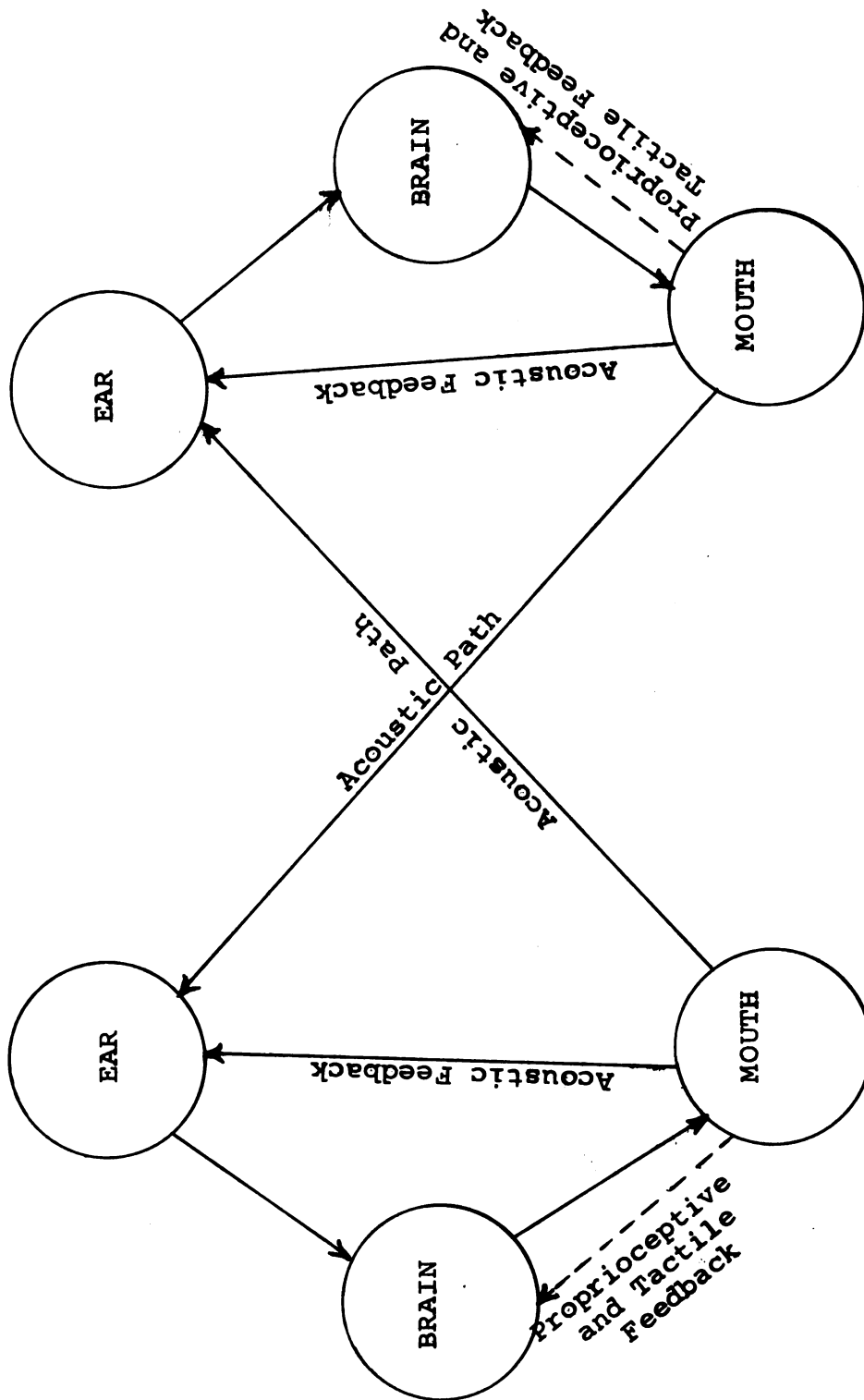


Figure 5. Schematic of two individuals illustrating the essential components of the speech communication process (Peterson, 1968).

Ladefoged (1967) suggested that a speaker has three types of feedback concerning the sounds he produces: auditory, tactile, and kinesthetic. He differentiated between tactile and kinesthetic feedback. Information about the contacts between lips, tongue, palate and other parts of the vocal tract was considered tactile feedback. Information about muscle stretch and joint movements was considered to be kinesthetic feedback. He hypothesized that vowels are monitored more by auditory feedback while consonants are primarily dependent upon tactile feedback. It was noted that speakers are, however, able to adapt quickly to the use of another channel in cases where one feedback channel is damaged.

Ladefoged (1967) also reported an informal experiment using only five subjects in which the lips, tongue, and roof of the mouth were anesthetized in an attempt to reduce tactile feedback. The anesthetization was done topically with amethocaine hydrochloride lozenges and in most cases did not extent further backward than the soft palate. Speakers made errors even under this slight degree of anesthetization. Auditory feedback was eliminated with a masking noise in the ears which was loud enough to prevent the subject's hearing his own voice even by bone conduction. With the removal of both tactile and auditory feedback, speech remained intelligible. Ladefoged noted that the errors were seldom the replacement of a consonant by another consonant

different enough to alter the meaning of the word, although this kind of substitution is a common type of speech pathology. Ladefoged did not say what these errors were, i.e., distortions, other kinds of substitutions, etc. He only reported what they were not. He then concluded that, in general, with removal of both tactile and auditory feedback, speech was "disorganized" but intelligible.

Lieberman (1967) argued that any well-formulated phonetic theory must include the physiology of the oral mechanism as an inherent property. His theory, which is associated with the myoelastic-aerodynamic theory of phonation and with speech perception, included the idea that listeners perceive speech signals by using their knowledge of the phonologic features which produce the speech signal in an analysis-by-synthesis type of feedback mechanism. The speaker "knows" the physiological restrictions of his speech production apparatus, the semantic and syntactic restrictions of his language, and the particular social context of the message (Lieberman, 1967). As a listener he performs a given amount of preprocessing, then uses a process of hypothesis formation based upon this articulatory knowledge over a rather large unit of speech production at one time (Lieberman, 1967). Basically the listener is decoding the input signal by using his knowledge of the output system, making hypotheses of what the message is and using feedback to compare what he hears to what he produces (Lieberman, 1967).

Fairbanks (1954) presented a model of the speech mechanism as a servosystem in which it was hypothesized that the output of speech was fed back from the sensory mechanisms to a place of central control, where it was compared to the input (see Figure 6). Subsequent output was then regulated by this sensory monitoring of motor activity. The ear was considered the primary sensor in this system with auditory feedback as the primary data used by the control system (Fairbanks, 1954). The tactile and proprioceptive end-organs supplied data about the mechanical operation of the speech mechanism but not directly about its output (Fairbanks, 1954). The comparator used the input and feedback signals in a comparison calculation, in which the difference between the two were computed. An error signal which reduced the difference was utilized (Fairbanks, 1954).

Mysak (1959) also presented a model in which the communication system was described as a servosystem. This model was considered to be an extension of Fairbanks' theory and aimed at facilitating therapy. He, too, included the idea of sensory feedback. He added to the Fairbanks model a fourth sensor unit, a four-component receptor unit, and a two-component integrator unit. His four receptors represented vision, audition, taction, and motion. The sensory information from these four was then integrated and stored in the same unit which Fairbanks postulated as storing information for the production cycle. From this point of view speech

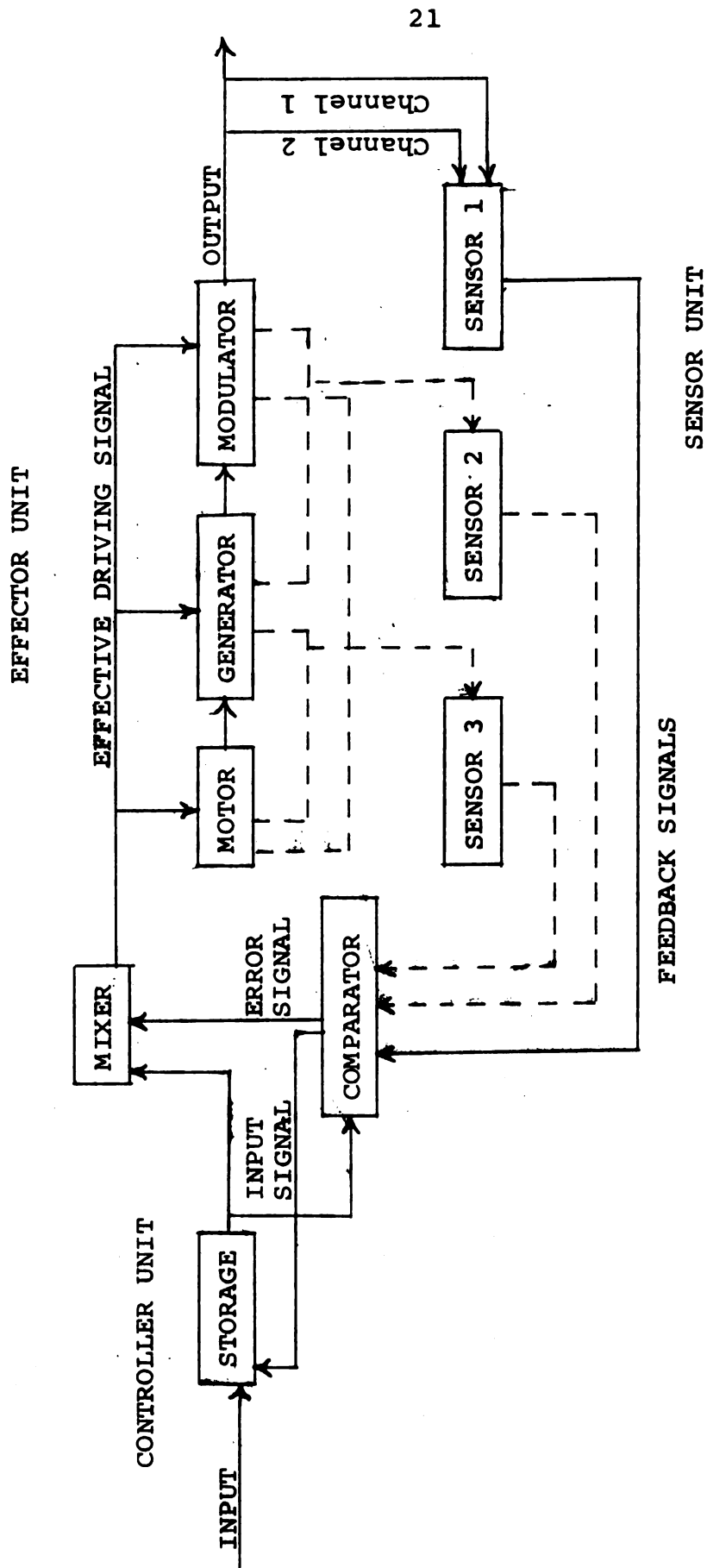


Figure 6. Model of a closed cycle system for speaking (Fairbanks, 1954).

therapy was aimed at superimposing a new sound system on the client's control system, and called for the careful evaluation and use of all four sensory receptors (Mysak, 1959).

As the result of cineradiographic studies, Perkell (1969) concluded that both vowel and consonant production were affected by feedback, but were affected differently. Vowels were seen as most affected by acoustic and myotactic (pertaining to a stretched muscle) feedback, and consonants by tactile feedback and intra-oral air pressure (Perkell, 1969). He conceived the speech production mechanism as being composed of two neuromuscular systems, each with different characteristic behaviors and responding to different feedback.

MacNeilage (1970) presented an attempt to account for the aspects of the serial ordering process which are most directly responsible for the ability of a speaker to sequence the movements of sound production and therefore to sequence the sounds. He concluded that many writers see the process of the sequencing of speech sounds, or serial order, as "the generation of a command for a particular pattern of muscle contraction, or a particular gesture, some part of which has an invariant relation to some linguistic category" (p. 185). He presented an alternative view, that the command is given for a body part to adopt a certain position by programming a spatial target rather than a specific movement. We achieve the act of opening a door not by a door-opening pattern, but

by somehow being able to eliminate the discrepancy between where the parts of our body are and where we want them to be (MacNeilage, 1970). He argued that we achieve a particular phoneme in the same way, by specifying a target in an internalized space coordinate system. He suggested that we have a space coordinate system of phonological information. This system translates a desired utterance into a series of spatial targets, then requires the motor system to generate movement command patterns which allow the articulators to reach the targets in order, and finally issues commands to the muscles (MacNeilage, 1970). He noted that sensory information played a specific but as yet not clearly understood role in this process. MacNeilage considered it probable that motor, somesthetic, kinesthetic, and auditory information is integrated to build up spacial coordinates. These coordinates then become a part of the representation of the oral area, in which the target is specified (MacNeilage, 1970).

Lieberman (1956) began his analysis of the cues used for acoustic analysis of consonants by dividing them into classes based on where and how the sounds are produced. He postulated acoustic differences among sound classes but noted that it was difficult to characterize those differences in acoustic terms. Although Liberman's basic interest in speech perception was with the acoustic cues or aspects of speech sounds used for identifying differences among phonemes, he suggested that the possibility must be considered that the perception

of speech cannot be explained without taking into account the physiological-proprioceptive dimension. He concluded that when a sound gives one cue to perception in the acoustic dimension and another in the proprioceptive dimension, that perception always goes with articulation, i.e., with the physiological proprioceptive dimension (Liberman, 1956).

Henke (1967) suggested that proprioceptive feedback provides the mechanism by which the timing or rate of articulatory activities is accomplished. He described the production of a stop consonant in which closure of the articulators was completed before articulation continued, then concluded that awareness of this closure, probably through proprioceptive feedback, was used as a trigger for continuing articulatory activity. Ringel (1970) pointed out that this view is in conflict with some recent data on coarticulation which shows that some articulatory movements do not depend on previous articulatory events.

Ringel (1970) suggested that in general investigators agree that articulatory integrity and speech quality are increasingly disrupted as feedback is increased by anesthesia. Ringel and Steer (1963) investigated feedback phenomena with thirteen college age subjects whose mouths were anesthetized by nerve block techniques performed by a dental surgeon. They measured mean amplitude peak level,¹ fundamental

¹Amplitude of performance refers to average peak levels measured in dB re 0.0002 dynes/cm². The peak counting method was used to determine amplitude of performance. The amplitude of energy peaks above a pre-set reference of 60 dB SPL was

frequency, syllable duration, and articulation from recordings of a six sentence passage read by the subjects. They compared these measurements for six conditions: (1) absence of either experimentally introduced noise or anesthesia; (2) binaural white masking noise; (3) topical anesthetization of the oral region; (4) local anesthetization of the oral cavity with nerve block techniques; (5) simultaneous use of binaural masking noise and topical anesthetization of the oral area; and (6) simultaneous use of binaural masking noise and local anesthetization of the oral cavity with nerve block techniques. They found that under nerve block anesthesia speech was characterized by significant increases in amplitude of performance, a lack of variation in rate, and inaccuracy of articulation.

McCroskey (1958) also found a significant increase in articulation errors under nerve block anesthesia. With regard to the rate of progress of speech, or rate at which a speaker progresses through a phrase, McCroskey (1958) obtained significant differences among the four conditions of (1) normal side-tone, (2) delayed side-tone, (3) anesthetized articulators, and (4) delayed side-tone plus anesthetized articulators. He found the greatest difference in the conditions which involved delayed side-tone. With regard to articulatory accuracy he found the greatest difficulty in the

measured by feeding taped speech into an analyzer and measuring the graphs obtained from a graphic level recorder (Ringel, 1970).

conditions involving anesthetization of the articulators. Intelligibility was most affected by loss of tactile cues, i.e., in the conditions of anesthetization of the articulators. He concluded that auditory side-tone seemed to be the most important factor in determining the rate of speech, while tactile feedback was the primary factor in determining the accuracy of speech (McCroskey, 1958).

Using the same nerve block anesthetization techniques as McCroskey (1958) and Ringel and Steer (1963), McCroskey, Corley, and Jackson (1959) investigated the loss of tactile cues in normal monitoring and found a greater degree of consonant errors under the condition of anesthetization, i.e., loss of tactile feedback cues. Further, they reported that the errors were predominantly errors of substitution in the initial position and errors of distortion in the final position. They suggested that the monitoring task shifts from tactile to auditory channels at a point of critical duration of a sound. Schliesser and Coleman (1968) compared the effect of auditory masking, oral anesthetization, a combination of both, and normal feedback conditions on speech. They measured sensory performance by testing oral stereognosis and motor performance with mean rates of speech production and tongue mobility. Using both topical and nerve block anesthesia, they tested oral stereognosis with ten geometric objects in both the anesthetized condition and under normal conditions. All subjects identified all objects

correctly in the normal condition and identified only as many as could be expected from guessing in the anesthetized condition. Therefore, the authors concluded that nearly total insensitivity could be assumed for the oral area. In the anesthetized condition subjects produced speech which was intelligible and less defective than that judged by speech therapists to be moderately defective (Schliesser and Coleman, 1968).

Gammon, Smith, Daniloﬀ, and Kim (1971) also agreed generally that speech quality is increasingly disrupted as feedback disruption increases. However, they concluded that although consonant articulation is disrupted by tactile deprivation, stress-juncture production tasks are not disrupted by blocking auditory and tactile feedback. They constructed thirty sentences using compound and cognate words with stress/juncture differences such as "redcoat vs red coat" and "impact" (verb) vs "impact" (noun). Neither anesthesia nor noise nor a combination of both reduced the subjects' ability to produce the appropriate stress and juncture. Consonant articulation not only suffered most from tactile deprivation but showed a consistent pattern of misarticulation. The majority of errors were the result of changes of manner or changes of place and rarely across these classes. Place errors tended to be the result of a front to back movement, and manner errors tended to move from open to closed articulatory positions (Gammon et al., 1971).

Recent research by Scott and Ringel (1971a) suggested that oral sensory deprivation resulted largely in nonphonemic articulatory defects. They suggested that, because the speech mechanism can operate in spite of lack of feedback information from the peripheral oral receptors, the speech mechanism probably operates in response to target specification motor commands. They argued that the speech mechanism, having issued these commands, then needs some closed-loop refinements of instruction which are especially necessary for phonemes which require very precise types of apical and blade configurations, such as the consonant /r/ and the sibilants. In another study (Scott and Ringel, 1971b), they suggested that speakers with articulatory difficulties caused by motor problems can be distinguished from those with sensory based disorders by close phonetic analysis of the specific consonant mis-articulations they produce. Subjects with motor damage frequently de-voiced stop consonants, while de-voicing was not characteristic of the stops produced by the sensory deprived subjects. The motor damaged subjects either omitted /θ/ or produced it as a dental stop 50% of the time the sound was supposed to be produced; substituted one fricative for another; or occasionally voiced a voiceless fricative. The sensory-deprived speakers usually produced less close and retracted variations of the /s/ and /ʃ/ phonemes. The subjects of this investigation were six dysarthric speakers and two normal adults who had been anesthetized with a series of oral

nerve block injections. Scott and Ringel (1971b) further noted that whether or not a complete sensory nerve block of the oral structures is possible is still questionable. It was also possible that the dysarthric subjects suffered from some degree of sensory deprivation. Therefore, these differences may not actually be differences between sensory-deprived and motor-damaged subjects.

Methodologies for Oral Sensation

During the period from 1952 through 1967 a series of investigations concerning oral sensation and perception were carried out in several university speech departments. These investigations led to a series of conferences which resulted in a larger number of research studies, conferences, and publications (Bosma, 1967; Bosma, 1970). These investigations used various methods and considered many different aspects of oral sensation.

Taste and Temperature Studies

Up to the mid-1960's, most investigations of oral sensory phenomena involved the study of taste or thermal stimulation (Grossman and Hattis, 1967). Research of these phenomena was important in relation to a complete anatomical, physiological, and neurological understanding of the oral cavity. However, no definitive conclusions were drawn from the thermal studies and neither taste nor thermal studies were directly relevant to speech production.

Tactile Acuity

Two early studies by Rutherford and McCall (1967) and McCall (1969) defined a series of oral tasks involving different types of stimuli. None of these tasks was intended to be an accurate test of sensation; the tasks were aimed at stimulating further research. Such tasks as detecting the depth of a groove on a plastic plate or recognizing a pattern either with the tongue tip or when drawn on the tongue were included. The results of this testing suggested that the tongue tip was the most sensitive of the oral structures.

Vibratory, Electrical, and Vibrotactile Studies

Using mechanical vibrations, Perilhou (1947), Geldard (1940), and Cosh (1953) found the tongue and other oral structures relatively insensitive to vibration. Grossman (1967) and Pleasonton (1970) used electrical stimulation and found the anterior structures of the mouth and tongue more sensitive than the posterior structures. Haas (1970) and Goldstein (1972) investigated the concept of tactile distinctive features, but were concerned with the reception of phonemes by the finger or other surfaces and not with oral sensitivity.

Two Point Discrimination

Several researchers have studied two point discrimination, the ability to tell whether a stimulus touching a tissue is composed of one or two objects (Ringel and Ewanowski, 1965;

Grossman, 1967; McCall, 1969; Lass, Kotchek, and Deem, 1972; McCall and Cunningham, 1971; and Olroyd, 1965). There was agreement that oral structures are more sensitive from front to back and from midline out. There was also general agreement on the specific distance by which two points must be separated in order to be felt as two stimuli. There was disagreement as to the asymmetricality of this sensitivity.

Tactile Stimulation

Tactile stimulation, or sensitivity to pressor stimuli, has been studied by Grossman (1967), Grossman and Hattie (1967), and Henkin and Banks (1967). This research agreed with Rutherford and McCall (1967) and with the research on two point discrimination, that the sensitivity of oral structures decreases from front to back.

Mandibular Kinesthesia

Mandibular kinesthesia has been investigated by measuring the magnitude of change in mandibular positioning necessary for the perception of such changes (Ringel, Saxman, and Brooks, 1967). A modified vernier-type caliper was used for measuring the size of the mouth opening. The authors found that a judgment of difference in the size of the mouth opening required proportionately smaller changes in mouth opening as the size of the mouth opening increased. They hypothesized that the sensory activities of the temporomandibular joint may be the system which regulates and controls

mandibular motor activity. They concluded that this regulation and control was probably accomplished by means of a feedback system.

Texture

Discrimination of texture was measured by Ringel and Fletcher (1967) using swatches of emery cloth graded from coarse to smooth and by Ringel (1970a) using sandpaper discs graded from rough to smooth. Both studies found that the lingual structures were more accurate in evaluating texture than the labial structures, and that oral sensitivity increased from back to front.

Object Size

A study by Dellow, Lund, Babcock, and Van Rosendaal (1970) required subjects to compare the size of a series of plastic cylinders of varying lengths placed in the mouth to another identical series being manipulated with the hands. They found that subjects erred on the positive or large side when making intra-oral judgments of size, and that such judgments when made by finger or visual assessment did not tend toward such errors. Subjects in this study usually made the size assessment by using the tip of the tongue to hold the object against the inner surfaces of the front teeth and then moving the tongue tip back and forth along the length of the object. The object was also rolled about in the anterior portion of the mouth. Subjects rarely used their lips (Dellow et al., 1970).

Studies of the assessment of the size of objects are common in the literature of sensory psychology but deal mainly with assessment by the use of the hands or eyes. However, Dellow et al. (1970) suggested that studies of the oral area may challenge the common assumption that the fingers are the major avenue of perception. They considered oral size assessment to be one of the areas which should be investigated because of the possibility that this type of test may provide knowledge of the articulatory and speech processes.

Lingual Orientation

Moser and Houck (1970) studied left-right lingual orientation with the braille characters :· , ·: , :· , ·: , which represent the letters d, f, h, and j. The characters were written with a braille writer which produced characters with a wider spacing than the usual braille writing. Each character was mounted on a one inch area at the end of a tongue blade. Subjects were given a package containing three tongue depressors. The braille characters on these could be all alike, all different, or two alike and one different. The subject matched the character on each of the three tongue depressors with one of six arrangements of dots printed on an answer sheet. The answer sheet contained these four braille characters plus two other similar characters. Significant differences were found between normal male and normal female speakers, between right-handed and left-handed

normal speakers, and between normal and articulatory defective speakers. Males, left-handed speakers, and defective speakers made more inverted responses; that is, they selected the character which was an inverted form of the one presented, e.g., they identified (:·) for (:.).

Summary of Sensory Research Other Than Oral Stereognosis

Studies of tactile stimulation and tactile acuity have been more closely related to the speech process than the thermal and vibratory studies. McCall (1969) pointed out that the oral touch receptors probably subserve a proprioceptive function. Rutherford and McCall (1967) concluded that the perception of the motion of the articulators is probably a synthesis of several sensations, none of which is clearly understood. They also concluded that it is probable that kinesthesia and touch are the sensations most involved in articulatory motion perception (Rutherford and McCall, 1967). Grossman (1967) concluded that tactile and other sensory cues are related to motor function of the mouth in speech, eating, and respiration.

As presented in the discussion of terminology, neither the physiology nor the terminology of sensation and perception is clear. Kinesthesia, proprioception, and tactile activity are, however, all viewed as related to the senses of touch and pressure in some way, and the senses of touch

and pressure are viewed as related to the individual's knowledge of the position of his body parts. Sensory information from the oral cavity, including knowledge of the position or movement of the articulators, is viewed by speech scientists as being in some way involved in the process of producing and regulating the flow of speech sounds. Therefore, since knowledge of the correct production of sounds is necessary to changing an incorrect production of sounds, knowledge of the sensory activities underlying correct speech production is directly related to the clinical task of correcting speech production.

Research Using Geometric Forms

Currently, the most popular method of measuring oral stereognosis is by the use of three dimensional plastic geometric forms (see Table 1). However, to date the procedures employed for this purpose have been inconsistent. Differences in methodology have included differences in form set, in answer type required, in amount of time allowed for retention of the forms in the mouth or between presentations of the forms, in amount and kind of manipulation of the forms allowed, in size of the forms, and in whether or not the subject was told the correctness of his responses.

Studies Developing or Comparing Form Sets

One of the major questions involved in testing oral stereognosis has been that related to the most appropriate

set of forms to use. Some studies have used new sets and some have used a selection of forms from an older set or a combination of older sets.

Woodford (1964) developed a set of materials for testing oral stereognosis. He used three spheres, with diameters of 4, 6, and 8 mm; six geometric forms, three symmetrical and three asymmetrical shapes; and a disc 15 mm in diameter with two equidistant holes, each 3 mm in diameter. He inserted and removed the forms himself, did not tell the subjects the correctness of their decisions, allowed all the manipulation the subject wished, and set no time limits for manipulation. The subjects responded by marking cards. For the spheres and discs the subjects made two judgments for each three test items. They ranked the three items as largest, medium, or smallest, and thickest, medium, or smallest. For the geometric shapes the subject selected a matching outline on a card depicting five shapes. For the holed disc the subject marked whether the disc had zero, one, two, or three holes. The subjects included 18 9-14 year olds with normal teeth and occlusion; 18 children comparable in age but with severe malocclusions; 12 children whose ages were not given but who had been diagnosed as neurologically impaired, including four with defective articulation, two with minimal brain damage and defective articulation, three with spastic cerebral palsy, three with unilateral Bell's Palsy, and one with a marked hearing loss;

24 adults with full dentures, tested with and without the dentures; and 12 adults with normal dentition and varied degrees of malocclusion, including four with normal occlusion. He concluded that: (1) perception of size, thickness, and two-hole discrimination was more accurate than oral perception of varying shapes; (2) oral discrimination of two-hole difference was more accurate than manual discrimination, but that manual discrimination of size, thickness, and shape was slightly better than oral discrimination; (3) oral discrimination of size, shape, thickness, and two-hole localization was not affected by the wearing of dentures; (4) although the children with malocclusions performed less well on shape identification than those with normal occlusion the difference was not significant, nor were significant differences found between these two groups on the other measures; (5) the neurologically normal children performed more skillfully on all tests than the neurologically impaired group; (6) the adult sample with natural teeth performed better on shape and two-hole discrimination with both the hand and the mouth than the adult sample without natural teeth. It was noted that, in agreement with the results of several investigations which state that the tongue tip is extremely sensitive to tactile stimuli, all groups were more successful in perceiving the two-hole spatial arrangement with the tongue tip than with the hand (Woodford, 1964).

Shelton, Arndt, and Heatherington (1967) did a series of studies in an attempt to develop a test using the NIDR oral forms. In Pilot Study I they used the 20 forms and asked each of 20 adult subjects to match the object which was in his mouth with tracings of the 20 objects which had been placed together on one sheet of paper. A ten second time limit was set for oral manipulation of the form and one minute was allowed for visual study of the tracings and selection of an answer. In Pilot Study II they presented one tracing of each of the twenty objects to each of seventeen subjects. After two seconds the tracing was removed and the subjects were asked to draw what they had seen. From the 17 drawings of each object which were thus obtained, the four which were most different from the original tracing were selected. These four tracings and the original tracing were arranged on a 3 by 5 card and used as the answer choices for the next series. In part 2 of Study II the same procedure as had been used in Study I was used, except for the difference in choices from which the answer was made. The authors concluded that the test material used in Study II was more difficult than that used in Study I. The data from Study I (three trials) and Study II (two trials) were analyzed for learning effect. Subjects made higher scores on second trials than on first trials which suggested a learning effect. A study to be discussed in greater detail later (Lass, Bell, Chronister, McClung, and Park, 1972) found no learning effect, but used

both unlimited time of oral manipulation of the object and a different response procedure. Either of these differences, in response time or type of response procedure, may have been responsible for the disagreement in findings of learning effects.

In Pilot Study III, Shelton et al., had an artist prepare two-dimensional representations of the 20 test forms. Plans were made to have the subjects match one of five drawings presented on a page in a test booklet to a drawing presented by a slide projector. The authors planned to study item homogeneity visually rather than orally. Preliminary testing with four, five, six, and seven year old children indicated that the visual task was easier than the oral task. The possibility of developing items for an oral test by visual presentation of items was subsequently discarded (Shelton et al., 1967).

A fourth study using ten graduate students, 26 first grade students, and 66 third grade students was carried out by Shelton et al. Unlimited time was allowed for manipulation, and the answer choice was made from a five item form. It is presumed that this five item form is the same as that used in Pilot Study II, but the authors did not so state. No information about correctness of choice was given to the subjects. Choices were made while the form was still in the subject's mouth. An increase in mean number of correct responses occurred from first grade to third grade to graduate

students. The authors felt that many of the first grade children were responding by chance. For the third grade children, there was no significant difference found either between different sets of hand-made forms or between different examiners or between halves of the test (Shelton et al., 1967). Out of a possible 20, the mean number of correct responses was 11.6 for graduate students, 6.00 and 7.57 for two groups of first graders, and 8.82 for third graders.

Class (1956) used four experimental groups of 20 college age subjects per group. The four groups consisted of cerebral palsied persons, stutterers, articulation defectives, and normal subjects. Six geometric forms (a circle, half-oval, square, rhombus, isosceles triangle, and right isosceles triangle) were utilized as stimuli, each in seven sizes ranging from one-eighth to one-half inch. The forms were cut from one-sixteenth inch plexiglass stock and cemented to one-eighth inch plexiglass strips one inch wide and four and one-half inches long. Each subject was tested with the forty-two forms in random order and with no visual cues. The subject matched each form to a drawing on a chart and gave the number of the drawing. The cerebral palsied subjects had significantly lower mean scores than the other three groups. Further, the scores of the subjects with articulation problems and the stutterers were significantly lower than those of the normals. The curve of scores for all four groups reached asymptote on correct identifications with the one-fourth inch size forms. The mean number of correct

identifications of the six forms of this size was 5.7 of a possible six for normals, 4.5 for stutterers, 4.2 for the persons with articulation disorders, and 4.3 for all groups combined. For the normal group, sizes smaller than one-fourth inch (three-sixteenths and one-eighth inch) were increasingly difficult to identify.

In a study done by Kile and reported in Moser, LaGourgue, and Class (1967) the strip-mounted forms first used by Class (1956) were used with normal and articulatory disordered adults and teenagers. These strips were used with no limit on the time the subject could take for exploring the form with his tongue. The subjects matched each form to one of the outlines of the twenty NIDR forms drawn on a form chart. No significant difference was found between the performance of normal and articulatory disordered subjects. Further, high reliability was demonstrated by the fact that there was no significant difference between test and retest scores. For this experiment the forms used were described as two-thirds size, but two-thirds of what is not stated.

Moser et al. (1967) reported another study (Kile and Class, 1967) using the same general procedures as those used in the Kile and the Class (1956) studies. "Critical differences" were reported between "standard" sized forms, forms two-thirds of "standard" size, and forms one-half of "standard" size. The dimensions of "standard" size are not given, but presumably standard size is that of the NIDR forms.

Ringel, Burk, and Scott (1968 and 1970) and Ringel, House, Burk, and Scott (1970) carried out oral stereognosis studies in which they used only ten of the twenty NIDR forms (see Figure 5). They selected the ten items to obtain several gross geometric categories in which items differed only slightly, e.g., an isosceles and an equilateral triangle. Each of the ten forms was paired with every other form and with itself for a total of 55 pairs, plus ten additional pairs selected randomly from these pairings, for a total of 65 pairs. The subject kept one form in his mouth for five seconds, then was given the second form for five seconds. After removing the second form from his mouth, the subject was asked whether the two forms were the same or different. This procedure was followed in all three studies. Ringel, Burk, and Scott (1968 and 1970) presented the task to 20 normal speaking adults and 27 articulatory defective adults. They concluded that the articulatory defective subjects made more errors than normals, and that their errors were more varied than those made by normals. They also concluded that an increase in the average number of errors was correlated with an increase in the severity of the articulation problem.

Ringel, House, Burk, Dolinsky, and Scott (1970) used 60 children with "functional" articulation disorders as subjects. Twenty each of these children were judged as having a mild, a moderate, and a severe degree of articulation disorder. A control group of 60 normal speaking children was

used. These data were also compared to adult results, using data from Ringel, Burk, and Scott (1968 and 1970). Ringel, House, Burk, Dolinsky, and Scott (1970) concluded that the subjects with articulation defects made a greater number of errors on this task than normals. They reported that error increases were correlated with mean increase in the severity of the articulation defect. They also noted that more errors were made by normal children than by adults with articulation defects, suggesting that age and improvement in form discrimination may be correlated.

Locke (1968b and 1969) used another selection of ten of the twenty NIH forms (see Figure 7). Locke (1969) used 76 children who were allowed to manipulate the forms by the handles and were required to respond by pointing to an outline on a chart. The ten subjects with the highest oral stereognosis scores and the ten with the lowest oral stereognosis scores were then given ten trials to imitate three non-English speech sounds. The question was then raised whether children who were good at this oral stereognosis task were better than children who were poor at the task in overall ability to learn new consonant sounds. He concluded that they were. The difference in learning new consonant sounds was mainly in the level of approximation to a standard production of the new sound rather than in the rate at which the new sound was learned. He also noted that some subjects made greater use of the handle during oral stereognostic testing

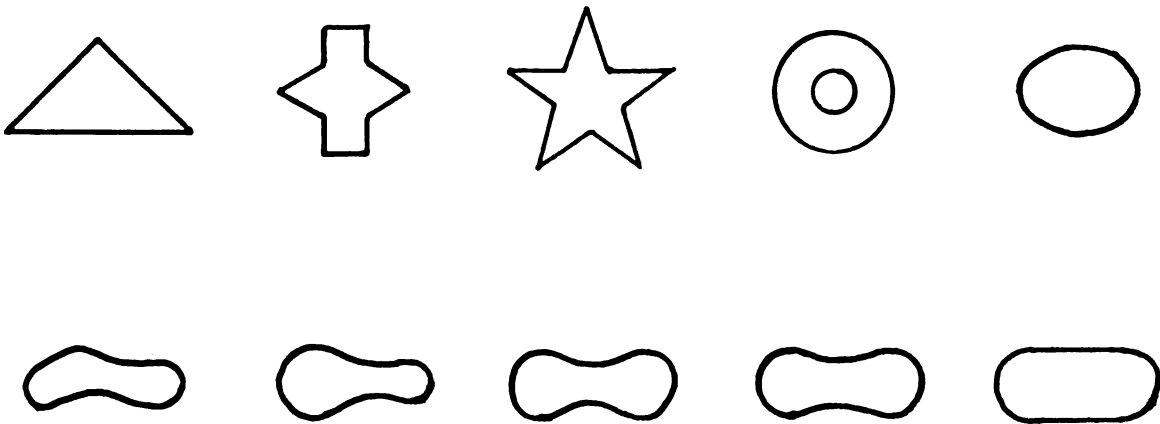


Figure 7. Outlines of the ten NIDR forms used by Locke (1968b and 1969).

and speculated that greater or lesser use of the handle might be connected to a difference between tactile sensation and motor-sensory processes.

McDonald and Aungst (1970a) also attempted to reduce the number of required forms per test. They selected from the 20 NIDR forms and the five Penn State forms ten items which were frequently confused with each other, showed decreasing difficulty with age, and involved one possible confusion for each item. The ten item test was administered in the same manner as the 25 item test (McDonald and Aungst, 1967), except that the visual display contained only the outlines of the ten selected items plus one demonstration item. The authors concluded that a test composed of these ten items was a satisfactory measure of oral stereognosis with normal children and possibly with children with neurological impairments.

Weinberg, Lyons, and Liss (1970) used the 20 NIDR forms with stems and asked third grade, junior high school, and university age subjects to palpate each form with the tongue and to identify it by pointing to one of a set of forms mounted on a board and grouped according to similar shapes as grouped in the LaGourgue study reported by Moser et al. (1967). They compared oral, manual, and visual recognition of the forms and reported that oral form perception skills were significantly poorer than visual or manual form perception skills.

Weinberg, Liss, and Hillis (1970) used the same procedures as above to compare oral, visual, and manual form identification in normal speaking children and children with a defective /r/ sound, finding the defective /r/ speakers significantly less proficient than the normal speakers in oral form perception.

Arndt, Gauer, Shelton, Crary, and Chisum (1970) also used the NIDR forms. Three groups of subjects, first grade children, third grade children, and adults matched the form in the mouth to outline drawings of the forms, selecting one of five drawings. Each item was presented once and there were no time limits. The mean number of correct answers on the test of oral stereognosis increased from first grade children to third grade children to adults. The authors concluded that oral stereognostic ability reaches maturity at about eight years of age. The subjects were also tested on a task of kinesthetic pattern recognition using plates prepared in the manner used by Rutherford and McCall (1967). The scores on the pattern recognition test were significantly correlated with the scores on the test of oral stereognosis for the adult group.

Arndt, Elbert, and Shelton (1970) used third grade children and adults as subjects on an expanded test which included the twenty NIH forms, the five Penn State forms, and ten new forms developed at the University of Kansas Medical Center. These test results differentiated between the adult

group and the children but were not correlated with either articulation or tongue sensitivity to pressure. Tongue tip pressure sensitivity was measured with a version of the oral esthesiometer. Articulation proficiency was measured with the Templin-Darley Tests of Articulation.

Bishop, Ringel, and House (1972) compared eighteen primarily manual deaf high school students to an analogous group of normal-hearing high school students on measures of two-point discrimination and oral stereognosis. No significant differences were found on measures of two-point discrimination. Nine plastic forms were used, three triangles, three squares, and three parallelograms. The shape was kept constant within each category but size (in area) was varied. Each form was paired with itself and every other form for a total of 45 pairs, nine identical and 36 different. The nine identical pairs were repeated, giving each subject 36 different pairs and 18 identical pairs, to reduce response bias. The interstimulus interval was approximately five seconds, but time allowed for manipulation of the form in the mouth was not limited. When responding to identical pairs, both groups made approximately the same number of errors, but the deaf group made twice as many errors when responding to the different pairs. In this study, the forms were also presented manually. No significant difference was found between performances of deaf and normal-hearing subjects on the manual task (Bishop, Ringel, and House, 1972).

Studies Comparing Answer Types

Several authors have suggested that the task of comparing a form in the mouth to an outline, picture, or other form is not the same perceptual task as comparing one form in the mouth to another form in the mouth. Ringel, Burk, and Scott (1968 and 1970), Weinberg, Lyons, and Liss (1970), and Arndt, Elbert, and Shelton (1970) suggested that pointing to a visual display makes the task one of oral form recognition rather than of oral stereognosis.

Lass, Tekieli, and Eye (1971) compared these two methods of giving a response to a test of oral stereognosis. They compared a variation of the Ringel, Burk, and Scott (1968) procedure with a variation of that of Shelton et al. (1967). The procedure used in this study differed from Ringel et al. (1968) in several ways. Eleven of the NIDR forms were used instead of ten (the third triangle from the NIDR 20 was added) (see Figure 8). Each form was paired with the other forms in its geometric shape subdivision (rectangle, triangle, oval, biconcave). One form from each subdivision was paired with itself, and five pairs were randomly selected and repeated for a total of 19 pairs instead of the 65 pairs used by Ringel et al. (1968). In addition, the commercially available NIDR forms with handles were used. Unlimited time for manipulation of the form was allowed, but time between presentation of the two forms was held to no more than five seconds. The procedure used by Ringel et al. differed from Shelton et al. (1967) in that the 11 forms described above were used

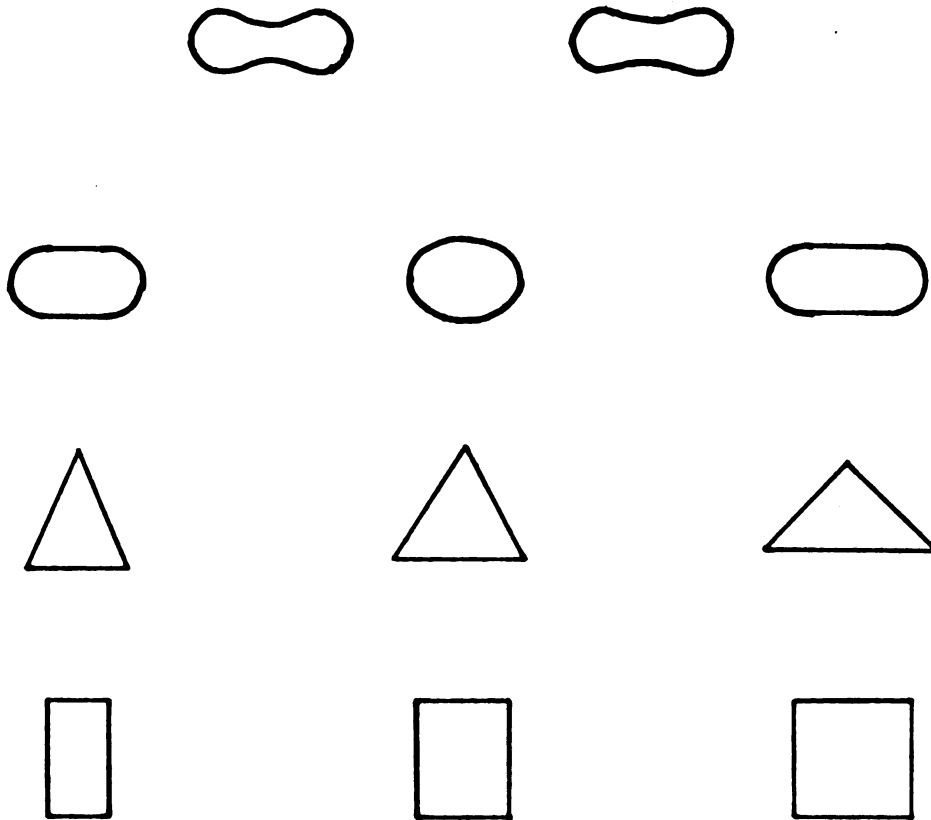


Figure 8. Outlines of the 11 NIDR forms used by Lass, Tekieli, and Eye (1971) and Lass and Hammed (1972).

instead of 20, but the test booklet in which one of five outlines was circled was the same. At one session 30 college age subjects were given a hearing screening test, an articulation screening test, an oral peripheral examination, two tests of superficial tactile sensation, one visual matching task, and a neurological history and status questionnaire. Subjects made a significantly smaller percentage of errors on the visual matching task (the Shelton procedure) than on the form discrimination task (the Ringel procedure). The visual matching scores also seemed to be more reliable. The largest number of errors was made on the triangular shape (Lass, Tekieli, and Eye, 1971). Other studies have used one or the other of these two answer types, but this was the only study which compared the two types.

Studies Comparing Form Retention Times

Several studies have used a time limitation, either on the time a subject was allowed to retain a form in his mouth or on the time between presentation of two forms (see Table 1). However, only one study has compared time conditions.

Lass and Hammed (1972) used the same eleven forms and the same pairings as Lass, Tekieli, and Eye (1971), but they used a different presentation procedure. They used 30 subjects and two conditions. They presented the forms one at a time with a five second delay between forms but with unlimited time for manipulation in the mouth in the delay condition. In the no-delay condition they presented both forms at

one time. They asked for a same-different judgment in both conditions. No significant difference was found between the delay and no-delay conditions. For both conditions, the largest number of errors involved the triangular shapes. The authors concluded that the factor of memory did not have a significant effect on subject performance and therefore could not be considered the factor responsible for the better performance on a visual matching task than on a form discrimination task which was found by Lass, Tekieli, and Eye (1971).

Studies Comparing Methodological Factors
Other Than Form Set, Answer Type, and
Form Retention Time

Williams and LaPointe (1971) selected 12 geometric shapes from the Southern California Kinesthesia and Tactile Perception Test (see Figure 9), and moulded these shapes in eight sizes (four variations of width and two of thickness) from dental acrylic. A six inch piece of monofilament line was embedded in each. The 96 forms were presented to 40 normal adult subjects who indicated identification responses by pointing to the correct answer on a chart containing outlines of the 12 shapes. Williams and LaPointe (1972) then administered this test to 25 normal speaking subjects and correlated the results with measurements of light touch and two point discrimination. No significant relationships were found among the three tasks.

LaPointe and Williams (1971a) also administered the same test to 12 normal speaking adults with the ten forms attached

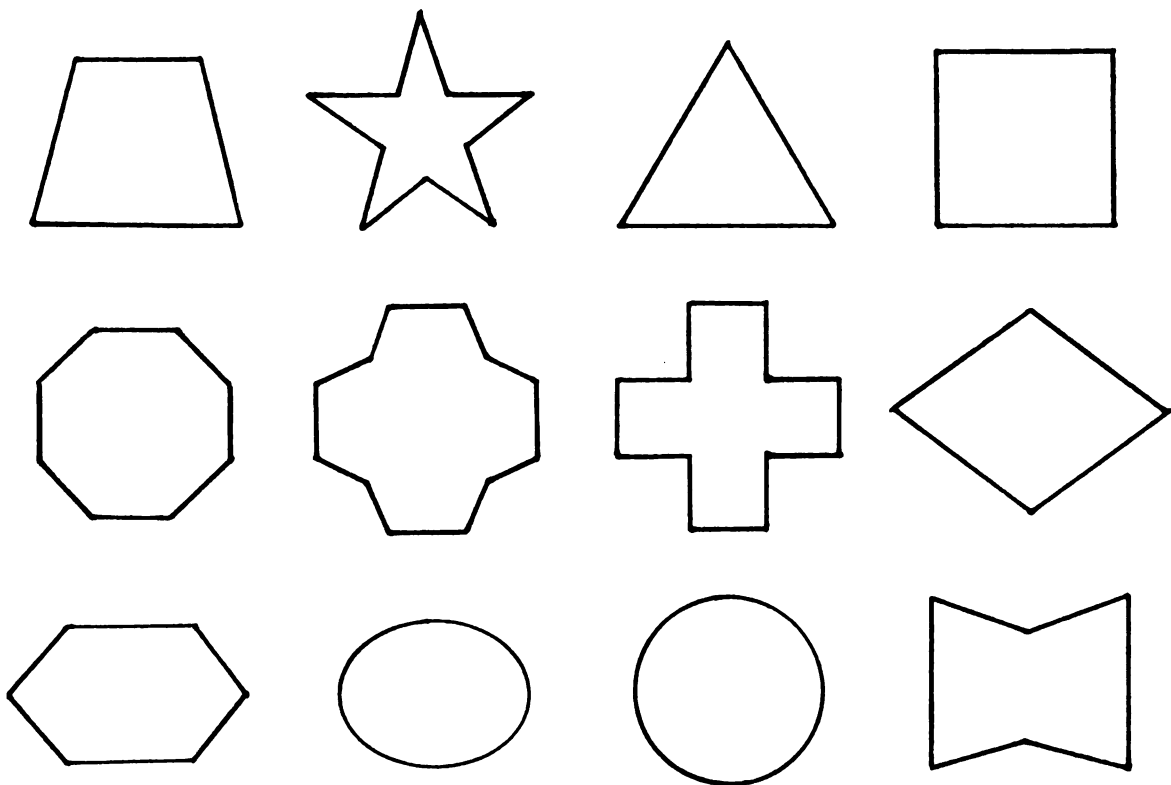


Figure 9. The 12 shapes adapted from the Southern California Kinesthesia and Tactile Perception Tests by LaPointe and Williams (1972).

to stainless steel orthodontic wire, to nylon filament as described above, and with no attachment device. No significant differences were found in either response time or response accuracy as a function of the manipulability of the forms. LaPointe and Williams (1971b) then presented the 12 shapes in one size (approximately $3/4$ inch x $3/4$ inch x $1/4$ inch) to 15 aphasic patients. The forms were presented visually as pictures on 3 x 5 cards, manually with larger wooden shapes, and finally in combinations with the oral, visual, and manual modes. Aphasics performed most accurately with visual presentation alone and least accurately with oral presentation. The authors state that the most important and potentially significant finding of this study is that simultaneous, multi-modal presentations of the geometric forms did not improve performance on recognition tasks.

Lass, Bell, Chronister, McClung, and Park (1972) used the same screening procedures as Lass, Tekieli, and Eye (1971). They used the ten shapes described by Ringel, Burk, and Scott (1968), but used the commercially available NIDR forms rather than the Ringel forms. They performed a series of four experiments using different subjects in each experiment. In the first experiment the Ringel et al. (1968) procedure of presenting 65 pairs of forms and asking for a same-different judgment was used. Thirty subjects were given feedback or no feedback about the correctness of their responses. No significant differences were found between the two conditions.

The second experiment used 11 subjects and the same method, but spread four identical sessions over a period of four weeks to determine whether or not learning effects were present. No significant differences were found in subject performance among the four sessions. The third experiment was to determine whether results were affected by the handled-handleless condition of the forms. Thirty subjects were tested using the same procedure as above. No significant difference between the two conditions was found. The fourth experiment used 25 subjects and the same procedures, except that forms were placed on the midline of the tongue tip and on the midline of the tongue dorsum. The subjects in this study made many more errors than did the subjects of the previous three studies.

Studies Comparing Normal and Articulation Defective Subjects

A study by McDonald and Aungst (1970b) reported two observations which seemed to indicate that oral sensory function as measured by form discrimination tests may not be an adequate conceptualization and may not be related to articulation proficiency. They presented a case study of a young adult male who had difficulty in identifying forms and in discriminating two-point stimulation, but who articulated normally. They also presented a study of 50 children who showed no relationship between scores on the ten item test of oral stereognosis and the ability to produce complex movements.

Aungst (1965) used 80 kindergarden and first grade children. To each child he administered the Deep Test of Articulation for /s/, /l/, /r/, and /θ/, and a measure of oral stereognosis. The test of oral stereognosis was comprised of 25 forms, the five Penn State forms and the 20 NIDR forms. A loop of dental floss was attached to a small metal eye in the five Penn State forms and to a hole drilled in each of the 20 NIDR forms. A set of all 25 clear plastic forms was sewn to blue felt to make a visual display. The subject was shown each form and was asked to match it to the visual display. Then each form was placed in the subject's mouth without his seeing it and he was asked to match it to the visual display. His response was recorded without his being told whether he was right or wrong. Results revealed a moderate relationship between oral stereognostic ability as measured by this task and articulatory proficiency. Oral stereognostic ability as measured by this task was found to be related to the correct articulation of /r/ and /θ/, but not to /s/. Aungst concluded that these findings supported McDonald's hypothesis (1964) that proprioceptive feedback from the tongue plays the most important role in the development of /r/, tactile cues from the tongue tip in the development of /θ/, and acoustic feedback cues in the development of an acceptable /s/.

Fucci and Robertson (1971) compared ten normal speakers aged 12 to 16 years with ten children in the same age range

but considered by a speech therapist to have a "functional" speech defect characterized by at least two defective sounds. The 20 NIH forms were used. The task was to match the forms eye to picture, finger tip to picture, tongue tip to picture, and tongue blade to picture. The 20 forms were divided into two classes, curves and points. A significant difference in mean error scores was found between the two groups of subjects. Both groups made significantly more errors when the forms were placed on the tongue blade. No significant difference was found between the groups designated as "curves" and "points". The authors concluded that subjects with "functional" articulation disorders make both more and different types of errors than subjects with normal articulation, suggesting that "functional" may not be a correct term to use with some persons with articulation disorders.

Studies Comparing Persons with Various Physical and Medical Abnormalities

Moser et al. (1967) reported a study in which 27 aphasic subjects from 25 to 75 years of age were compared to 32 normal subjects on tests of both manual and oral stereognosis. The 20 stem-mounted NIDR forms were used for the oral testing and a set of 20 plexiglass forms of the same thickness but twice as large as the NIDR forms was used for the manual testing. For both tests, each form was presented twice, in random order, and the subject was asked to point to the correct form on a sheet of tracings of all the forms. On the

manual testing, aphasic subjects made a significantly greater number of errors than the normal subjects. All of the aphasic subjects had originally been right-handed but were using the left or non-preferred hand due to right hemiplegias. Normal subjects used the preferred hand. On the test of oral stereognosis aphasic subjects made three times as many errors as the normal subjects. In general, on tests of both oral and manual stereognosis, aphasic and normal subjects made the same types of errors, but aphasic subjects made them with far greater frequency than the normal subjects.

Solomon (1965) questioned whether or not cerebral palsied individuals who exhibited differences in their abilities to chew, drink and articulate also exhibited differences in degree of sensory and perceptual disfunction of the oral cavity. She categorized athetoids according to normal, mildly defective, and grossly defective in chewing, drinking, and articulation abilities and tested them on five measures of perception involving the oral cavity. The five measures of perception were stereognosis, weight perception, texture perception, two-point discrimination, and localization. Oral stereognosis was tested with the five Penn State forms without handles but with dental floss attached. The subjects were blindfolded and allowed unlimited response time. The subjects responded by pointing to one of a set of forms placed on a table in front of them. Two out of three correct responses were considered to be one correct response.

Significant differences in oral stereognostic abilities were found between subjects whose drinking abilities were classified as normal and moderately defective, between mildly and moderately defective, between normal and grossly defective, and between mildly and grossly defective. A correlation of .70 was found between scores on an articulation test and scores on the test of stereognostic ability. A correlation of .81 was found between ratings of chewing ability and stereognostic test scores. The relationship between the combined measures of chewing, drinking, and articulation and the test of oral stereognosis was more marked than the relationship between the motor ability measurements and any of the other four measures of perception (Solomon, 1965).

Lagourgue, in a study reported by Moser et al. (1967), compared subjects with defective vision and subjects with defective hearing, using the 20 NIDR forms on handles. The visually impaired subjects matched forms manually. Both groups matched each form to one of a set of the 20 forms which had been arranged in groups of similar shapes and cemented to a sheet of plexiglass to form a sample board. No significant differences were found between blind, oral deaf, and manual deaf subjects (Moser et al., 1967).

Moser et al. concluded that the "present set of NIH forms is useful in differentiating normal and aphasic subjects but a smaller size would be more effective in testing for differences among normal subjects, deaf, blind, and speech defective individuals" (p. 283). It was also concluded that forms

mounted on wands or handles should be used in preference to forms mounted on plexiglas strips because the scores from tests which utilize the blade mounted forms have been consistently lower than the scores from tests which utilize wand-mounted forms.

Mason (1967) tested cleft palate subjects from six to forty-five years of age. The 20 NIH forms, on wands, were matched by pointing to duplicate test items mounted on an 8 x 11 inch board. The subject was told to manipulate the object in his mouth with the wand and was given unlimited time for manipulation and response. The mean number of correct responses was 15.2 out of 20 items. The patterns of items most often identified correctly and incorrectly were stated to be consistent with the data presented by Shelton et al. (1967) and McDonald and Aungst (1967). The authors also stated that no significant differences in oral stereognostic ability were found between cleft palate subjects and normals.

Using the above procedure, Mason (1967) tested adult subjects in the absence of anesthesia, after unilateral mandibular block anesthesia, and after bilateral mandibular block anesthesia. He concluded that: (1) without anesthesia, most oral perception (used synonymously with oral stereognosis) was done in the area of the anterior two-thirds of the tongue; (2) unilateral mandibular block anesthesia had little effect on oral stereognosis scores; (3) bilateral mandibular block

anesthesia was associated with a loss of perception in some subjects; (4) during mandibular block anesthesia more structures were used, and the objects were manipulated more vigorously in relation to tongue, lips, teeth, and palate; and (5) block anesthesia did not appear to cause loss of deep pressure sensation in the oral area.

Henkin (1970) used the 20 NIH forms with handles and without the use of lips or teeth with normal adults and with adults with chronic diseases (progressive systemic sclerosis, chromatin negative gonadal dysgenesis, Type I familial dysautonomia, Type I and Type II hyposmia). The subjects pointed to a picture board to identify the stimulus. The normals took significantly longer to perform the oral than the manual task but recognized the forms very quickly and accurately, both manually and orally. The authors concluded that measurements of both oral and manual stereognosis could be used to distinguish among patients with various chronic diseases and between normal patients and patients with chronic diseases.

Summary and Statement of the Problem

As discussed above, it has been suggested (McDonald and Aungst, 1967) that oral stereognosis (form identification in the mouth) is a more promising measure of oral sensory function than two-point discrimination, weight perception,

localization, or texture discrimination. Prior investigators have found that oral stereognostic testing scores are related to measures of chewing, drinking, and articulation (Solomon, 1965), to measurements of two-point discrimination and light touch (Williams and LaPointe, 1971), and to kinesthetic pattern recognition (Arndt, Gauer, Shelton, Crary, and Chisum, 1970), but are not related to measurements of tongue sensitivity or to pressure as measured with an oral esthesiometer (Arndt, Elbert, and Shelton, 1970).

There seemed to be agreement that oral stereognostic ability improves with age up to a point of maturity, but the age at which that point is reached was disputed (McDonald and Aungst, 1967; Shelton, Arndt, and Heatherington, 1957; Arndt, Gauer, Shelton, Crary, and Chisum, 1970). There also seemed to be agreement that the presence or absence of handles or threads attached to the forms makes no significant difference in test results (LaPointe and Williams, 1971a; Lass, Bell, Chronister, McClung, and Park, 1972). There seemed to be disagreement on whether or not there is a learning effect on successive administrations of forms, with Shelton et al. (1967) suggesting that there is, and Lass, Bell, Chronister, McClung, and Park (1972) suggesting that there is not.

Attempts to establish a relationship between oral stereognostic ability and articulation proficiency were less clear. The preponderance of evidence pointed to the existence of a relationship, but there was some disagreement. Class (1956)

found adults with articulation disorders making more errors on a test of oral stereognosis than stutterers or persons with normal articulation. Ringel, Burk, and Scott (1968 and 1970) and Ringel, House, Burke, Dolinsky, and Scott (1970) found both children and adults with articulation disorders making a greater number of errors than persons with normal articulation. Further, they found the number of errors correlated with the severity of disorder. Weinberg, Liss, and Hillis (1970) found a correlation between /r/ defective speakers and speakers with normal articulation of /r/, while Aungst (1965) found a correlation between correct production of both /r/ and /θ/ but not with /s/. Fucci and Robertson (1971) found a significant difference between 12-16 year olds with normal articulation and those with at least two defective sounds. Locke (1968b and 1969) found a relationship between oral stereognostic scores and the accuracy of learning of new consonant sounds.

On the other hand, McDonald and Aungst (1970b) reported a case history of a neurologically involved adult who had an almost total inability to identify forms but who had normal articulation. They also reported a study which tested fifty children and found no relationship between oral stereognostic scores and the ability to make complex articulatory movements. Arndt, Elbert, and Shelton (1970) and Kile in Moser et al. (1967) also reported no significant differences between subjects with normal and with defective articulation. Kile used

the NIDR shapes mounted on plastic strips, a method not used by any of the other investigators who found relationships. Arndt et al. (1970) used a thirty-five item test containing twenty-five forms used by other investigators. McDonald and Aungst (1970b) used their selection of ten of the 20 NIDR forms. All three of the studies which found no relationship were using a point to outline type response.

Considering that the disputed relationship between articulation proficiency and oral stereognosis scores arises from scores made on different forms and using different responses, it is possible that the investigators may be dealing with a relationship which can be better measured with some combinations of form set and answer type than with others.

In both the studies which compared normal and defective articulation and those which compared other classifications of physical disorders, the two methodological factors of form set used and answer type required have been varied. In addition, size of form, presence or absence of manipulation of the forms, time restrictions, the effect of telling the subject whether or not his answer was correct, and type of attachment to the form, if any, have been varied.

If the idea is to be accepted that testing oral stereognosis evaluates sensory capacities which may or may not be related to articulation proficiency, then there seem to be two basic questions which need answering. The first implies determination of the best method to test oral stereognosis,

and the second is whether or not a test of oral stereognosis is testing the oral sensory abilities which are directly related to speech production. It is suggested that the second question cannot be answered until the first question has been answered. Therefore, this study has attempted to compare three aspects of the methodologies used in testing oral stereognosis.

Specifically, the following questions were investigated.

- (1) Will differences among sets of oral stereognosis forms (the Penn State set, the Ringel set, the McDonald and Aungst set, and the NIDR set) result in different oral stereognostic scores for young adult subjects with normal articulation?
- (2) Will differences between answer types, i.e., between giving a response based on visual matching of the oral forms to outline drawings, or giving a same-different judgment between two forms, result in different oral stereognostic scores for young adult subjects with normal articulation?
- (3) Will differences in form retention time, i.e., between unlimited time for retention of the forms in the mouth and a five second time limit on retention, result in different oral stereognostic scores for young adult subjects with normal articulation?

CHAPTER II

EXPERIMENTAL PROCEDURES

This study consisted of a comparison of three aspects of the process of testing oral stereognosis: form set used, type of response required from the subject, and form retention time.

Subjects

The subjects of this study were 40 young adults (16-30 years of age) with no history of neurological or sensory defects. All subjects exhibited normal hearing as measured by a pure tone audiometric screening test at 500, 1000, and 2000 Hz at 25 dB (re ISO). All subjects exhibited normal articulation as judged by a speech pathologist during conversational speech.

Experimental Conditions

Sixteen experimental conditions were presented to every subject, including all possible combinations of: (1) four sets of oral stereognostic forms (the NIDR set of twenty forms, the ten NIDR forms used by McDonald and Aungst, the

ten NIDR forms used by Ringel, and the five Penn State forms); (2) two form retention times (a five second limit for oral manipulation of the forms and no time limit); and (3) two types of responses (pointing to an outline of a single form being tested and giving a same-different judgment to pairs of forms presented sequentially). Thus, each subject received the following 16 combinations in a different random order:

1. Penn State + five seconds + same-different
2. Penn State + five seconds + point to outline
3. Penn State + unlimited + same-different
4. Penn State + unlimited + point to outline
5. NIDR 20 + five seconds + same-different
6. NIDR 20 + five seconds + point to outline
7. NIDR 20 + unlimited + same-different
8. NIDR 20 + unlimited + point to outline
9. McDonald and Aungst + five seconds + same-different
10. McDonald and Aungst + five seconds + point to outline
11. McDonald and Aungst + unlimited + same different
12. McDonald and Aungst + unlimited + point to outline
13. Ringel + five seconds + same-different
14. Ringel + five seconds + point to outline
15. Ringel + unlimited + same-different
16. Ringel + unlimited + point to outline

The order of presentation of the individual forms or pairs of forms used in each condition was randomized for each subject.

For the eight conditions in which a same-different judgment was required, each form was paired with itself and with

every other form in the set. Order of presentation of each pair was alternated, i.e., circle-square then square-circle. The Ringel and the McDonald and Aungst sets each contained ten forms. Therefore, pairing each form with itself and all other forms produced 55 pairings. Ten of these pairings were randomly selected for repetition, giving a total of 65 pairs per set to be presented. All possible combinations of the NIDR set, which contained 20 forms, gave 210 possible pairings. Fifty-five of these pairings were randomly selected for presentation, and ten of these 55 were randomly selected for repetition, thus giving the same total of 65 pairs presented as presented in the Ringel and the McDonald and Aungst form set combinations (for a list of the 55 pairings selected, see Appendix E). For the Penn State form set, only 15 pairings were possible when each form was combined with itself and all other forms. Five of these 15 pairings were randomly selected for repetition, giving a total of 20 pairs presented.

For the 8 conditions of point to outline type response, each form of a set was presented singly, in a different random order for each subject, and the subject was required to match the form to an outline. He selected the outline from a chart. A separate chart drawn for each set gave outlines of all the forms contained in that set.

Therefore, for each of the two combinations of the Penn State forms and a point to outline response, the subject received five presentations. For each of the two combinations

of the Penn State form set and a same-different response, he was presented 20 pairs. Thus, for the four Penn State combinations he received a total of 50 presentations.

For each of the two combinations of the NIDR form set with a point to outline response, the subject received 20 presentations. For each of the two combinations of the NIDR form set and a same-different response, the subject was presented 65 pairs. Thus, for the four NIDR combinations he received 170 presentations.

For each of the two combinations of the Ringel form set with a point to outline response, the subject received ten presentations. For each of the two combinations of Ringel forms and a same-different response, he was presented 65 pairs. Thus, for the four Ringel combinations he received a total of 150 presentations.

Since there were also ten forms in the McDonald and Aungst form set, the number of presentations was the same as for the Ringel form set. All of the above combinations were presented under both limited (to five seconds) and unlimited retention times.

For all 16 combinations, each subject received 90 presentations of single forms and 430 presentations of pairs of forms, thus receiving a total of 520 presentations.

Procedures

The subjects were asked not to smoke, eat, or drink anything except water for thirty minutes prior to being tested. All subjects were asked to complete a personal history form (see Appendix B). Subject responses under the imposed time limit were timed with a stop watch. Completion of the 16 experimental tasks required from two to three hours, averaging approximately two hours and 15 minutes. The subjects were allowed to rest or have a drink of water at any time they wished. Both preliminary testing and the results of other research indicated that this time period was not excessively long. Since manipulation of the forms sometimes caused excess salivation, tissues were provided for the subject's use. Each subject was tested individually.

Subjects were shown all four sets of forms and the four charts of form outlines used in the point to outline response before testing started. They were allowed to refer back to the charts or the forms at any time they wished except during actual pair presentations (for exact instructions to the subjects, see Appendix C). The examiner used sterilized forceps to place those forms without handles in the subject's mouth. When finished with the form the subject spit it onto the sterile towel. For forms with handles, the examiner placed the handle in the subject's hand and the subject placed the form in and removed it from his own mouth. The subjects closed their eyes during the presentation of the forms.

The subjects, therefore, were allowed no manual or visual cues. The subjects were told each time an incorrect answer was given and were allowed to look at the forms they had missed if they wished.

A list of the forms to be presented was prepared for each combination for each subject. Forms or form pairs were listed by number. Each form with a handle was marked with a number on a piece of masking tape fastened to the handle. For the handleless forms the numbers and outlines of the forms were written on a card which was placed on the table above the forms. Each subject's responses were recorded on the list of forms to be presented.

Outlines of the forms were drawn to scale on large sheets of heavy white paper. Each set of forms was drawn on a separate sheet. The ordering of the outlines on the charts was the same as the numbered orders shown on Figure 1 (Penn State forms), Figure 2 (NIDR forms), Figure 3 (McDonald and Aungst forms), and Figure 4 (Ringel forms).

CHAPTER III

RESULTS

An analysis of variance using arcsin transformations was performed upon the percentages of incorrect scores obtained for the several variables under study (the four sets of oral forms, the two levels of form retention time, and the two levels of answer type) and their respective interactions. Significant main effects were found for the factors of oral form set and answer type. There was no significant effect associated with the form retention time factor. A significant interaction was found to occur between oral form set and answer type. A significant three way interaction was found to occur between oral form set, answer type, and form retention time. Mean data for all variables and interactions can be found in Table 2. (A complete analysis of variance table can be found in Appendix D).

Effect of Differences Among Oral Form Sets

There was a significant main effect ($F = 212.45$, $df = 3$, $p < 0.0005$) for the factor of oral form set. As can be seen in Figure 10 and Table 2, the Ringel form set was the most

Table 2. Mean percentage error scores for each level of each factor under study (Form Set, Answer Type, Form Retention Time) and their respective combinations.

Form Retention Time	Answer Type	Form Set				= M
		Penn State	Ringel	McDonald & Aungst	NIDR 20	
5 seconds	Outline	0.0	25.3	11.0	24.0	15.1
	Same-different	0.5	5.4	1.9	4.7	3.1
	Combined	0.3	15.4	6.5	14.4	9.1
Unlimited	Outline	0.0	27.8	6.8	18.6	13.3
	Same-different	0.8	4.4	2.7	4.0	2.9
	Combined	0.4	16.1	4.8	11.3	8.1
Total combined		0.7	15.7	5.6	12.8	

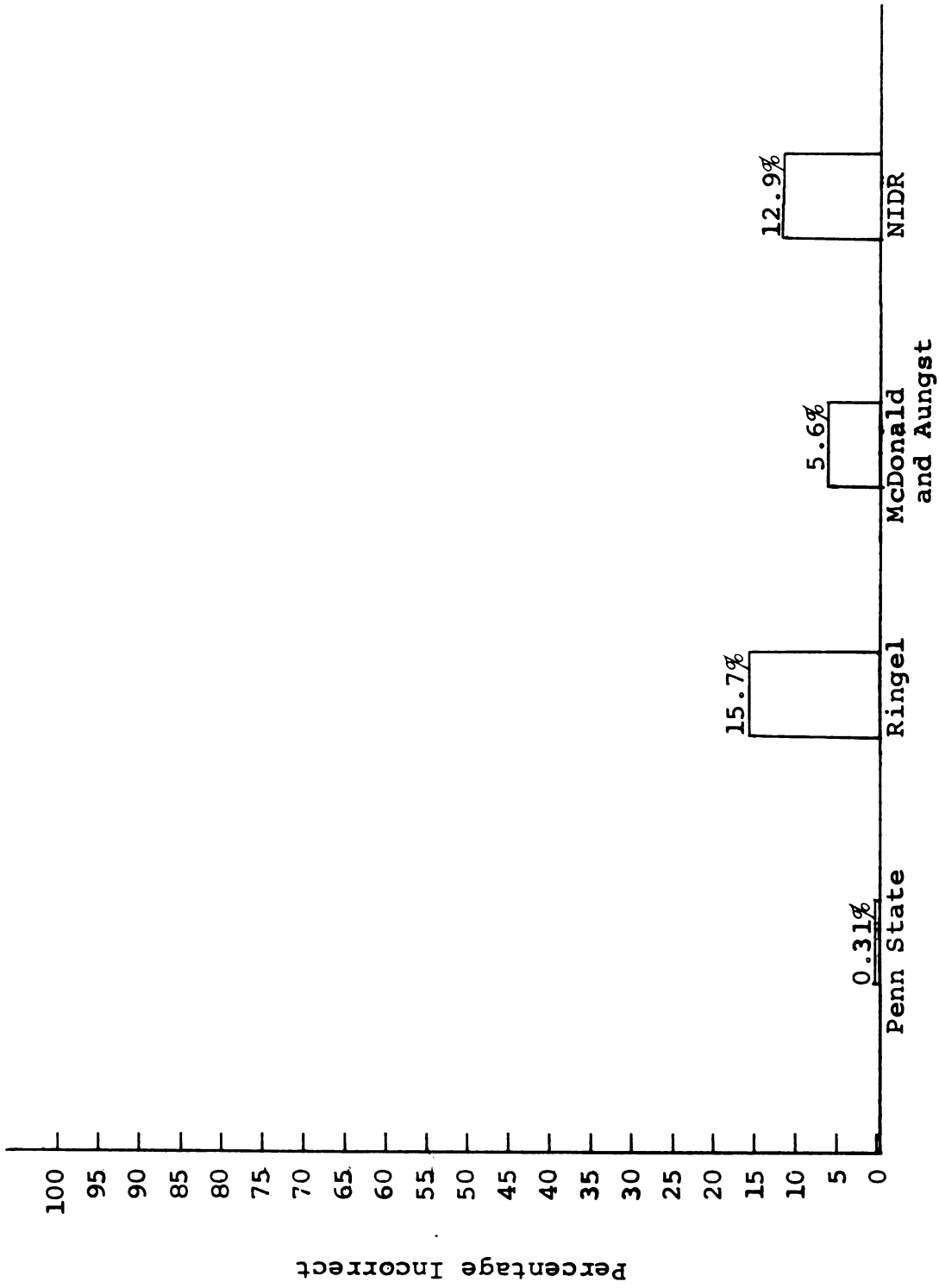


Figure 10. Mean percentage of errors for each form set summed across answer type and form retention time.

difficult overall, followed by the NIDR form set, the McDonald and Aungst form set, and the Penn State form set, respectively. There was less difference in difficulty between the Ringel and NIDR form sets than between any other two sets. Thus, different form sets do result in different scores.

Effect of Differences Between Answer Types

There was a significant main effect ($F = 238.51$, $df = 1$, $p < 0.0005$) for the factor of answer type. As can be seen in Figure 11 and Table 2, the percentage of errors made when responding by pointing to an outline was nearly five times greater than the percentage of errors made when subjects were asked to make a same-different judgment.

Effect of Differences Between Form Retention Times

The difference between an unlimited time for retention of a form in the mouth and a five second time limit was not significant ($F = 2.95$, $df = 1$, $p < 0.082$). As can be seen in Table 2, the percentage of errors for the five second time limit, while not significantly different, is slightly larger than that for the unlimited retention time.

Interactions

There were four interactions possible among the three factors tested. No significant interaction was found for the

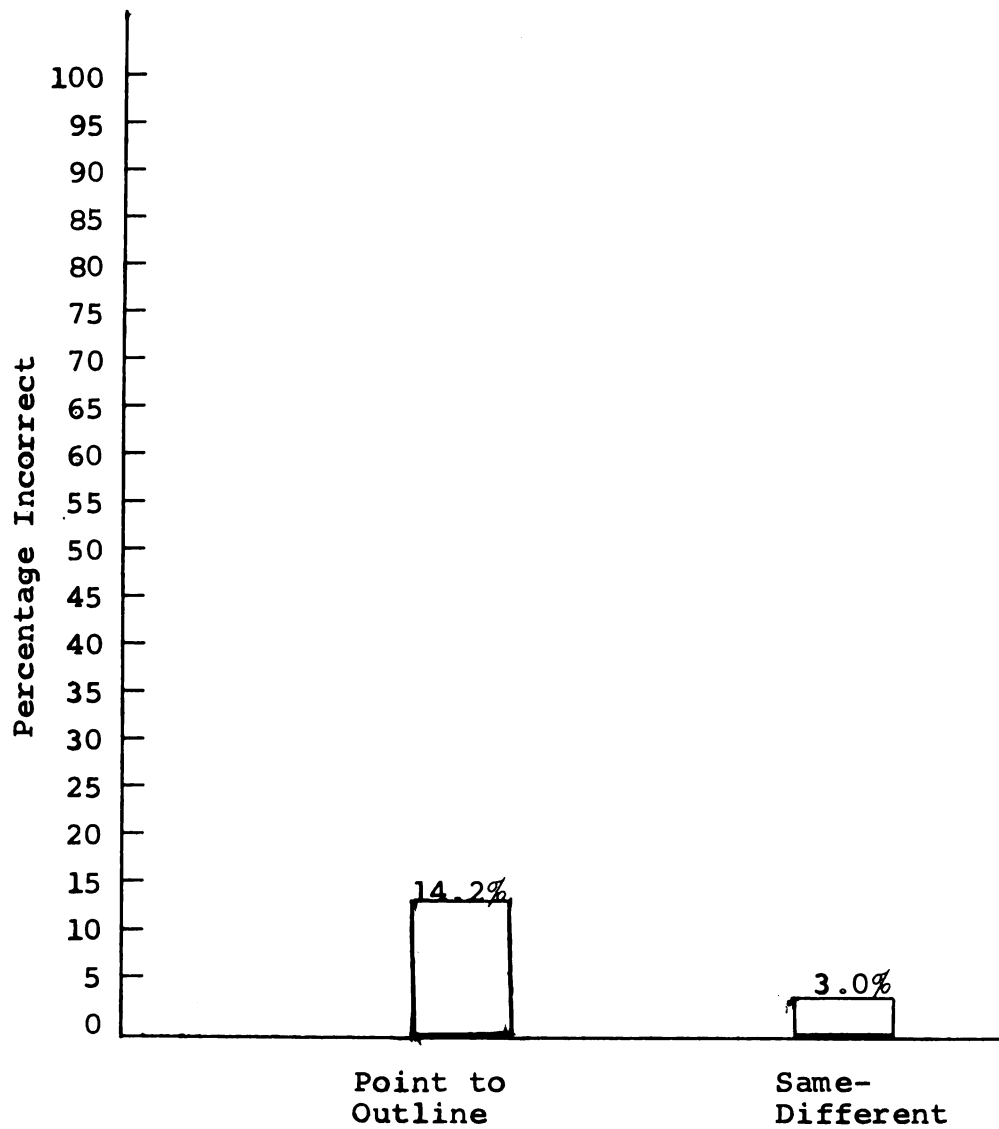


Figure 11. Mean percentage of errors for each answer type summed across form set and form retention time.

combination of form set and form retention time ($F = 1.27$, $df = 3$, $p < 0.282$) or the combination of form retention time and answer type ($F = 1.48$, $df = 1$, $p < 0.222$). A significant interaction was found for the factors of answer type and form set ($F = 55.87$, $df = 3$, $p < 0.0005$). This interaction is illustrated in Figure 12 and Table 2.

In addition to the above effects, a significant three way interaction ($F = 3.01$, $df = 3$, $p < 0.029$) was found between oral form set, answer type, and form retention time. This interaction is illustrated in Figure 13 and Table 2. (An analysis of variance table for all factors and the several combinations studied can be found in Appendix D.)

Difficulty of Different Combinations

The order of difficulty of the 16 different combinations of form set, form retention time, and answer type can be seen in Table 3. It can be seen that for the two most difficult sets, the Ringel and NIDR sets, the point to outline type answer tends to yield more errors than the same-different type response when no time limit response is required. The point to outline response produced more errors when combined with either time limit than did the same-different response when combined with either time limit. This was true for all sets of forms except the Penn State set. The Penn State forms maintained their position as the easiest set under all conditions.

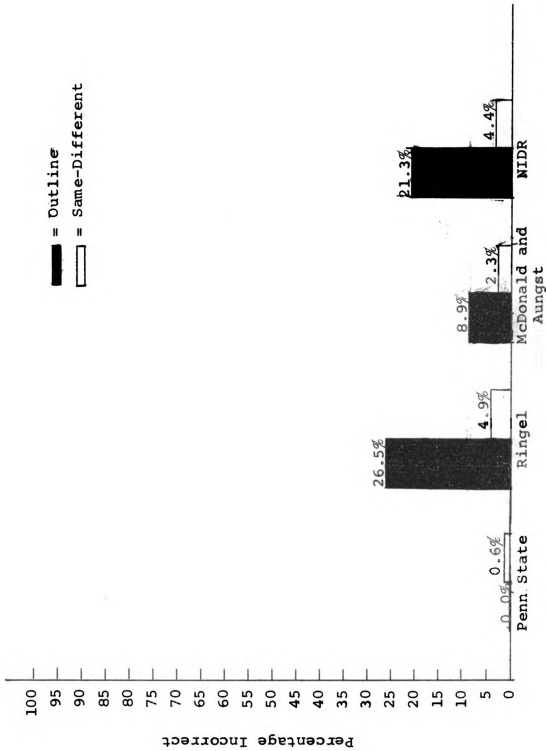


Figure 12. Mean percentage of average for each response type by form set, summed across form retention times.

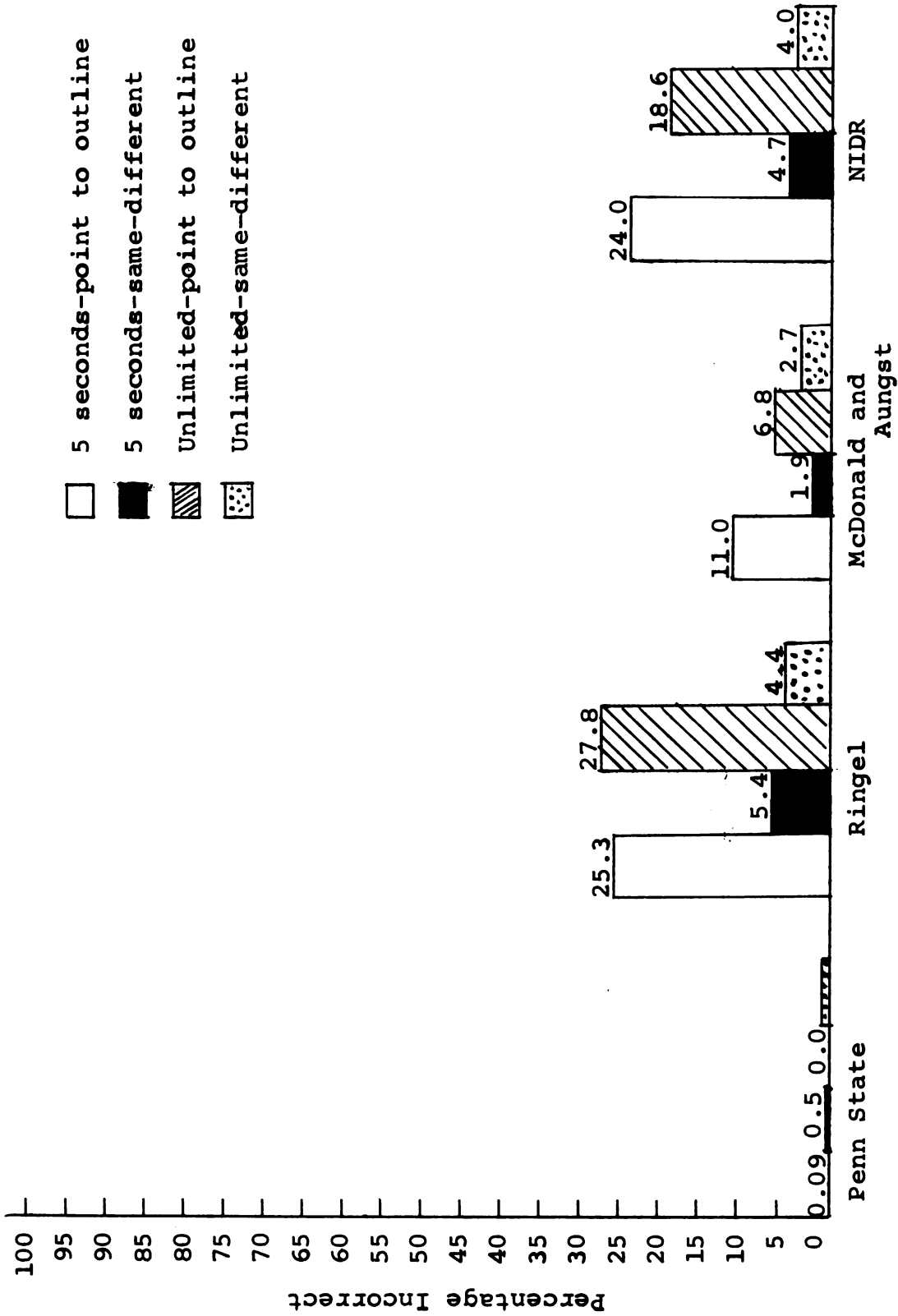


Figure 13. Mean percentage of errors for each combination of form set, answer type, and form retention time.

Table 3. Mean percentage of errors for each of the 16 possible combinations of form set, answer type, and form retention time used in this study, in order of difficulty.

Combination	Mean Percentage of errors
1. Ringel + unlimited + point to outline	27.8
2. Ringel + 5 seconds + point to outline	25.3
3. NIDR 20 + 5 seconds + point to outline	24.0
4. NIDR 20 + unlimited + point to outline	18.6
5. McDonald & Aungst + 5 seconds + point to outline	11.0
6. McDonald & Aungst + unlimited + point to outline	6.8
7. Ringel + 5 seconds + same-different	5.4
8. NIDR 20 + 5 seconds + same-different	4.7
9. Ringel + unlimited + same-different	4.4
10. NIDR 20 + unlimited + same-different	4.0
11. McDonald & Aungst + unlimited + same- different	2.7
12. McDonald & Aungst + 5 seconds + same- different	1.9
13. Penn State + unlimited + same-different	0.8
14. Penn State + 5 seconds + same-different	0.5
15. Penn State + unlimited + point to outline	0.0
16. Penn State + 5 seconds + point to outline	0.0

Difficulty of Individual Forms and Pairs

The order of difficulty for forms in all four sets, both for single presentations and for pair presentations, is reported in Tables 4, 5, 6, and 7. Possible pairs not given in the tables for the Penn State, Ringel, and McDonald and Aungst form sets had no errors. Pairs not given for the NIDR set either had no errors or were not used in this study. (For a list of the NIDR pairings used in this study see Appendix E.) Since some of these forms do not have names, the forms are referred to by the numbers used in Figures 1 through 4.

Using visual categories, each of the five Penn State forms (see Table 4) falls into a separate category, and there is insufficient knowledge of oral sensory categories to divide them any other way. There were no errors for the Penn State forms presented singly and less than 1% error when presented in pairs. Thus the individual forms of this set appeared to be approximately equal in difficulty.

Table 4. Descending order of difficulty for pair presentation of the Penn State form set, including only presentations on which errors were made.

Pairs	
1.	1-2
2.	1-1*
3.	2-2
4.	3-3*
5.	3-5
6.	5-5

* Pairs which were among those repeated.

For the Ringel form set, when forms were presented singly, form number 7 was the most difficult and form number 3 was the least difficult (see Table 5). If the forms are classified according to the visual categories used by Ringel, Burk, and Scott (1970) and using only total errors without regard to whether the category contains two or three forms, then the ovals (forms 6, 7, 8) were the most difficult, followed by the biconcaves (forms 9 and 10), the triangles (forms 1 and 2), and the rectangles (forms 3, 4, 5), respectively.

The McDonald and Aungst set cannot easily be classified according to the visual categories used by Ringel (1970). It can be noted, however, that the most difficult pair is composed of the two most difficult single forms (see Table 6).

The NIDR form set can be classified using the four Ringel, Burk, and Scott (1970) categories of triangles (forms 1, 2, and 3), rectangles (forms 6, 7, and 8), biconcaves (forms 18 and 19), and ovals (forms 14, 15, and 20), plus the addition of a category for circular forms (forms 11, 12, and 13), for irregular curved shapes (forms 16 and 17), and for forms with pointed protuberances (forms 4, 5, 9, and 10). The use of such categories will be questioned in the discussion. However, if these categories are used, then in terms of total errors without regard for category size, the descending order of difficulty for pair presentations was biconcaves, ovals, irregularly shaped curved forms, forms with points or protuberances, rectangles, triangles, and circular forms. Pair 18-19, the

Table 5. Descending order of difficulty for pair presentations and single presentations of the Ringel form set, including only presentations on which errors were made.

Pairs		Singly	
1.	9-10	1.	7
2.	7-8	2.	4
3.	1-2	3.	1
4.	2-2 *	4.	8
5.	3-4	5.	9
6.	10-10	6.	10
7.	9-9	7.	6
8.	5-5	8.	2
9.	1-1	9.	5
10.	6-7	10.	3
11.	8-8		
12.	5-7		
13.	7-7		
14.	4-4		
15.	1-5 *		
16.	6-6		
17.	8-9		
18.	5-8		
19.	6-8 *		
20.	7-10 *		
21.	2-5 *		
22.	3-3		
23.	4-5		
24.	4-10		
25.	1-4		
26.	2-6		
27.	4-6		
28.	5-6 *		
29.	5-10		
30.	7-9		

*Pairs which were among those repeated.

Table 6. Descending order of difficulty for pair presentations and single presentations of the McDonald and Aungst form set, including only presentations on which errors were made.

Pairs		Singly	
1.	3-5	1.	3
2.	1-1	2.	5
3.	9-9	3.	6
4.	3-4	4.	9
5.	2-2 *	5.	7
6.	7-7	6.	4
7.	1-7 *	7.	1
8.	3-3	8.	2
9.	6-6	9.	8
10.	4-5	10.	10
11.	5-5		
12.	2-6		
13.	3-6 *		
14.	2-7		
15.	6-9		
16.	2-5 *		
17.	2-9		
18.	8-8		
19.	4-4		
20.	1-2		
21.	1-3		
22.	2-10		
23.	4-7 *		
24.	6-7		
25.	7-8		
26.	7-9		
27.	10-10		

* Pairs which were among those repeated.

Table 7. Descending order of difficulty for pair presentations and single presentations of the NIDR form set, including only those presented pairs on which errors were made.

Pairs		Singly	
1.	18-19 *	1.	20
2.	16-19 *	2.	19
3.	6-7	3.	18
4.	14-14 *	4.	15
5.	9-10	5.	3
6.	15-15	6.	2
7.	14-15	7.	7
8.	1-1	8.	10
9.	4-4	9.	16
10.	5-9 *	10.	17
11.	11-13	11.	14
12.	1-7	12.	1
13.	1-16	13.	9
14.	11-11	14.	8
15.	1-6 *	15.	6
16.	8-16	16.	4
17.	4-9	17.	5
18.	1-13	18.	11
19.	1-17 *	19.	13
20.	2-9	20.	12
21.	6-9		
22.	14-17		
23.	14-20		

* Pairs which were among those repeated.

two biconcave forms, is the most difficult pair and was missed 50% of the times presented. These two forms were also the second and third most difficult of the twenty when presented singly. For single presentations, the decending order of difficulty was ovals, biconcaves, triangles, rectangles, forms with points or protuberances, irregular curved forms, and circular forms.

CHAPTER IV

DISCUSSION

This study compared the effects of varying oral stereognostic form set, answer type, and form retention time on the percentage of errors made by normal adult subjects. All subjects ($N = 40$) received 16 treatments, including all possible combinations of the four form sets, two answer types, and two form retention times under study.

Form Set

There is no question that the selection of a set of forms to use in testing affects the percentages of errors obtained from testing oral stereognosis. Thus, results of prior research with different sets of forms are not comparable to each other. The fact that Arndt, Elbert, and Shelton (1970) found no correlation between oral stereognostic scores and articulation ability may be due to the fact that the researchers used the difficult NIDR set of forms for testing. The presence of a correlation between oral stereognostic scores and articulation found by Class (1956) may be due to the use of her particular form set. Since the form set used by Class (1956) was not employed in the present study, her

results cannot be compared with those of studies using the form sets of the present investigation. Since the testing instruments gave significantly different results, no conclusion can be made concerning whether or not articulation ability and oral stereognosis are in fact related, or, if so, how they are related. The difference in degree of difficulty between form sets found in this study suggests that the different sets of forms may be testing different abilities. The differences in order of difficulty of pairs and individual presentations presented in Tables 4-7 showing that some shapes are more difficult to identify when presented either singly or in pairs also suggests that the different forms are measuring different abilities, or at least that different characteristics of the forms may be being used in making judgments.

The sensory ability to judge whether a form is the same as or different from an outline on a chart or from another form is essentially an ability to make categorizations using sensory criteria. The question then arises, what are the criterial attributes of the categories involved? What are the attributes whose presence or absence is the basis for the categorical judgments? Definition of the criterial attributes of the categories involved would enhance explanation of the sensory ability being tested. At present we know neither the categories into which the sensory mechanism is sorting stimuli nor the process by which the sorting is being done.

One perceptible attribute by which a form shaped like a star and a form shaped like a triangle (or any two of the oral stereognostic forms of any sets) can be differentiated is the attribute of distance. The length of the perimeter, height at tallest and shortest places, ratio of length to width, and other such measurements may be evaluated by the subject.

That the sensory mechanism is capable of judging distance was illustrated by the findings of Dellow et al. (1970) who had subjects make size judgments. They noted that subjects seemed to hold plastic cylinders of varying lengths against the front of the mouth and move the tongue back and forth along the length of the cylinder in order to make their judgments. Further, Ringel, Saxman, and Brooks (1967) reported that subjects were capable of judging the size of mouth openings.

Further support for the possibility that the sensory system is able to measure distances comes from the target specification theory of articulatory movements proposed by MacNeilage (1970). He suggests that commands for articulatory and other physical movements are not commands to move through a particular pattern but are commands to move to a specified place, regardless of what the position of the articulators may have been when the command to move was given. If this is true, then it is necessary that the oral sensory system be able to measure distances. It is also then possible that a

particular form may be categorized on the basis of the distances which the tongue must move in order to reach the positions necessary for the exploring of the form.

Additionally, tongue sensitivity to pressure, which requires no distance judgment, was not found to be correlated with oral stereognostic scores (Arndt, Elbert, and Shelton, 1970). Oral stereognostic scores were found to be correlated with kinesthetic pattern recognition (Arndt, Gauer, Shelton, Crary, and Chisum, 1970), which does require tongue movement to trace a pattern grooved into a plastic plate. It would seem from these correlations that there may be some relationship between the ability to measure movements and the ability to identify oral stereognostic forms. However, McDonald and Aungst (1970b) found no relationship between oral stereognostic scores and the ability to produce complex movements, an ability which does require a distance judgment.

Another criterial attribute by which the sensory system may be categorizing these forms is rate of movement. It may be that not only is the distance moved by the articulatory structures a basis for categorical judgments, but also the amount of time needed to move that distance.

Recent research by Manning (1972) into the effects of coarticulation, i.e., the overlapping and influencing by a phone of the characteristic features of a preceding or succeeding phones, suggested that speed of production of ongoing speech influences the articulatory end-product. He suggests

that the more rapid the rate of speech, the greater the degree of coarticulation. He also suggested that perceptual strategies may vary with the temporal conditions under which the articulatory system is operating. If it is true that the oral sensory system is capable of and uses precise measurements of time during articulation, it may be that a measure of the time necessary to move the tongue tip from one end of a form to another or around the perimeter of a form may be one of the attributes by which forms are being discriminated and categorized.

The developmental theories of Piaget (1955) and Barsch (1965) propose that children start to learn concepts of distance while still in a motor stage of development, that the concept of distance is related to the knowledge that it takes longer to move from A to B than from A to C, and that, consequently, the distance from A to B is greater than the distance from A to C. This use of a time judgment to make a distance judgment may be used by the oral sensory system.

If these two judgmental abilities are related at all it would be expected that a condition which affected one would affect the other. It has been found that articulatory errors, which involve a distance judgment, and rate of speech, which involves a time judgment, are both affected by anesthesia. Ringel (1970) found both a greater number of articulation errors and less variation in rate when the articulatory structures were anesthetized. McCroskey (1958) also found

differences in rate of speech associated with the reduction of tactile feedback under oral anesthetization.

The differences among the four sets of forms studied are so great that during the testing subjects consistently remarked on the ease of the Penn State set and the difficulty of the NIDR set. There were fewer comments about the difficulty of the Ringel set even though it was harder overall than the NIDR set. This may be due to the fact that the subjects were more concerned about using forms without handles, as reflected in their comments. Some subjects, however, rather than considering the Ringel forms awkward, commented that it was easier to manipulate the Ringel forms because the absence of handles allowed them to position the form in the mouth in any way desired. LaPointe and Williams (1971a) and Lass, Bell, Chronister, McClung, and Park (1972) reported that the handle-handleless condition of the forms was not significant. The LaPointe and Williams study (1971a) used a set of forms different from any tested here and the Lass et al. (1972) study used the same shapes as the Ringel set. The lack of significance found for the factor of handled versus handleless condition in these two studies may be due to the choice of form set or to the interaction between a form set and an answer type or the interaction between a form set, an answer type, and a form retention time as found in this study.

Most subjects stated a preference for the smoother, sharper-edged plastic of the Ringel set to that used in the commercially available NIDR and Penn State sets, even though

the Ringel set was the most difficult. This was primarily a preference for the material of which the forms were made, not a preference for the shapes of the form set. However, since the Ringel set was the most difficult, this suggested that subject preferences, at least in the matter of materials, were irrelevant to accuracy. Several of the NIDR forms (which include the McDonald and Aungst set) had rough edges which were not noticeable to the eye but were noticed by the first two or three subjects and were filed off with an emery board. Subjects also remarked that the texture of the plastic differed among the Penn State forms, particularly between the sphere and the cylinder.

Subjects seemed to choose to use different oral structures for identification of the forms. Most subjects appeared to use the tongue tip most of the time. All prior investigations that compared the sensitivity of the tongue tip to other oral structures found greater sensitivity in the tongue tip. It may be that this greater sensitivity of the tongue tip is related to the abilities to measure distances moved and time needed for that moving, as discussed above. The tongue is more flexible than any other oral structure and capable of more movement to be measured. If sensory judgments are based, even in part, on the two attributes of distance moved and time required to move a given distance, then a structure with greater ability to gather this information would logically be of more use in making oral stereognostic judgments.

Subjects seemed to vary in the amount of manipulation needed to recognize a form. One group of subjects, including most of those who made the smallest number of errors, typically appeared to place the form on the tip of the tongue and make a kind of overall or Gestalt-type judgment. Either they knew which form they had in the mouth or they did not know, and manipulation or movement of the form did not seem to help much in making the judgment. The other group seemed to need exploratory type movements of the tongue and movements of the form against the lips in order to make their decisions. However, even those subjects who typically made the Gestalt-type judgments seemed to need to run the tongue tip around the edge of the form or lightly bite down on the form when making a difficult decision, such as identifying one of the two biconcave forms in either the NIDR or the Ringel sets. (The two biconcave forms were the most difficult to identify when presented as a pair in both the NIDR and Ringel form sets.) It is possible that in biting down on the forms the subjects were utilizing the ability to judge differences in size of mouth opening which was reported by Ringel, Saxman, and Brooks (1967). It may be that different type measurements are being made to recognize different forms. The biconcaves may be recognized by measuring the size of the mouth opening needed to hold the form at its narrowest part, but other forms were perhaps being judged by area or perimeter measurements or other attributes.

Some subjects made very little use of the tongue tip, choosing to use the lips as the primary structure for either the Gestalt-type judgments or manipulation. When the lips were used, the subject usually pushed the form in and out between the partially opened lips, using the form handle, thus dragging the form across the inner surface of both lips.

Since most subjects who made the least number of errors seemed to be using both the tongue tip and the Gestalt-type judgments, it may be that a test of oral stereognosis should force the use of these methods. A set of forms could be selected by determining those forms which are most easily recognizable when placed on the tongue tip and a Gestalt-type judgment forced by not allowing any manipulation. Such a test would eliminate the use of distance of movement and time of movement as criterial attributes of judgments. Since Lass, Bell, Chronister, McClung, and Park (1972) found that a greater number of errors were made when subjects were not allowed to manipulate the forms, such a test should also produce a greater number of errors than any of the combinations studied here with manipulation allowed.

Semmes (1967) postulated the existence of two factors involved in all forms of stereognosis, a general spatial factor and a specific factor. It may be that those subjects who identified forms by the Gestalt-type method were utilizing the general spatial factor and those who required manipulation, tongue movement, or measurement of mouth opening were utilizing some more specific factor.

Several subjects commented about the orientation of some of the forms. If, for example, a triangular form was placed in the mouth with the base to the anterior of the tongue tip and the apex to the posterior of the tongue tip, some subjects believed that it was more difficult to determine whether the pair was the same or different. Since Moser and Houck (1970) found subjects selecting braille characters which were an inversion of the one presented, it may be that the orientation of the forms did have some relation to the correctness of the subject's response. One subject reported that if an oblong handleless form such as one of the biconcaves or the narrowest rectangle of the Ringel set was placed in his mouth crosswise, he could not get the form positioned in such a manner that he could easily feel for corners. The report of Locke (1968b and 1969) that subjects differed in how much use they made of the handle for manipulation may be related to the orientation of the form in the subject's mouth. The subject may be using the handle to position the form. It may be more difficult to make a distance judgment or a time judgment from certain positions of the forms. For example, the subject, when using the handle may be trying to place the form in an orientation which allows most accurate judgment of area. The tongue does not move as great a distance from side to side as from front to back. The subject may need to place the form so that the longest dimension can be measured with a back and forth movement. It may also be that some physiological process is operating analogous to the reversed image

from the eye which has to be righted by the nervous system.

Answer Type

One reason for the differences between answer types found by this study may be that, perceptually, the two response types used in this study are two different tasks. Making a same-different judgment allows only oral sensory cues to be used in the judgment. Matching a form to an outline requires the use of visual cues as well as oral sensory cues and requires an interaction between the oral sensory system and the visual system. Arndt, Elbert, and Shelton (1970) make this distinction and refer to the point to outline procedure as a "test of oral form recognition" (p. 382) rather than a test of oral stereognosis. Weinberg, Lyons, and Liss (1970) argued that although McDonald and Aungst (1967), Moser et al. (1967), and Shelton, Arndt, and Heatherington (1967) have referred to this procedure as stereognosis, stereognostic testing precludes the use of visual cues. A procedure using a match to outline or match to form type response is therefore a form identification or form recognition task. Lass, Tekieli, and Eye (1971) and Ringel, Burk, and Scott (1968 and 1970) agreed to this distinction.

The results of the present study indicated that these two perceptual tasks, indeed, differ greatly in difficulty. The findings in regard to difficulty of the two answer types do not agree with those of Lass et al. (1971). These

researchers, using the Ringel forms plus one triangle, found a significantly smaller percentage of errors on the point to outline response (26.4%) than on the same-different response (29.3%). It may be that the reason for this disagreement (the present study found 14.2% errors for the point to outline response and 3.0% for the same-different response) lies in the addition of one form to the Ringel set. Nearly half of the errors made in the study by Lass et al. (1971) were confusions of the triangles with each other, and it was an extra triangle which they added to the Ringel set.

Another possible explanation of the greater difficulty of the point to outline response may lie in errors in the outline charts themselves. Moser et al. (1970) show two different arrangements of the NIDR forms on the answer charts used in two different studies. For both of these, the small oval form was shown as having a flat top and bottom instead of its true curved or rounded top and bottom; the shorter of the two ovals which had a flat top and bottom was shown as wider than the longer flat top and bottom oval, when, in fact, the two were equal in width; and did not show the degree of concavity of the two biconcave forms in proportion to the degree which exists in the commercially available NIDR forms. The outlines published in McDonald and Aungst (1970a) showed the biconcave form with a different arc of concavity than exists in the commercially available forms. The thicker biconcave form was out of proportion to the actual form in the

Ringel, Burk, and Scott (1970) publication. In addition, these and other published outlines did not show the sizes of the forms in true proportion to each other. These may be errors present in the outline renditions made for publication; but if these discrepancies existed in the actual form charts used in the research, then subjects did not always have true relative form to outline matches.

A third possible explanation for the wide difference in difficulty between answer types may be that subjects who are asked to point to a form on a chart may not actually be making a mouth to eye comparison. The subjects of the present study seemed to identify the form in terms of naming it, saying "oh, that's the circle" or "the little triangle" or "the big square", etc. They seemed to place the form into some sort of mental picture and then look on the chart for the thing they had named. They often took the form out of the mouth and named it without ever opening their eyes, and had to be reminded to look at and point to the chart.

Even though Lass, Bell, Chronister, McClung, and Park (1972) and LaPointe and Williams (1971) reported no significant differences between the handled and handleless conditions of the forms, using the Ringel set, the possibility of this factor having some interaction effect and helping to cause the wide differences between findings on answer type must be considered. The present study found that form retention time entered into a three way interaction with answer type and

form set, although the factor of form retention time was not itself significant. Subjects repeatedly commented on the awkwardness of the handleless forms. Since this factor was so noticeable to the subjects, it may be that, like form retention time in this study, the factor of handled or handleless condition of the forms may be contributing to an interaction even though it is not itself significant.

Presentation of pairs of forms and asking for same-different judgments requires a great deal more time than presentation of single forms. Presentation of 65 pairs of forms took 20-40 minutes, while presentation of five to 20 single forms took about five minutes. If presentation of pairs is eventually determined to be the most effective answer type, it may be better to eliminate some of the pairings to shorten the testing time. Bishop, Ringel, and House (1972) found that deaf and normal hearing subjects made approximately the same number of errors on identical pairs. It seemed that the different pairs were the ones discriminating between the two groups. In light of these results, it is possible that the test could be shortened to some degree by eliminating at least all of the identical pairings. The subjects would therefore be asked for a same-different judgment even though all of the pairs presented would be different.

There are several variables within each answer type which were not investigated here. It is possible that such factors as size of the outline drawings on the charts, number and arrangement of outlines on each chart or answer booklet, or

use of outlines versus photographs, drawings, or mounted forms may be responsible for some part of the difference between the point to outline type answer and the same-different type answer. Obviously, future research is necessary in order to discover the reason(s) for these differences.

Form Retention Time

The writer has been unable to find any rationale for the selection of five seconds as the time period to which possession of a form in the mouth is limited, although this time period had been used in several studies (see Table 2). The present study found no significant difference in results whether the forms were presented with or without the five second limit. However, since the effect of the time limit approached significance (see Appendix D) and entered into a three-way interaction with answer type and form set, effect of time limits must still be considered. It is possible, for example, that a shorter or longer time limit might have produced a significant main effect.

The examiner informally timed several of the unlimited time combinations for several subjects. After the first few combinations had been presented to each subject, the subjects typically used 2-4 seconds for identifying a form, whether or not any time limit was imposed. On a few of the more difficult forms, 7-8 seconds were used. Added to this observation is the fact that although form retention times were not

significantly different, the five second time limit did produce slightly more errors. Therefore, it is possible that the overall scores might be affected by 1, 2, 3, or 4 second time limit and that scores on some very difficult forms might be affected by either these limits or a 5, 6, 7, or 8 second limit. Several subjects, whose error percentages were among the highest recorded in the study, took extremely long times, up to a full minute per form, to manipulate some forms.

Some subjects also seemed to habitually take more time and make more errors on some particular forms or pairs of forms or groups of forms. For example, several subjects consistently confused the cross and the star in both the McDonald and Aungst set and the NIDR set or the similar in length flat sided oval and smallest rectangle from the Ringel set. These subjects took more time on these forms, both when presented singly and when presented in pairs, and made more errors on them. Other subjects would have no difficulty with these forms but would consistently confuse the three sizes of triangles and rectangles in the sets in which they were presented, and consistently take more time before they made the error.

It is also possible that the time limitation may be affecting the results of the first few presentations more than the results of the later presentations in which the subject is more familiar with the forms. If this is true, then allowing the subject to familiarize himself with the feel of

the forms by taking each into his mouth before the testing starts may eliminate that effect. Subjects tended to use more time and to manipulate the forms more on the first presentation of a set of forms than on later presentations of the same set.

Several observations about the testing but not directly related to form set, answer type, or form retention time can be made about the behavior of the subjects in this experiment. Some subjects responded to the testing with excess salivation. More responded with a drying of the mouth, a frequent need for water, and a whitish or yellowish coating of the tongue. Subjects in this study were allowed water whenever they wanted it. Allowing or not allowing water may be another significant variable. Several subjects, particularly those who did a great deal of moving the tongue tip around the edges of each form, developed red and raw looking tongue tips. Two subjects reported slightly sore tongues and/or mouths for a day or two after the testing.

Considerations for Therapy

The present study addressed itself to a comparison of methodological factors rather than to the support or rejection of a specific theoretical position. If research in oral stereognosis is advanced enough to support a legitimate concern with the methodology of testing, then it should be advanced enough to justify use of one or another of these

methods in clinical testing.

It has been suggested that oral stereognostic testing helps to differentiate between articulatory disordered subjects with motor disorders and those with sensory disorders (Scott and Ringel, 1971b). Clinicians have long been aware of the existence of a group of children who come into speech therapy at the age of six or seven years, stay in therapy, still uncorrected, well into the teens or adult years, and eventually leave therapy, still uncorrected. McDonald and Aungst (1967) report that clinical observations suggest the existence of a group of children with defective oral motor and sensory abilities and who may or may not have associated articulatory difficulties.

It may be that these clinicians and investigators are talking about the same children. The children who do not seem to benefit from the same kind of speech therapy which corrects other children may be children with undiagnosed sensory problems. One way to determine whether or not this is true would be to do oral stereognostic testing for all children entering speech therapy, then determine whether or not those making the greatest number of errors are still in therapy one, two, or three years later.

There seems to be a preponderance of evidence that some relationship between oral stereognostic ability and articulation proficiency exists. Even without knowing exactly what this connection is or how it operates, the predictive

value of an oral stereognostic test for determining the child who will be least successfully corrected by speech therapy can be determined. If one of these tests predicts the child who will still be in therapy three years hence, then the clinical observations made with this child may help shed light on the questions of just what the connection between oral stereognostic ability and articulation is, and how this connection operates.

Additionally, though McDonald and Aungst (1967) have suggested that oral stereognostic ability does not improve with training, concentrated programs aimed at improving this ability in the speech defective child have not been employed, at least according to current literature. It may be that a therapy program aimed at improving oral stereognostic skills or at teaching correct sound production using oral sensory based methods may refute the contention that oral stereognostic abilities do not improve with training.

Although they cannot be considered the final answer to the question of what is the most effective method of testing oral stereognosis, any of the four methods suggested above could presently be used in direct clinical application. They are combinations of testing factors which represent some of the most commonly used sets of oral stereognostic forms and the two most commonly used answer types, in combinations of medial difficulty. Although better methods may be found, these are available and should perhaps be used.

Considerations and Suggestions for
Future Research

The results of this study must cast serious doubt on several previous conclusions regarding relationships between normal subjects and various types of abnormal subjects, and between such factors as handled or handleless conditions of forms, feedback on correctness of answers or no feedback. Considering the highly significant effects found between form sets and between answer types, the interaction found between these two factors, and the three-way interaction found between these two factors and form retention time, it is possible that both relationships which were found and relationships which were not found by previous investigators were due at least in part to the combinations of these factors in the testing.

A recent trend in oral stereognostic research has been to use the same-different response for paired forms, with the forms constituting the pairs chosen in such a way that between class and within class errors could be compared (Fucci and Robertson, 1971; Bishop, Ringel, and House, 1972; Lass, Tekieli, and Eye, 1971; Lass et al., 1972; Ringel, Burk, and Scott, 1968; etc.). However, the categories used for this purpose typically have been visual categories (squares, circles, triangles, etc.). There has been no research to support the assumption that visual and oral categories are identical or that the defining attributes of a visual category are the same

as the defining attributes of an oral category. Categories defined by the hearing sense (phonemes) are not the same as visual categories, and it may be that categories defined by the oral sensory system are not the same either. The attributes by which visual categories are built may not be the same as those by which oral categories are built, and a significant visual attribute may not be a significant oral attribute. The Fucci and Robertson (1971) study attempted to delineate a new category system, but found no significant difference based on whether the forms were curved or pointed. Such attributes as distance measurements of the forms, time measurements of the rate at which the distance measurements are made, degree of angle between straight surfaces, degree of curvature of curved surfaces, and area-weight correlations have not been considered. It is not known whether differences in between-class and within-class judgments which have been found at this stage in oral stereognostic research will still hold true if different categories are established based on different variables.

Carhart (1965) has suggested that speech discrimination tests should be difficult enough to discriminate but easy enough to allow the upper limits of a patient's articulation function to be plotted. The items must be relatively non-redundant or the multiplicity of the clues available will obscure his abilities to discriminate consonants and vowels (Carhart, 1965). If these two requirements for a test of

speech discrimination are applied to a test of oral form discrimination, then the difficulty of specific combinations of factors must be considered. The present study revealed the four Penn State forms to be easiest, in all combinations of factors. Two of the eight point to outline combinations contained the Penn State forms. The other six point to outline combinations are the six most difficult of the total sixteen combinations (see Table 3).

It is difficult, if not impossible, to select a "best" method for testing oral stereognosis at this point. However, if the Carhart criteria are applied to the combinations utilized in the present study, then the combinations of Ringel forms + unlimited time + same-different response, and the NIDR forms + a five second time limit + a same-different response are the two medial combinations in terms of difficulty (see Table 3). The two combinations next to these in difficulty, Ringle forms + five second time limit + same-different response, and NIDR forms + unlimited time + same-different response, might also be considered. However, further research, particularly with pathological subjects is needed before a "best method" can be stated.

There seem to be three major aspects of oral stereognostic testing which need immediate research. The first is the area of neurological and neuro-physiological bases for sensory perception. As was stated in Chapter I, neither of these fundamental processes is fully known for the oral sensory

processes. An explanation of these processes, a resolution of the sensation-perception terminology controversy, and a clear theory of sensation-perception would go far toward increasing the effectiveness of oral stereognostic testing.

Approaching the problem from the opposite direction should also be of help. Further research into the methodologies of testing sensory capacities by means of oral stereognosis forms should help explain the neurophysiology of the processes. The sets of forms used in this study, plus other sets of forms, need to be compared to each other in terms of other variables which may be influencing test results. Since subjects in this study did not seem to need the full five seconds, time limits of one, two, three, and four seconds should be investigated. Since subjects seemed to take more time on the more difficult forms, time limits of six, seven, or eight seconds on the more difficult forms should be investigated. The effects of training or prior familiarization with the forms should also be studied. Individual forms should be analyzed in terms of their difficulty when manipulation is present or absent. Other sizes of outlines and other types of form representation such as pictures, drawings, and objects should be systematically compared. All of these variables and others have been used in various oral stereognostic studies. Considering the interactions between variables which were found in this study, any or all of these untested variables may be influencing test results. These methodological

considerations need to be tested with subjects with normal articulation and with various pathologies in order to determine the comparability of such subjects in oral stereognostic abilities.

Finally, there is a need to define the criterial attributes used in the formation of oral sensory categories. One way to begin study in this area might be a comparison of the forms now being used for oral stereognostic testing on every possible measurable attribute. There can be no valid comparisons of within-class and between-class errors until the classes are delineated.

REFERENCES

REFERENCES

- Arndt, W. B., Gauer, J., Shelton, R. I., Crary, D., and Chisum, L., Refinement of a test of oral stereognosis. In J. F. Bosma (Ed.), Second Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1970).
- Arndt, W. B., Elbert, M., and Shelton, R. I., Standardization of a test of oral stereognosis. In J. F. Bosma (Ed.), Second Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1970).
- Aungst, L. F., The Relationship Between Oral Stereognosis and Articulation Proficiency. Unpublished Ph. D. thesis, Pennsylvania State University (1965).
- Ayres, A. J., Southern California Kinesthesia and Tactile Perception Test. Los Angeles: Western Psychological Services (1966).
- Baker, D. J., The amount of information in the oral identification of forms by normal speakers and selected speech-defective groups. In J. F. Bosma (Ed.), Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1967).
- Barsch, R. H., A Movigenic Curriculum. Madison, Wisc.: Bureau for Handicapped Children (1965).
- Berry, M. F., Language Disorders of Children. New York: Appleton-Century-Crofts (1969).
- Bishop, M. E., Ringel, R. L., and House, A. S., Orosensory perception in the deaf. Volta Review, 74, 289-298 (1972).
- Bosma, J. F., (Ed.) Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1967).
- Bosma, J. F., (Ed.) Second Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1970).

- Bruner, J. S., Goodnow, J. J., and Austin, G. A., A Study of Thinking. New York: Science Editions, Inc. (1962).
- Carhart, R., Problems in the measurement of speech discrimination. Arch. Otolaryngol., 82, 253-260 (1965).
- Catford, J. C., The articulatory possibilities of man. In B. Malmberg (Ed.), Manual of Phonetics. Amsterdam: North-Holland (1968).
- Chusid, J. C., Correlative Neuroanatomy and Functional Neurology. Los Altos, Calif.: Lange Medical Publications (1970).
- Class, L. W., A Comparative Study of Normal Speakers and Speech Defectives with Regard to the Tactual-Kinesthetic Perception of Forms with the Tongue. Unpublished M. A. thesis, Ohio State University (1956).
- Cosh, J., Studies on the nature of vibration sense. Clinical Sci. 12, 131-151 (1953).
- Dittman, H. H. The Role of the Proprioceptive Sensibilities in Speech Production. Unpublished Ph. D. thesis, University of Denver (1955).
- Dellow, P. G., Lund, J. P., Babcock, K., and Von Rosendaal, G., The oral assessment of object size. J. Speech Hearing Res., 13, 526-536 (1970).
- Egland, G. C., Speech and Language Problems. Englewood Cliffs, N. J.: Prentice-Hall (1970).
- Eisenson, J., Auer, J. J., and Erwin, J. V. Psychology of Communication. New York: Appleton-Century Crofts (1963).
- Eisenson, J., and Ogilvie, M. Speech Correction in the Schools, 3rd edition. New York: Macmillan (1971).
- Fairbanks, G., Systematic research in experimental phonetics: 1. A theory of the speech mechanism as a servosystem. J. Speech Hearing Dis., 19, 133-139 (1954).
- Gammon, S. A., Smith, P. J., Daniloﬀ, R. G., and Kim, C. W., Articulation and stress/juncture production under oral anesthetization and masking. J. Speech Hearing Res., 14, 271-282 (1971).
- Geldard, F. A., The perception of mechanical vibration, IV. Is there a separate vibratory sense? J. Gen. Psych., 22, 291-308 (1940).

- Gibson, J. F., The mouth as an organ for laying hold on the environment. In J. F. Bosma (Ed.), Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1967).
- Goldstein, J. L. The Effects of Speaker, Training, and Transducer on the Recognition of Tactile Differences in Combined Speech Sounds. Unpublished Ph. D. thesis, Michigan State University (1972).
- Gray, G. W. and Wise, C. M. The Bases of Speech. New York: Harper and Brothers (1959).
- Grossman, R. C., Methods for evaluating oral surface sensation. J. Dent. Res., 43, 301 (1964).
- Grossman, R. C., Methods of determining oral tactile experience. In J. F. Bosma (Ed.), Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1967).
- Grossman, R. C., and Hattis, B. F., Oral mucosal sensory innervation and sensory experience: a review. In J. F. Bosma (Ed.), Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1967).
- Grossman, R. C., Hattis, B. F., and Ringel, R. L., Oral tactile experience. Arch. oral Biol., 10, 691-705 (1965).
- Haas, W. H. Vibrotactile Reception of Spoken English Phonemes. Unpublished Ph. D. thesis, Michigan State University (1970).
- Henke, W., Preliminaries to speech synthesis based upon an articulatory model. Paper presented at the Conference on Speech Communication and Processing, Cambridge, Mass. (1967).
- Henkin, R. I., Manual and oral stereognosis in normal volunteers and in patients with various abnormalities of taste and olfaction. In J. F. Bosma (Ed.), Second Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1970).
- Henkin, R. I., and Banks, V., Tactile perception on the tongue, palate, and the hand of normal man. In J. F. Bosma (Ed.), Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1967).
- Hollinshead, W. H. Anatomy for Surgeons: Vol. I, The Head and Neck, 2nd edition. New York: Harper and Row (1968).

- Jenkins, W. L., Somesthesis. In S. S. Stevens (Ed.), Handbook of Experimental Psychology. New York: Harper and Brothers (1951).
- Johnson, W., Darley, F. L., and Spriestersbach, D. C. Diagnostic Methods in Speech Pathology. New York: Harper and Brothers (1963).
- Kantner, C. E., and West, R. Phonetics. New York: Harper and Brothers (1960).
- Kaplan, H. M. Anatomy and Physiology of Speech. New York: McGraw-Hill (1971).
- Ladefoged, P. Three Areas of Experimental Phonetics. London: Oxford University Press (1967).
- LaPointe, L. L., and Williams, W. N., Effect of selected form and attachment devices on oral stereognosis scores. Percept. Mot. Skills, 32, 469-470 (1971).
- LaPointe, L. L., and Williams, W. N., Recognition of geometric shapes by unimodal and simultaneous multimodal presentation in aphasics. Unpublished paper obtained from author (1972).
- Lass, N. J., Bell, R. R., Chronister, J. A., McClung, N. J., and Park, W. E., Assessment of oral tactile perception: some methodological considerations. Unpublished paper obtained from author (1972).
- Lass, N. J., and Hammed, T. C., The effect of memory on subject performance on a test of oral form discrimination. Unpublished paper obtained from author (1972).
- Lass, N. J., Kotchek, C. L., and Deem, J. F., Oral two-point discrimination: further evidence of asymmetry on the right and left sides of selected oral structures. Unpublished paper obtained from author (1972).
- Lass, N. J., Tekieli, M. E., and Eye, M. P., A comparative study of procedures for assessment of oral tactile perception. Can. States Speech J., 22, 22-26 (1971).
- Lenneberg, E. H., Biological Foundations of Language. New York: John Wiley and Sons (1967).
- Liberman, A. M., Some results of research on speech perception. J. Acoust. Soc. Amer., 29, 117-123 (1957).
- Liberman, P. Intonation, Perception, and Language. Cambridge, Mass.: M. I. T. Press (1967).

- Locke, J. L., Questionable assumptions underlying articulation research. J. Speech Hearing Dis., 33, 112-116 (1968a).
- Locke, J. L., Oral perception and articulation learning. Percept. Mot. Skills, 26, 1259-1264 (1968b).
- Locke, J. L., Short-term auditory memory, oral perception, and experimental sound learning. J. Speech Hearing Res., 12, 185-192 (1969).
- MacNeilage, P. F., Motor control of serial ordering of speech. Psychol. Rev., 77, 182-196 (1970).
- Manning, W. H., Coarticulation as an Adjunct to Speech Perception. Unpublished Ph. D. thesis, Michigan State University (1972).
- Mason, R. M., Studies of oral perception involving subjects with alterations in anatomy and physiology. In J. F. Bosma (Ed.), Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1967).
- McCall, G. N., The Assessment of lingual tactile sensation and perception. J. Speech Hearing Dis., 34, 151-156 (1969).
- McCall, G. N., and Cunningham, N. M., Two-point discrimination: Asymmetry in spatial discrimination on the two sides of the tongue, a preliminary report. Percept. Mot. Skills, 32, 368-370 (1971).
- McCroskey, R. L., Relative contribution of auditory and tactile cues to certain aspects of speech. Sou. Speech J., 24, 84-90 (1958).
- McCroskey, R. L., Corley, N. W., and Jackson, G., Some effects of disrupted tactile cues upon the production of consonants. Sou. Speech J., 25, 55-60 (1959).
- McDonald, E. T. A Deep Test of Articulation: Picture Form. Pittsburg: Stanwix House (1964).
- McDonald, E. T. Articulation Testing and Treatment: A Sensory-Motor Approach. Pittsburg: Stanwix House (1964).
- McDonald, E. T., and Aungst, L. F., Studies in oral sensorimotor function. In J. F. Bosma (Ed.), Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1967).

- McDonald, E. T., and Aungst, L. F., An abbreviated test of oral stereognosis. In J. F. Bosma (Ed.), Second Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1970a).
- McDonald, E. T., and Aungst, L. F., Apparent Independence of oral sensory functions and articulatory proficiency. In J. F. Bosma (Ed.), Second Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1970b).
- McDonald, E. T., and Solomon, B., Ability of normal children to differentiate textures, weights, and forms in the oral cavity: a pilot study. Unpublished paper (1962). [Cited by McDonald, E. T., and Aungst, L. F., in Bosma, Symposium on Oral Sensation and Perception.]
- Moser, H. M., and Houck, R. E., A study of the lingual orientation of normal and articulatory defective speakers on a test of lingual identification of selected arrangements of haptic forms. In J. F. Bosma (Ed.), Second Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1970).
- Moser, H. M., LaGourgue, J. H., and Class, L. W., Studies of oral stereognosis in normal, blind, and deaf subjects. In J. F. Bosma (Ed.), Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1967).
- Mysak, E., A servo-model for speech therapy. J. Speech Hearing Dis., 24, 144-149 (1959).
- Neff, W. D., Sensory discrimination. In J. Field (Ed.), Handbook of Physiology; Section 1, Neurophysiology; Vol. III. Washington: American Physiological Society (1960).
- Olroyd, M. H. Lingual Somesthetic Sensibilities of Normal Nine and Eleven Year Old Children. Unpublished M. A. thesis, Louisiana State University (1965).
- Paine, R. S., Manual stereognosis. In J. F. Bosma (Ed.), Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1967).
- Penfield, W., Neurophysiological basis of the higher functions of the nervous system--introduction. In J. Field (Ed.), Handbook of Physiology; Section 1, Neurophysiology; Vol. III. Washington: American Physiological Society (1960).

- Perkell, J. S. Physiology of Speech Perception: Results and Implications of a Quantitative Cineradiographic Study. Cambridge, Mass.: M. I. T. Press (1969).
- Perkins, W. H. Speech Pathology. Saint Louis: C. V. Mosby (1971).
- Perilhou, P., The vibratory sense. J. Gen. Psych., 36, 23-28 (1947).
- Peterson, G., The speech communication process. In B. Malmberg (Ed.), Manual of Phonetics. Amsterdam: North-Holland (1968).
- Piaget, J. The Language and Thought of the Child. New York: World Publishing Co. (1955).
- Pleasanton, A. K., Sensitivity of the tongue to electrical stimulation. J. Speech Hearing Res., 13, 635-644 (1970).
- Ringel, R. L., Studies of oral region texture perception. In J. F. Bosma (Ed.), Second Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1970a).
- Ringel, R. L., Oral region two-point discrimination in normal and myopathic subjects. In J. F. Bosma (Ed.), Second Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1970b).
- Ringel, R. L., Oral sensation and perception: a selective review. ASHA Reports No. 5, 188-206 (1970c).
- Ringel, R. L., Burk, K. W., and Scott, C. M., Tactile perception: form discrimination in the mouth. Brit. J. of Dis. of Comm., 3, 150-155 (1968).
- Ringel, R. L., Burk, K. W., and Scott, C. M., Tactile perception: form discrimination in the mouth. In J. F. Bosma (Ed.), Second Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1970).
- Ringel, R. L., and Ewanowski, S. J., Oral perceptions: 1. Two-point discrimination. J. Speech Hearing Res., 8, 389-398 (1965).
- Ringel, R. L., and Fletcher, H. M., Oral perception: III. Texture discrimination. J. Speech Hearing Res., 10, 642-649 (1967).

- Ringel, R. L., House, A. S., Burk, K. W., Dolinsky, J. P., and Scott, C. M., Some relations between orosensory discrimination and articulatory aspects of speech production. J. Speech Hearing Dis., 35, 3-11 (1970).
- Ringel, R. L., Saxman, J., and Brooks, A., Oral perception: II Mandibular kinesthesia. J. Speech Hearing Res., 10, 637-641 (1967).
- Ringel, R. L., and Steer, M. D., Some effects of tactile and auditory alterations on speech output. J. Speech Hearing Res., 6, 369-378 (1963).
- Rose, J. E., and Mountcastle, V. B., Touch and kinesthesia. In J. Field (Ed.), Handbook of Physiology; Section 1, Neurophysiology; Vol. III. Washington: American Physiological Society (1960).
- Ruch, T. C., Sensory mechanisms. In S. S. Stevens (Ed.), Handbook of Experimental Psychology. New York: John Wiley and Sons (1951).
- Rutherford, D., and McCall, G., Testing oral sensation and perception in persons with dysarthria. In J. F. Bosma (Ed.), Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1967).
- Schliesser, H. F., and Coleman, R. C., Effectiveness of certain procedures of alteration of auditory and oral tactile sensations for speech. Percept. Mot. Skills, 26, 275-281 (1968).
- Scott, C. M., and Ringel, R. L., Articulation without oral sensory control. J. Speech Hearing Res., 14, 804-818 (1971a).
- Scott, C. M., and Ringel, R. L., The effects of motor and sensory deprivation on speech: a description of articulation. J. Speech Hearing Res., 14, 819-828 (1971b).
- Semmes, J., Manual stereognosis after brain injury. In J. F. Bosma (Ed.), Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1967).
- Shelton, R. L., Arndt, W. B., and Heatherington, J. J., Testing oral stereognosis. In J. F. Bosma (Ed.), Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1967).

- Smith, R. W., Stereognostic perception within the mouths of children with speech problems. Unpublished M. Ed. research paper, Pennsylvania State University, August, 1964. [Cited in McDonald, E. T., and Aungst, L. F., Studies in oral sensorimotor function. In J. F. Bosma (Ed.), Symposium on Oral Sensation and Perception.]
- Solomon, B. The Relation of Oral Sensation and Perception to Chewing, Drinking, and Articulation in Athetoid Children and Adults. Unpublished Ph. D. thesis, Pennsylvania State University (1965).
- Templin, M. C., and Darley, F. L. The Templin-Darley Tests of Articulation. Iowa City: University of Iowa Bureau of Educational Research and Service (1960).
- Tuber, H. L., Perception. In J. Field (Ed.), Handbook of Physiology; Section 1; Neurophysiology; Vol. III. Washington: American Physiological Society (1960).
- Weinberg, B., Liss, G. M., and Hillis, J., A comparative study of visual, manual, and oral form identification in speech impaired and normal speaking children. In J. F. Bosma (Ed.), Second Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1970).
- Weinberg, B., Lyons, Sister M. J., and Liss, G. M., Studies of oral, manual, and visual form identification in children and adults. In J. F. Bosma (Ed.), Second Symposium on Oral Sensation and Perception. Springfield, Ill.: Charles C. Thomas (1970).
- Williams, W. N., and LaPointe, L. L., Intra-oral recognition of geometric forms by normal subjects. Percept. Mot. Skills, 32, 419-426 (1971a).
- Williams, W. N., and LaPointe, L. L., Correlations between oral form recognition and lingual touch sensitivity. Percept. Mot. Skills, 32, 840-842 (1971b).
- Winitz, H. Articulatory Acquisition and Behavior. New York: Appleton-Century-Crofts (1969).
- Woodford, L. D., Oral Stereognosis. Unpublished M. S. in Orthodontics thesis, University of Illinois at the Medical Center, Chicago (1964).
- Zemlin, W. R. Speech and Hearing Science Anatomy and Physiology. Englewood Cliffs, N. J.: Prentice-Hall (1968).

APPENDICES

APPENDIX A

**ADDRESSES OF COMPANIES FROM WHICH
FORM SETS ARE AVAILABLE**

The Penn State form set and the NIDR form set both with and without handles are available from:

Wilks Precision Instrument Co.
5706 Frederick Ave.
Rockville, Maryland 20850

The Shelton forms (not used in this study) are available from:

Technical Instruments Service Co.
7101 Mission Road
Prairie Village, Kansas 66208

The Ringel forms are currently not commercially available.

APPENDIX B

PERSONAL HISTORY AND DATA FORM

COMPLETED FOR EACH SUBJECT

Name _____ Birth Date _____

1) Do you smoke? yes _____ no _____ How much? _____

2) Do you drink alcohol? yes _____ no _____ How much? _____

3) Have you ever had any operations in the oral cavity?

Explain. _____

4) Have you ever had any problem with taste or smell?

Explain. _____

5) Approximately how often do you have a cold? _____

6) Do you have any sinus or other drainage in the oral cavity?

yes _____ no _____ If so, how often do you have it? _____

_____ Do you have it now? yes _____ no _____

7) Were you a full-term baby? If not, how premature were you?

8) Have you ever had any kind of neurological disorder?

yes _____ no _____ Learning disability? yes _____ no _____

Perceptual problem? yes _____ no _____ Explain. _____

9) Do you wear dentures? yes _____ no _____ A partial plate?

yes _____ no _____

APPENDIX C

INSTRUCTIONS TO SUBJECTS

GENERAL INSTRUCTIONS

I have here four sets of plastic forms which I want you to identify by feeling them with your mouth. There are twenty of these flat forms with the handles, ten of this set of flat forms with handles, ten of this set of flat forms without handles, and five of this set of solid forms. Look at these as I present them one by one and match them to the outlines on these charts. Notice that both of the sets of ten are selections of forms from the set of twenty.

Close your eyes until I place a form in your mouth or put the handle of a form in your hand. After the form is in your mouth you may open your eyes if you like. You are not to look at or touch the forms. I will give you several different sets of instructions. Sometimes I will give you a pair of forms, first one then then a second; sometimes I will give them to you singly. Sometimes I will ask you to identify the forms by pointing to one of these charts; sometimes I will ask you if a pair of forms is the same or different. Sometimes I will allow you all the time you want to manipulate the forms; sometimes I will give you a limited amount of time. There are sixteen series of form presentations; I will give you instructions before each series.

For Combinations 1, 5, 9, and 13:

For this series I will present the forms to you in pairs. I will give you one form and allow you to keep it in your mouth for five seconds. You may move the form any way you wish, either with your tongue or with your hand on the handle. After you are finished with the second form, tell me if the two forms were the same or different. (For the handleless forms, conditions 13, 14, 15, and 16, the subject was also told that the examiner would place the form in his mouth and he could drop it out on the towel when he was finished.)

For Combinations 2, 6, 10, and 14:

For this series, I will present the forms to you one at the time. You may move the form any way you wish, either with your tongue or with your hand on the handle. At the end of five seconds I will ask you to take the form out of your mouth. After I have put the form back on the towel I will tell you to open your eyes. Then tell me which form on the chart represents the one you had in your mouth.

For Combinations 3, 7, 11, and 15:

For this series I will present the forms to you in pairs. I will give you one form. When you are ready, signal me for the second form. You may have all the time you need. Keep either form in your mouth as long as you like. You may move them in any way you wish, either with your tongue or with your hand on the handle. After the second form is removed, tell me whether the two forms were alike or different.

For Conditions 4, 8, 12, and 16:

For this series I will present the forms to you one at the time. You may move the form any way you wish, either with your tongue or with your hand on the handle. You may have all the time you wish. When you feel that you can identify the form, take it out of your mouth. After I have replaced the form on the towel, open your eyes and point to the outline on the chart which matches the form you have had in your mouth.

APPENDIX D

ANALYSIS OF VARIANCE TABLE
(IN ARCSIN TRANSFORMATIONS)
PERFORMED UPON THE PERCENTAGE
INCORRECT SCORES

<u>Source of Variance</u>	<u>Sum of Squares</u>	<u>Degrees of Freedom</u>	<u>Mean Square</u>	<u>F Statistic</u>	<u>Approx. Significance Prob. of F Statistic</u>
Form Set	41.22	3	13.74	212.45	0.0005*
Form Retention Time	0.19	1	0.19	2.95	0.0820
Answer Type	15.42	1	15.42	238.51	0.0005*
Form Set x Form Retention Time	0.25	3	0.08	1.27	0.2820
Form Set x Answer Type	10.84	3	3.61	55.87	0.0005*
Form Retention Time x Answer Type	0.10	1	0.10	1.48	0.2220
Form Set x Form Retention Time x Answer Type	0.58	3	0.19	3.01	0.0290*

* p < 0.05

APPENDIX E

LIST OF 55 PAIRINGS RANDOMLY SELECTED FROM THE
210 POSSIBLE NIDR PAIRINGS FOR USE IN THIS
STUDY, NUMBERED ACCORDING TO THE
FORM NUMBERS SHOWN IN FIGURE 2

1.	1-1	37.	8-16
2.	1-6 *	38.	9-10
3.	1-7	39.	10-13 *
4.	1-13	40.	11-11
5.	1-16	41.	11-13
6.	1-17 *	42.	11-15
7.	2-9	43.	12-12
8.	2-11	44.	12-15
9.	2-15	45.	12-17 *
10.	3-5	46.	12-19
11.	3-12	47.	13-17 *
12.	3-14	48.	13-20
13.	3-18	49.	14-14 *
14.	4-4	50.	14-15
15.	4-6	51.	14-17
16.	4-9	52.	14-20
17.	4-11 *	53.	15-15
18.	4-16	54.	16-19 *
19.	4-20	55.	18-19 *
20.	5-9 *		
21.	5-12		
22.	5-13		
23.	5-15		
24.	5-16		
25.	5-17		
26.	5-18		
27.	6-7		
28.	6-9		
29.	6-12		
30.	6-15		
31.	6-18		
32.	7-12		
33.	7-14		
34.	7-18		
35.	7-19		
36.	8-13		

* Pairs chosen for repetition.

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