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THE EFFECTS OF ALTERED AUDITORY AND TACTILE FEEDBACK ON VOWELS AND ON CONSONANTS

By

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CHAPTER I

INTRODUCTION

The self-monitoring of articulation probably depends on some combination of auditory, kinesthetic, and tactile feedback from the speech mechanism. For the past few decades, writers on articulation therapy have emphasized ear training, utilizing auditory feedback as the primary corrective technique (Berry and Eisenson, 1956; Curtis, 1967; Milisen, 1954; Powers, 1957; Van Riper, 1963), although there has been speculation as to the contributions of tactile and kinesthetic cues (Berry and Eisenson, 1956; Carrell, 1968; McDonald, 1964; Mysak, 1966). A possible basis in theory for utilizing the various feedback channels in therapy is suggested by Ladefoged (1967) and Perkell (1969), who write that consonants may be under tactile control while vowels are under auditory. The present experiment attempts to test this theory.

BACKGROUND

Three related topics will be discussed in detail: 1) the concept of speech feedback, 2) the present focus of articulation therapy, 3) the differential feedback of vowels and consonants.

Feedback

In Fairbanks' cybernetic model of speech behavior, data about speech just emitted by the speaker are fed back to the speech programming mechanism where they affect selected parameters of the on-going speech. The model is a closed-cycle servo-system which

> employs feedback of the output to the place of control, comparison of the output to the input, and such manipulation of the output-producing device as will cause the output to have the same functional form as the input (Fairbanks, 1954, p. 135).

Control is maintained by the sensors: Sensor 1, the auditory; and Sensors 2 and 3, the tactile and proprioceptive end-organs. To Fairbanks, the auditory sensor is the most direct while the others provide data which are correlated with the auditory but are "comparatively fragmentary" (Fairbanks, 1954, p. 136).

Mysak also compares speech production and control mechanisms to servo-mechanisms, describing a process whereby the actual word product is compared with the desired word product by scanning and measuring for accuracy. But in discussing the role of the sensor he places more emphasis than does Fairbanks on tactile-proprioceptive cues; for evidence he cites the deterioration of articulation experienced under oral anesthesia in the dentist's chair (Mysak, 1966, pp. 13-14).

Articulation therapy

Phonetic placement was traditionally used to correct misarticulations (Mulgrave, 1946; Nemoy and Davis, 1954; Powers, 1957). Early advocates of this method tended to assume that there is only one correct way to make each sound.

> (The case) is shown where the position of his tongue, or other parts of his speech mechanism, is faulty and what changes in positioning are required to produce the sound correctly (Powers, 1957, p. 788).

The obvious objection is that acoustically acceptable versions of a given phoneme can result from a variety of articulatory positionings, and that there is no one standard method of production independent of the individual speaker. Another kind of objection was raised against a special type of phonetic placement method, the moto-kinesthetic method developed by Young and Hawk (1955). There the therapist moves the case's articulators.

> In a sense, the appropriate movements were given outside "motive power," in the hope that the appropriate kinesthetic sensation would then provide the goals or referents for future movements: hence "motokinesthetic." (Young, 1965, p. 271).

Critics said that the manipulations of the therapist seemed unrelated to the actual formation of the sound, and the method has not received wide acceptance (Van Riper and Irwin, 1958, p. 147; Powers, 1957, p. 789).

Phonetic placement may be defined more broadly, however, as any procedure which directs the attention of the case toward what he is doing with his articulators. The basic principle underlying all such procedures is that "the pupil attend to, and consciously attempt to control, the movements and positioning of the articulatory structures" (Curtis, 1967, p. 152). Under this definition, no one, standard, correct positioning is necessarily applied to all individuals.

Despite the occasional concern with the use of tactile and kinesthetic cues, the major articulation therapy techniques developed over the last 30 or 40 years have emphasized the auditory channel.

> Hearing is the primary sensory basis for the natural acquisition of speech in early childhood. Hearing is an infinitely more complex and highly differentiated sense than the tactile or kinesthetic and, therefore, permits of finer discrimation (Powers, 1957, p. 789).

The best known of these methods are the stimulus-response technique, and ear training. Although the terms refer to essentially similar techniques, stimulus-response connotes a high proportion of case-to-clinician sound production, while in ear training the clinician may produce the sound for weeks or months before asking the case to attempt it (Ainsworth, 1948; Milisen, 1954; Van Riper, 1963).

The viewpoints of a few representative writers on articulation therapy are discussed briefly:

Berry and Eisenson (1956). These authors emphasize ear training recommending general auditory stimulation and development of auditory discrimination as well as stimulation with the specific sounds to be taught.

But they speculate about the importance of kinesthetic perception, admitting "we do not know the best way to teach it" (Berry and Eisenson, 1956, p. 138).

They also suggest that some individuals may respond more readily to kinesthetic than to auditory stimulation.

> If experience with an individual indicates that his sound (auditory) discriminative ability is weak, and his visual or kinesthetic responses relatively strong, emphasis should be placed in training through the sensory avenue or avenues which are most potent for him (Berry and Eisenson, 1956, p. 162).

Curtis (1967). James F. Curtis, writing in Speech Handicapped School Children edited by Wendell Johnson, says that phonetic placement techniques are less direct than ear training because they focus attention on placement and movement rather than on the auditory pattern which is "a major part of the end result being sought" (Curtis, 1967, p. 153). He also writes that sounds obtained through placement are less stable than those obtained through the ear alone, and that they must be strengthened and reinforced immediately.

Curtis does mention certain phonetic placement activities, such as mirror watching, looking at diagrams and models, and listening to verbal instructions from the clinician. He suggests these activities may be most useful for cases who have only a few tongue movements in their repertoire, and for those with structural deformities who must learn compensatory movements.

It is interesting that in the latest edition of the book, Curtis adds a footnote regarding tactile and kinesthetic cues. In part it reads:

> The present state of knowledge does not permit us to assign an order of importance to these different types of cues for individuals who have achieved a thorough mastery of speaking skills, and it may well be that such an order of importance would vary for different age levels and for different individuals (Curtis, 1967, p. 124, footnote).

Carrell (1968). The author of Disorders of Articulation, in the Foundations of Speech Pathology series, calls ear training the "most simple, straightforward, and satisfactory method" because it minimizes "the stress that goes along with mouth consciousness" (Carrell, 1968, p. 99). He says, however, that the term "ear training" may be too narrow "since the feedback cues that should be exploited include touch and kinesthesis as well as audition," and he suggests that the case become aware of these cues by practicing new sounds under auditory masking conditions.

Van Riper and Irwin (1958); Van Riper (1963). Van Riper is identified with the term and technique "ear training," and it is no surprise to find his books strongly emphasizing the method as the best way for the case to locate and identify the sound he must make (Van Riper, 1963, p. 249; Van Riper and Irwin, 1958, p. 114). The basic problem of the functional articulation case, according to these authors, is his "failure to match the auditory feedback from his own mouth with the auditory pattern coming from the mouths of other people" (Van Riper and Irwin, 1958, p. 114). He must learn to listen to others and then to himself in order to find, fixate, and stablize a new sound.

These authors do not ignore the importance of tactile and kinesthetic cues, however. They believe that these feedbacks are in control for the older child and adult, and that consequently the case no longer listens to himself.

> At first he must compare the self-hearing of his own utterance with the sounds that come from his parents' mouths. If they match and he is rewarded, the kinesthetic or tactual echoes or messages from his tongue position at that moment tend to become vivid and important. Soon the kinesthetic or tactual feedback is sufficiently stabilized to serve as the dominant control for speech, and the ear feedback, though still present, takes a secondary role (Van Riper and Irwin, 1958, pp. 109-110).

These tactile and kinesthetic feedbacks cannot be corrected directly because:

> it is almost impossible for the case to get true tactual or kinesthetic impressions from another person. Only the auditory pattern can be internalized easily. Matching must always be primarily to the auditory pattern (Van Riper and Irwin, 1958, p. 115).

They do say that proprioceptive cues must be attended to eventually. "We feel that in terminal therapy it is wise to emphasize the kinesthetic and tactual experiences as we increase the speed" (Van Riper and Irwin, 1958, p. 158). Speech must be returned to proprioceptive control because "no one can listen to himself constantly" (Van Riper, 1963, p. 299).

McDonald (1964). This author, known for his "deep testing," agrees that proprioception becomes less, and audition more, important as the child grows older. Basing his impressions on introspective analysis, he writes that the relative strengths of the kinds of cues vary with the sounds produced; for phonemes in the production of which "a large surface of one articulatory structure contacts another articulatory structure" tactile feedback is especially strong (McDonald, 1964, p. 96).

McDonald, who calls speech "a series of movements made audible" (McDonald, 1964, p. 110), places more emphasis than do many authors on heightening awareness of tactile and proprioceptive as well as auditory stimuli. He suggests that the case can better do this by saying the sound himself than by listening to the clinician, as in ear training (McDonald, 1964, p. 183). "Deep testing" is an attempt to locate a phonemic environment for the misarticulated sound within which the case can say it correctly. When one is found, he is asked to "describe what parts of his mouth he felt touching each other and in what direction his tongue moved" (McDonald, 1964, p. 140).

> Only by an integration of finely discriminated auditory, proprioceptive, and tactile stimuli can the precise ballistic, overlapping movements of mature, normal articulation be developed from the gross motor behavior of an infant (McDonald, 1964, p. 92).

Mysak (1966). In this book, which is largely a theoretical discussion of the relationship of feedback to speech pathology, a few therapy procedures are suggested. The clinician places the case's fingers on his (the clinician's) mouth while he produces the movements for correct and incorrect sound production, without voice. The case may then put one hand on the clinician's mouth and the other on his own while they simultaneously read lists of words, first with voice and then without. "The task of the client would be to eventually detect tactile (through fingertips) error factors" (Mysak, 1966, p. 79).

Ear training has been a popular and successful method of articulation therapy for many years. But phonetic placement, defined here as any procedure which focuses the attention of the case on his articulators (Curtis, 1967), has never been abandoned as a class of techniques. Even authors who rely heavily on the auditory channel suggest that other feedback channels be used in conjunction with the ear (Carrell, 1968), or in terminal therapy (Van Riper, 1963), or for some sounds (McDonald, 1964), or for some cases (Berry and Eisenson, 1956). Some suggest that the kinesthetic and tactile channels may be of more importance to the adult than to the child (Van Riper and Irwin, 1958; McDonald, 1964). Others have expressed a need for more precise knowledge regarding these feedbacks (Berry and Eisenson, 1956; Carrell, 1968; Curtis, 1967).

Certainly there are many factors determining how, and whether, tactile and kinesthetic cues may be incorporated into articulation therapy. Conceivably there could be theories regarding the case who may respond better to one kind of cue than another, the therapist whose skill focuses on one channel rather than another, the point in therapy when a new approach is needed, et cetera. This study touches only on the verbal production factor, and on only one aspect of that: the distinction between vowels and consonants. Still it suggests one possible guideline for coordinating the use of auditory, tactile, and kinesthetic techniques.

Differential feedback - vowels and consonants

A possible basis in theory for the use of the tactile and kinesthetic feedback channels has been suggested by the work of Ladefoged (1967) and Perkell (1969), who state that vowels and consonants may be controlled differently by the speaker. Vowels differ from consonants in many ways, and this may be one of them.

The vowel-consonant dichotomy is universal. Vowels are voiced and produced with an open vocal tract, the blade of the tongue some distance from the roof of the mouth. They display a well-defined spectral pattern with a stable set of formant frequencies. Vowels are more intense than are consonants.

Consonants are generally characterized by greater tract constriction; they are produced by forming a complete occlusion or narrow constriction at a specific location in the vocal tract, by a specific part of the articulatory structures. They are more transient than are vowels; the short-time dynamic movements of the vocal apparatus are crucial to all but continuants.

In the formation of consonants, vowel sounds are interrupted to variable degrees in the mouth or diverted through the nose; consonant stimuli may justifiably be conceptualized as additions to vowel stimuli

(Flanagan, 1965; Jakobson, Gunnar, Fant, and Halle, 1951; Ladefoged, 1967; Perkell, 1969).

Perkell (1969) states that there may be important differences between vowels and consonants in velocity, complexity, precision of movement, and anatomy.

> The same organs seem to behave differently under the influence of the two different classes. Consonant articulations by the tongue and lips are generally observed to be faster and more geometrically complex, and they require more precision in timing than vowel articulation (Perkell, 1969, p. 67).

The muscles involved may be the large slow extrinsic muscles for vowels and the fast small intrinsic muscles for consonants. For consonants

> deformation of the articulating organ is superimposed on the positioning element, and the deformation is performed by the action of fast precise intrinsic musculature (Perkell, 1969, p. 66).

By "deformation" Perkell refers to movements such as the bulging of the midline portion of the tongue and the vertical movement of the lips.

Perhaps there are two neuro-muscular systems with different behavior characteristics and different feedbacks. He notes that "skilled employment of the simpler, slower, vowel-producing system appears earlier" in the utilization of the mechanism (Perkell, 1969, p. 62); it is true that, as a rule, vowels precede consonants in infant speech (Irwin, 1952).

Perkell suggests:

> In general, consonant production can be thought of as being more under the regulation of pressure control and tactile feedback than vowels. In contrast, vowel production could be more influenced by acoustic and myo-tactic feedback (Perkell, 1969, p. 62).

Ladefoged (1967) writes that normal speakers typically use one feedback channel over another for monitoring different aspects of speech, but that if the primary channel is damaged the speaker can adapt and switch to another. His experimental work suggests that tongue and lip movements used to produce consonants are controlled tactilely, while vowels, along with qualities such as nasality and pitch, are controlled auditorily.

It is not within the scope of this study to explore the anatomical, physiological, or acoustic implications of these theories. The concern here is only with the possibility, apparently not without experimental foundation, that vowels are controlled auditorily and consonants tactilely and kinesthetically. If this is true, it may provide one theoretical basis for combining auditory and tactile-kinesthetic cues in articulation therapy.

Summary

Self-monitoring is probably essential for the maintenance of adequate speech, and there appear to be three main feedback channels involved in this process - the auditory, the tactile, and the kinesthetic. In recent years articulation therapy has concentrated largely on the auditory channel, while use of the other two has been somewhat unsystematic and speculative. Perhaps theories are needed to provide guidelines for the incorporation of tactile and kinesthetic cues in therapy. There could be theories covering any number of aspects of the therapy situation; the case, the therapist, the progression of therapy, et cetera. The theory utilized in the present study, while it has far-reaching anatomical, physiological, acoustic, and other, implications, is here applied only peripherally and only to one aspect of therapy - that of verbal production. As presented by Ladefoged (1967) and Perkell (1969), this theory suggests that consonants may be controlled tactilely by the speaker, while vowels may be controlled auditorily. The study will attempt to test this. If it is true, it may provide one theoretical basis by which to incorporate tactile and kinesthetic cues into articulation therapy.

PREVIOUS EXPERIMENTATION

In order to discover whether in fact two separate feedback channels are operating, it is necessary to isolate them. Four previous studies bear upon this problem.

Ladefoged (1967) theorized that the control of vowels and consonants might be based on different properties of the sounds. Five subjects read passages and made spontaneous remarks under conditions of reduced auditory and tactile cues. Masking noise was used in the reduced auditory cues condition, and amethocaine hydrochloridic lozenges in the reduced tactile cues condition. Speech was judged to be disorganized but intelligible. Ladefoged felt that the masking affected principally vowels, pitch, nasality, and voice quality, while the lessened tactile cues affected lips and tongue, and, consequently, the production of consonants.

McCroskey (1958) had six subjects read three lists of words under conditions of normal side tone, delayed side tone, and anesthetized articulators. Analysis of variance indicated that loss of tactile cues had the greatest adverse influence on articulation. McCroskey concluded that tactile feedback "is of prime importance since the loss of this channel resulted in a statistically significant reduction in the number of words correctly spoken..." (McCroskey, 1958, p. 89). He found no difference between normal and delayed side-tone with respect to accuracy of articulation and intelligibility.

In a second article using data from the same experiment (McCroskey and Jackson, 1959), the effects of disrupted tactile cues on the production of consonants were assessed. Two judges made a frequency count of errors and found them to be significantly increased under the condition of anesthetized articulators. Data was graphed, but significance statistics were not used.

Ringel and Steer (1963) investigated some effects of tactile and auditory alterations on speech output. They used 13 subjects and six experimental conditions: 1) Control, 2) Binaural white masking noise, 3) Topical anesthesia (applied to the surfaces of the articulators), 4) Local anesthesia (injected, as in the McCroskey experiment), 5) Noise plus topical anesthesia, and 6) Noise plus local anesthesia. Analysis of variance indicated that the most articulation errors occurred with local anesthesia, and local anesthesia plus noise. Topical anesthesia alone and noise alone showed few errors, while the combination showed some errors but fewer than with local anesthesia. It will be noted that here, as in the McCroskey study, no notice was taken of vowel error.

Schliesser and Coleman (1968) tested the effectiveness of the kinds of procedures used by McCroskey and by Ringel and Steer. The study asked three questions: 1) Can tactile and positional sense within the mouth be eliminated by anesthetic? 2) Is the motility of the oral structures affected? 3) Can auditory masking noise be effective in eliminating auditory feedback?

Five male subjects recorded 42 sentences under the conditions of: 1) Oral anesthesia and bilateral masking; 2) Oral anesthesia alone, and 3) Masking alone. There was also a control condition. Conditions were rotated.

To test loss of sensation, subjects were asked to identify the shapes of ten plastic objects held in their mouths, with and without anesthesia. This is a test of oral sterognosis. All subjects identified all objects without anesthesia and performed as well as would be expected by chance with anesthesia (5 out of 50 correctly named). When their tongues were manipulated with forceps, they failed to identify the motion or the tongue position. The experimenters concluded that "practically total elimination of tactile sensitivity in the oral mechanism occurred from anesthesia" (Schliesser and Coleman, 1968, p. 280).

To answer the second question, on motility of the oral structures, mean rates of repetitive speech were compared, and remained within normal limits under anesthesia. Thus they found "very little interference, if any, of motor innervation to the speech musculatures..." (Schliesser and Coleman, 1968, p. 280).

The Problem

To summarize the results of the four experiments:

1) Ladefoged found that disruption of auditory cues by masking noise affected vowels, pitch, nasality, and voice quality, while disruption of tactile cues by anesthesia affected the production of consonants.

2) McCroskey found that disruption of auditory cues by delayed side-tone did not lead to misarticulations, while disruption of tactile cues by anesthesia did lead to misarticulations.

3) Ringel and Steer found that disruption of auditory cues by masking noise led to few misarticulations while disruption of tactile cues by anesthesia led to many misarticulations.

4) Schliesser and Coleman, testing the effectiveness of the procedures used in the McCroskey and in the Ringel and Steer experiments, found that anesthesia was indeed effective in eliminating tactile sensitivity without affecting motility of the structures, and that masking noise did eliminate auditory feedback.

From the results of these experiments, and from Perkell's theory that vowels may be controlled auditorily and consonants tactilely, the following hypotheses were generated:

H_1: That significantly more misarticulation will occur under the condition of auditory masking than under the control condition.

H_2: That significantly more misarticulation will occur under the condition of local anesthesia than under the control condition.

H_3: That significantly more misarticulation will occur under the condition of topical anesthesia than under the control condition.

H_4: That significantly more vowel misarticulation will occur under the condition of auditory masking than under the condition of local anesthesia.

H_5: That significantly more vowel than consonant misarticulation will occur under the condition of auditory masking.

H_6: That significantly more consonant misarticulation will occur under the condition of local anesthesia than under the condition of auditory masking.

H_7: That significantly more consonant than vowel misarticulation will occur under the condition of local anesthesia.

CHAPTER II

PROCEDURES

Eight subjects read consonant-loaded and vowel-loaded word lists under four conditions: 1) Control, 2) Auditory masking noise, 3) Topical anesthesia of the articulators, 4) Local anesthesia of the articulators. Thirty-one judges scaled each reading in terms of precision of articulation.

SUBJECTS

There were eight subjects, three male and five female, volunteers between the ages of 20 and 42 from a college population. Hearing tests were administered in which pure-tone threshold, speech reception threshold, and speech discrimination scores for all subjects were determined to be well within normal limits. Each subjects was included in four experimental conditions, three involving interference with a sensory channel and a control condition. The order in which conditions were presented was counterbalanced over the eight subjects (see Appendix A).

WORD LISTS

There were two experimental word lists, each containing 50 words. Words on one list were heavily loaded with consonants, while words on the other list were heavily loaded with vowels. For example, approximately 50% of the sounds contained in the consonant list were plosives or fricatives, while approximately 13% of the sounds in the vowel list fell into these classes (see Appendix E). All words were chosen from the Thorndike-Lorge frequency lists (Thorndike and Lorge, 1944), and none occurs more frequently than once per 1,000,000 words in English reading. It was felt that these relatively unfamiliar words presented a challenge to the articulatory skill of the subjects so that they were more dependent on their important feedback channels for maintenance of adequate articulation. Disruption of a channel would, then, be more likely to interfere with articulation. To guard against the possibility that errors resulting from ignorance of the correct pronunciation of words might be judged as errors resulting from channel disruption, each subject was instructed: "Read over this list and mark out any words you don't know how to pronounce." This instruction allowed vocal or sub-vocal rehearsal but did not allow an aural model since the experimenter did not say the words aloud. As many as 15 words from the 50-word list were eliminated following this instruction (see Appendix B), but since the experimental sample taken from each list consisted of only 10 words, it is believed that this abbreviation did not appreciably affect the results.

Consonant and vowel lists were designated as List (a) and List (b) in the instructions to the subjects, and the order in which the lists were read was alternated (see Appendix A).

PACING

In order to present a further challenge to articulatory skill, each subject was required to read his lists at the rate of speed at which his skill began to deteriorate without sensory channel alteration. The subject was given an alternate version of the experimental word list (see Appendix F), told to mark out words he felt he could not pronounce, and asked to read in time to an electric metronome.[1] The metronome speed was increased until the subject was unable to keep up; these "threshold" speeds were recorded and ranged from 110 to 120 beats per minute (see Appendix C).

Each subject attempted to read the experimental lists to the beat of the metronome, set at his "threshold" speed, under all experimental conditions. Although the subjects were not always able to conform to these metronome rates, it is felt that the metronome pushed each subject to read as rapidly as he could.

CONDITIONS

All readings were recorded on a Uher 4000 Report-L tape recorder at a tape speed of 7½ inches per second.

Control Reading

The subject read and recorded the experimental lists without sensory channel alteration.

Auditory Masking Reading

For this condition, masking noise was introduced into the subject's ears through Auraldome ear phones as he read the experimental lists. The Grason-Stadler Speech Audiometer Model 162 tailored speech noise, having as its base those frequencies most prominent in the speech range, was used.

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[1] Crystalab Metronome, Model MP-300-PA. This model contains a flashing light as well as an audible beat, so that monitoring was possible under the condition of auditory masking.

In order to prevent the subject from increasing his vocal intensity and overriding the noise, it was necessary that he monitor his voice visually. The subject read the alternate word list (see Appendix F) into the audiometer microphone as masking noise was introduced through the ear phones, monitoring his vocal intensity by watching the VU meter. The intensity of the masking noise was increased until the subject reported that he could no longer hear his voice. Decibel levels at which this point was reached were recorded, and ranged from 90 to 102 (see Appendix D).

The subject then read and recorded the experimental word lists with the previously determined intensity of masking noise introduced through the ear phones.

Topical Oral Anesthesia Reading

The subject rinsed his mouth with approximately two ounces of 2% Viscous Xylocaine for 30 seconds, and then spit out the solution. Since the structures most important for speech appear to be the anterior portion of the tongue, the hard palate, and the lips (Henkin and Banks, 1967; McDonald and Aungst, 1967; Mason, 1967) the subject was asked to make sure the solution contacted these structures.

When the subject reported a peak in the numbing sensation (after about two minutes) the experimental lists were read and recorded.

Local Oral Anesthesia Reading

According to previous research, the bilateral mandibular block is the best way to affect tactile and positional sense in the mouth without affecting motility (Schliesser and Coleman, 1968). The anesthetic was administered by an otolaryngologist. Two-percent Xylocaine was injected into the inferior alveolar nerves at the inferior alveolar foramen, and into the lingual nerves. Anesthesia of these nerves eliminates sensory innervation of the lower lip and cheek, buccal and lingual gingivae, and the anterior two-thirds of the tongue as well as the alveolus and teeth. The upper lip was numbed by having the subject bathe it in 2% viscous Xylocaine for 60 seconds.

When a peak in the numbing process was reported (after 15 to 30 minutes), the subject read and recorded the experimental lists.

JUDGING

Ten-word segments from each speaker, each list, and each condition, or 64 segments in all, were taken randomly from the tapes and spliced together randomly to compose a master tape. The master tape was played to 31 judges, students in a junior level course in speech pathology. Twenty of the judges were female and eleven were male.

The following instructions were read aloud to the judges:

> "You will hear words read in blocks of ten by a number of speakers. Please judge these readings in terms of precision of articulation. Listen to each block and rate it on a 1 to 7 scale, in which 1 represents very precise articulation and 7 represents very imprecise articulation. The word 'articulation' refers to the production of consonant and vowel sounds. Do not try to scale single words - scale only the block of ten.
>
> You will have 10 seconds between each block in order to record your rating."

Training

These instructions also appeared on the scoring form given the judges (see Appendix G). Four 10-word blocks, chosen from the tape and re-recorded, were played as examples of very precise, medium precise, and very imprecise articulation. These blocks were chosen auditorily, with no reference to the condition under which they were recorded. Two consonant and two vowel blocks were used in this training session.

Judgments

Following the brief training session, the experimental tape was presented as described in the instructions to the judges. When judgments were completed, the median of all 31 judgments for each block of ten words was figured and used as the single criterion measure in the statistical analysis.

SUMMARY OF PROCEDURES

Eight subjects read consonant-loaded and vowel-loaded word lists under four conditions: 1) Control, 2) Auditory masking noise, 3) Topical anesthesia of the articulators, and 4) Local anesthesia of the articulators. All experimental readings were done at the subject's "threshold" speed as previously determined. Readings were recorded, and ten-word blocks from each list, each subject, each condition, were taken randomly from the tapes and spliced randomly to compose a master tape. There were 64 blocks in all.

Thirty-one judges heard the tape and scaled each reading in terms of precision of articulation on a 1 to 7 scale. Median judgments constituted the basic data of this experiment and were used as the criterion measures for the purposes of statistical analysis.

CHAPTER III

RESULTS

The median judgments associated with the 64 experimental readings and the semi-interquartile ranges of the 31 judgments for each reading are shown in Table 1. It will be noted that semi-interquartile range figures were small, with a mean Q-score of .870.

The median judgments were evaluated through an analysis of variance procedure. A three-dimensional analysis of variance was used, a two-factor by subjects design (Lindquist, 1963, p. 237). Results are shown in Table 2.

As Table 2 reveals, both main effects - feedback interference and speech sound class - are significant experimental variables. None of the interaction effects, however, reached usually acceptable significance levels.

Since treatment main effects were significant, the differences between individual treatment pairs were evaluated using _t_ tests (Lindquist, 1963, p. 166). A single critical difference was computed for each treatment, and all individual differences were classed as either significant or non-significant through comparison with this critical difference (see Table 3). Results indicate that significantly more imprecision of articulation was heard in the masking condition than was heard in the control condition, the topical anesthesia condition, or the local anesthesia condition, and that more imprecision of articulation was heard in the local anesthesia condition than was heard in the control condition.

While results indicate that the type of sound heard - vowels or consonants - significantly affected judgment of articulatory precision, the interaction between type of sound and type of feedback disruption was not statistically significant.

HYPOTHESES

The hypotheses of this experiment were:

H_1: That significantly more misarticulation will occur under the condition of auditory masking than under the control condition.

H_2: That significantly more misarticulation will occur under the condition of local anesthesia than under the control condition.

H_3: That significantly more misarticulation will occur under the condition of topical anesthesia than under the control condition.

H_4: That significantly more vowel misarticulation will occur under the condition of auditory masking than under the condition of local anesthesia.

H_5: That significantly more vowel than consonant misarticulation will occur under the condition of auditory masking.

H_6: That significantly more consonant misarticulation will occur under the condition of local anesthesia than under the condition of auditory masking.

H_7: That significantly more consonant than vowel misarticulation will occur under the condition of local anesthesia.

Hypothesis 1 and Hypothesis 2 were verified. Results concerning Hypothesis 3, having to do with topical anesthesia, and Hypotheses 4-7, having to do with differential effects on vowels and consonants of auditory and tactile channel disruption, were not significant.

However, Figure I, showing judged imprecision in graph form, reveals a tendency for consonants to be affected by masking noise and by local anesthesia and for vowels to be affected principally by masking noise.

TABLE 1

MEDIANS AND SEMI-INTERQUARTILE RANGE OF 31 JUDGMENTS FOR EACH SUBJECT AND UNDER EACH FEEDBACK CONDITION AND MEAN VALUES FOR EACH FEEDBACK CONDITION

Subject Number		Conditions							
		Control		Masking		Topical Anesthesia		Local Anesthesia	
		cons.	vowel	cons.	vowel	cons.	vowel	cons.	vowel
1	Median	2.100	1.571	2.700	3.333	2.400	1.636	2.091	2.222
	Q	.768	.700	1.139	1.129	1.034	1.056	.701	.959
2	Median	1.867	1.462	1.667	1.615	1.333	2.333	3.500	2.111
	Q	.709	.725	.900	.688	.667	1.061	1.056	.792
3	Median	2.333	1.357	4.111	4.250	1.923	1.625	1.778	1.000
	Q	1.028	.601	.938	1.563	.784	.638	.856	.584
4	Median	3.182	2.733	6.211	6.211	4.000	3.200	6.286	2.500
	Q	.883	1.025	.601	.566	1.288	.834	.500	1.150
5	Median	2.800	2.000	3.454	3.700	1.923	1.471	2.444	1.667
	Q	.929	.864	.840	1.017	.784	.471	.967	.900
6	Median	1.167	2.667	5.143	2.769	3.444	1.923	3.273	1.500
	Q	.631	1.332	.941	.701	1.000	.989	.813	.444
7	Median	2.231	1.000	3.143	2.375	2.667	1.583	5.600	2.333
	Q	.736	.614	1.167	1.188	.903	.806	1.016	1.084
8	Median	1.167	2.286	1.900	1.611	1.583	1.333	1.417	2.400
		.631	1.013	1.075	.542	.806	.667	.737	1.167
Mean		2.106	1.885	3.541	3.233	2.409	1.888	3.299	1.967
		3.991		6.774		4.297		5.266	

TABLE 2

ANALYSIS OF VARIANCE
SHOWING EFFECTS OF FEEDBACK INTERFERENCE AND SOUND CLASSES

Source	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio	Significance
Feedback Interference	3	18.817	6.272	6.201	1%
Vowel-Consonant	1	5.676	5.676	6.639	5%
Subjects	7	34.011	4.859		
V-C x FB	3	3.084	1.028	1.886	NS
V-C x Ss	7	5.987	.855	1.569	NS
FB x Ss	21	21.207	1.010	1.853	NS
FB x V-C x Ss	21	11.443	.545		
Total	63	100.225	1.591		

TABLE 3

MEANS AND
DIFFERENCES BETWEEN FEEDBACK INTERFERENCE TREATMENT PAIRS

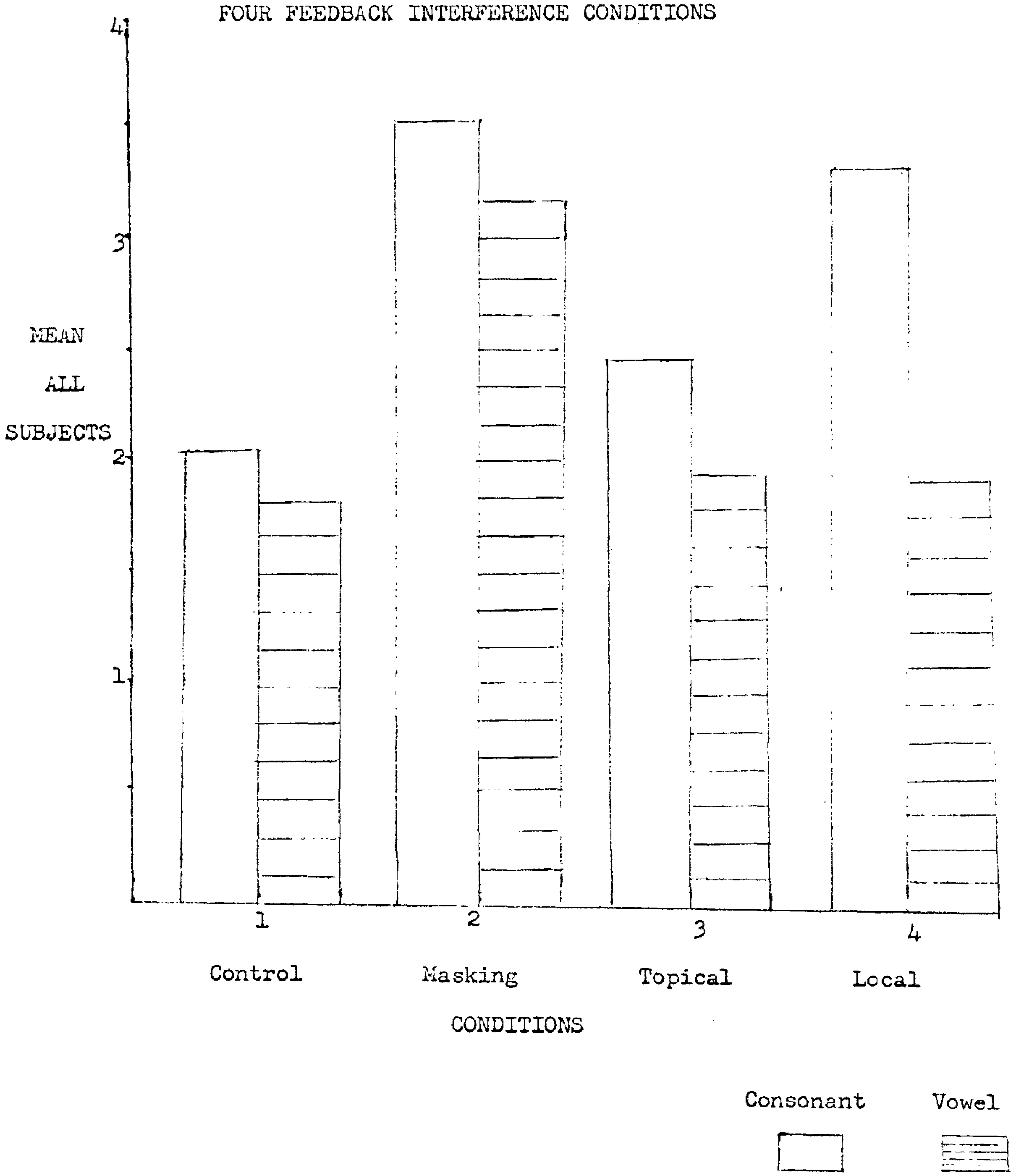
Masking	6.774	Masking	6.774	Masking	6.774
Control	3.991	Topical	4.297	Local	5.266
DIFFERENCE	2.783*	DIFFERENCE	2.477*	DIFFERENCE	1.508*
Local	5.266	Local	5.266	Topical	4.297
Control	3.991	Topical	4.297	Control	3.991
DIFFERENCE	1.275#	DIFFERENCE	.969	DIFFERENCE	.306

*Significant at the 1% level - value of critical difference 1.421.

#Significant at the 5% level - value of critical difference 1.044.

FIGURE I

JUDGED IMPRECISION OF ARTICULATION OF VOWELS AND CONSONANTS IN FOUR FEEDBACK INTERFERENCE CONDITIONS



CHAPTER IV

DISCUSSION

The finding that masking noise was even more disruptive of articulatory precision than was local anesthesia of the articulators was unexpected, and not to be predicted from the findings of previous experiments. Of the three previous researchers cited who tested the effects of disrupted auditory cues, only Ladefoged found that this disruption had a significant effect on speech. He concluded that masking noise affected principally vowels, pitch, nasality, and voice quality. The graphed results of the present study, shown in Figure I, indicate that masking noise affected consonant as well as vowel production. The theoretical implication would seem to be that vowels are controlled auditorily, as hypothesized, while consonants are controlled tactilely, as hypothesized, and auditorily as well. It must be remembered that the terms "vowels" and "consonants as used here refer to weighted lists rather than to isolated phonemes.

Vowel imprecision was regularly heard by the judges in this experiment, while in the McCroskey and in the Ringel and Steer experiments, little or no notice was taken of vowel sounds. A factor may be that this experiment was specifically constructed to detect vowel error if it in fact existed. But since relatively naive listeners - students in a junior level course in speech pathology - appear to judge articulatory precision by vowels as well as by consonants, future researchers might do well to take into account this class of speech sounds. Practicing clinicians, too, might discover that their judgment as to whether or not a case displays defective articulation is colored by his production of vowel as well as of consonant sounds.

The implication of the results for therapy of defective articulation seems to be that the several techniques known as ear training should be effective - as indeed they are. Since removal of tactile and kinesthetic cues also affected articulatory precision, however, some combination of stimulations in therapy should be even more effective. Precise techniques for achieving tactile and kinesthetic stimulation have yet to be devised.

FUTURE RESEARCH

It must be stressed that the interaction between speech sound class and feedback interference discussed here is inferred from the graphed results only, and that this interaction was not statistically significant. More clearly defined interaction might be found by using only two conditions - local anesthesia and masking noise. In the Ringel and Steer experiment and in the present experiment, topical anesthesia was found to be ineffective in disrupting articulatory precision, and it would seem fruitless to continue using this condition in future research.

It should also be stressed that the terms "vowels" and "consonants" here refer to weighted lists rather than to specific phonemes, and that this definition is a loose one. Future researchers might pinpoint the effects of feedback disruption by focussing on vowels unaccompanied by consonants, for example, or on fricatives as opposed to nasals. Any such design, however, must account for the fact that vowel and consonant phonemes may not be produced or perceived as discrete units in running speech, but may be somehow combined. Fairbanks doubts that the unit of control of the speech servo-mechanism is any "presently defined phonetic unit" (Fairbanks, 1954, p. 138). Van Riper and Irwin also doubt that the unit is the phoneme, since "sequences of movements are discharged as whole patterns not as serial items of behavior" (Van Riper and Irwin, 1958, p. 110). The point to be made here is that speech broken into isolated vowel and consonant phonemes for experimental purposes may not correspond to vowels and consonants interacting in running speech, and that any results obtained from such a design must be so qualified. While it can be asserted that weighted lists do not serve to define vowels and consonants, phoneme-by-phoneme breakdowns may not serve to define these sound classes as produced by the speaker and as perceived by the listener.

CHAPTER V

SUMMARY

An investigation was conducted concerning the auditory and the tactile and kinesthetic feedback used to monitor speech. In the cybernetic model of speech behavior, data about speech just emitted is fed back to the speech programming mechanism and used to control on-going speech. The auditory sensor has been assumed to assert primary control, with the tactile and kinesthetic sensors relegated to secondary roles, and most articulation therapy is currently based on this assumption. Yet some theorists have postulated that vowels may be controlled auditorily and consonants tactilely. If this is true, perhaps tactile and kinesthetic stimulation should more often be incorporated in therapy designed to correct defective consonant sounds. Previous experimentation would seem to corroborate this, since disruption of tactile cues was found to have a greater effect on articulation of consonants than was disruption of auditory cues.

In the present experiment, the following hypotheses were generated:

H_1: That significantly more misarticulation will occur under the condition of auditory masking than under the control condition.

H_2: That significantly more misarticulation will occur under the condition of local anesthesia than under the control condition.

H_3: That significantly more misarticulation will occur under the condition of topical anesthesia than under the control condition.

H_4: That significantly more vowel misarticulation will occur under the condition of auditory masking than under the condition of local anesthesia.

H_5: That significantly more vowel than consonant misarticulation will occur under the condition of auditory masking.

H_6: That significantly more consonant misarticulation will occur under the condition of local anesthesia than under the condition of auditory masking.

H_7: That significantly more consonant than vowel misarticulation will occur under the condition of local anesthesia.

Eight adult subjects were asked to read lists of vowel-loaded and consonant-loaded words under the following conditions:

1) Control
2) Auditory masking
3) Topical anesthesia of the articulators
4) Local anesthesia of the articulators

Thirty-one judges were presented with ten-word blocks from each speaker, each list, each condition - 64 blocks in all - and asked to judge the blocks on a 1 to 7 scale in terms of precision of articulation.

An analysis of variance showed that precision of articulation was significantly affected by feedback interference and by sound class. A comparison of means also showed that more imprecision of articulation was heard in the masking condition than was heard in the other three conditions, and that more imprecision of articulation was heard in the local anesthesia condition than was heard in the control condition. Interaction between type of sound class and type of feedback disruption was not statistically significant.

Therefore, Hypotheses 1 and 2 were verified, while results concerning Hypotheses 3, 4, 5, 6, and 7 were not significant.

However, graphed results showed a strong tendency for consonants to be affected by both masking noise and local anesthesia while vowels were affected primarily by masking noise. The theoretical implication would seem to be that vowels are indeed controlled auditorily while consonants are controlled both auditorily and tactilely.

Note was taken of the fact that vowel as well as consonant imprecision was regularly heard by the judges, and it was suggested that future researchers and practicing clinicians take into account this class of speech sounds.

Since the auditory channel was found to be of major importance in the maintenance of precise speech, the use of ear training as a corrective method was supported. Removal of tactile and kinesthetic cues also affected articulatory precision, however, and it was suggested that new techniques utilizing these feedbacks should be devised.

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APPENDIX A

ORDER OF ADMINISTRATION OF EXPERIMENTAL CONDITIONS

Subject Number	Condition Order			
1	C cv	M vc	T cv	L vc
2	L vc	C cv	M vc	T cv
3	T cv	L vc	C cv	M vc
4	M vc	T cv	L vc	C cv
5	C vc	M cv	T vc	L cv
6	L cv	C vc	M cv	T vc
7	T vc	L cv	C vc	M cv
8	M cv	T vc	L cv	C vc

Key

C - Control
M - Masking
T - Topical anesthetic
L - Local anesthetic
c - Consonants
v - Vowels

APPENDIX B

NUMBER OF WORDS ELIMINATED FROM EACH STUDENT'S EXPERIMENTAL WORD LISTS BECAUSE OF ANTICIPATED DIFFICULTY OF PRONUNCIATION

Subject Number	Consonant List	Vowel List
1	5	5
2	2	1
3	2	0
4	10	15
5	10	9
6	3	3
7	1	0
8	3	4

APPENDIX C

"THRESHOLD SPEED," METRONOME BEATS PER MINUTE AT WHICH ARTICULATORY SKILL BEGAN TO DETERIORATE

Subject Number	Beats Per Minute
1	120
2	112
3	116
4	116
5	116
6	110
7	116
8	112

APPENDIX D

DECIBEL LEVEL OF MASKING NOISE SUFFICIENT TO MASK SUBJECTS' VOICES

Subject Number	Decibel Level
1	102
2	100
3	94
4	100
5	100
6	90
7	94
8	90

APPENDIX E

EXPERIMENTAL WORD LISTS

Consonant-Loaded

extrude
wristbank
grubstake
portress
isthmus
Vladivostock
furbish
aesthete
furze
Hapsburg
swinish
vermiform
exorcist
Coptic
bumpkin
wizened
digitalis
seismic
delft
baptistry
sundries
juxtapose
purplish
Fascism
minstrelsy
bludgeon

asterisk
Ipswich
furbish
circumspect
disburse
splotch
rhymster
doldrums
dirigible
Charybdis
quint
Rothschild
crux
sludge
discus
hypnotist
synthesize
scathe
copiousness
cadmium
lumpish
torque
potsherd
transcendent

Vowel-Loaded

ukelele
oozy
alleyway
aria
roue
soiree
bowie
kiwi
aorta
Maya
Noel
boa
ennui
wooer
Peoria
melee
oriole
laity
alway
iota
yaw
tiara
peony
bayou
whoa
aerie

oho
Allah
loyally
nohow
oleo
Loyola
ahoy
aura
bylaw
aloha
oboe
Iliad
Aeolian
Tahiti
yowl
eel
payee
ire
bah
Iago
ion
heighho
eon
Lorelei

APPENDIX F

ALTERNATE WORD LIST

abrasive
radiography
location
beekeeper
compulsive
outland
impersonator
grandiloquence
semiprecious
ancillary
earthiness
flatworm
Rosicrucian
theosophist
waiver
yak
diabetic
prefrontal
marrowbone
Kiwanian
isometric
hayseed
largo
resiliency
scalawag
loamy
Grenoble
moonrise
newsprint
quinsy
Hindustani
anemic
wickerwork
telepathic
plagiarize
backbite
flagman
observational
undershot
cowbell
Fiji
yeasty
winecellar
potbellied
hooch
semilunar
adagio
echelon
butterfat
peppery

APPENDIX G

SCORING FORM

You will hear words read in blocks of ten by a number of speakers. Please judge these readings in terms of precision of articulation. Listen to each block and rate it on a 1 to 7 scale, in which 1 represents very precise articulation and 7 represents very imprecise articulation. The word "articulation" refers to the production of consonant and vowel sounds. Do not try to scale single words - scale only the block of ten.

You will have 10 seconds between each block in order to record your rating.

whoa
aerie
oho
Allah
loyally
nohow
oleo
Loyola
ahoy
bylaw
1. _____

juxtapose
purplish
Fascism
minstrelsy
bludgeon
asterisk
Ipswich
furbish
circumspect
disburse
2. _____

juxtapose
purplish
Fascism
furbish
circumspect
disburse
splotch
rhymster
doldrums
dirigible
3. _____

peony
bayou
whoa
aerie
oho
Allah
loyally
nohow
oleo
Loyola
4. _____

Vladivostock
stridulate
aesthete
furze
Hapsburg
swinish
vermiform
exorcist
Coptic
bumpkin
5. _____

wooer
Peoria
melee
oriole
laity
alway
iota
yaw
tiara
bayou
6. _____

isthmus
Vladivostock
stridulate
aesthete
furze
Hapsburg
swinish
vermiform
exorcist
Coptic
7. _____

Iliad
Tahiti
yowl
eel
payee
ire
bah
ion
heighho
eon
8. _____

purplish
Fascism
bludgeon
asterisk
furbish
circumspect
splotch
rhymster
doldrums
dirigible
9. _____

oboe
Iliad
Aeolian
Tahiti
yowl
eel
payee
ire
bah
Iago
10. _____

oboe
Iliad
Tahiti
yowl
eel
payee
bah
Iago
ion
heighho
11. _____

peony
bayou
whoa
aerie
Allah
loyally
nohow
oleo
Loyola
ahoy
12. _____

soiree
bowie
aorta
Maya
Noel
boa
ennui
wooer
Peoria
melee
13. _____

baptistry
sundries
juxtapose
purplish
Fascism
minstrelsy
bludgeon
asterisk
Ipswich
furbish
14. _____

delft
baptistry
sundries
juxtapose
purplish
Fascism
minstrelsy
bludgeon
asterisk
Ipswich
15. _____

doldrums
dirigible
quint
Rothschild
crux
sludge
discus
hypnotist
synthesize
scathe
16. _____

seismic
delft
baptistry
sundries
juxtapose
purplish
Fascism
bludgeon
asterisk
Ipswich
17. _____

quint
Rothschild
crux
sludge
discus
hypnotist
synthesize
scathe
copiousness
cadmium
18. _____

loyally
nohow
oleo
Loyola
ahoy
aura
bylaw
aloha
oboe
Iliad
19. _____

bludgeon
asterisk
Ipswich
furbish
circumspect
disburse
splotch
rhymster
doldrums
dirigible
20. _____

loyally
nohow
oleo
Loyola
ahoy
aura
bylaw
aloha
oboe
Iliad
21. _____

vermiform
exorcist
Coptic
bumpkin
wizened
digitalis
seismic
Delft
baptistry
sundries
22. _____

aura
bylaw
aloha
oboe
Iliad
Tahiti
yowl
eel
payee
ire
23. _____

oriole
laity
alway
iota
yaw
tiara
peony
bayou
whoa
aerie
24. _____

bumpkin
wizened
digitalis
seismic
delft
baptistry
sundries
juxtapose
purplish
Fascism
25. _____

wristband
grubstake
isthmus
Vladivostock
stridulate
aesthete
Hapsburg
swinish
vermiform
exorcist
26.______

laity
alway
iota
yaw
tiara
peony
bayou
whoa
aerie
oho
27.______

ukelele
oozy
alleyway
aria
roue
soiree
bowie
kiwi
aorta
Maya
28.______

aorta
Maya
Noel
boa
ennui
wooer
Peoria
melee
oriole
laity
29.______

disburse
splotch
rhymster
doldrums
dirigible
quint
Rothschild
crux
sludge
discus
30.______

bowie
kiwi
aorta
Maya
Noel
boa
ennui
wooer
Peoria
melee
31.______

disburse
splotch
rhymster
doldrums
dirigible
quint
Rothschild
crux
sludge
discus
32.______

laity
alway
iota
yaw
tiara
peony
whoa
oho
Allah
loyally
33.______

aura
bylaw
aloha
oboe
Iliad
Aeolian
Tahiti
yowl
eel
payee
34.______

Noel
boa
ennui
wooer
Peoria
melee
oriole
laity
alway
iota
35.______

kiwi
aorta
Maya
Noel
boa
ennui
wooer
Peoria
melee
36.______

bylaw
aloha
oboe
Tahiti
yowl
eel
payee
bah
ion
eon
37.______

wizened
digitalis
seismic
delft
baptistry
sundries
juxtapose
purplish
Fascism
bludgeon
38.______

stridulate
aesthete
furze
Hapsburg
swinish
vermiform
exorcist
Coptic
bumpkin
wizened
39.______

roue
soiree
bowie
aorta
Maya
Noel
bowie
ennui
wooer
Peoria
40.______

baptistry
sundries
juxtapose
purplish
Fascism
minstrelsy
bludgeon
asterisk
Ipswich
furbish
41.______

furbish
circumspect
disburse
splotch
rhymster
doldrums
dirigible
quint
Rothschild
crux
42.______

Iliad
Aeolian
Tahiti
yowl
eel
payee
ire
bah
Iago
ion
43.______

juxtapose
purplish
Fascism
bludgeon
asterisk
Ipswich
furbish
circumspect
disburse
splotch
44.______

quint
Rothschild
crux
sludge
discus
hypnotist
synthesize
scathe
copiousness
cadmium
45.______

bumpkin
wizened
digitalis
seismic
delft
baptistry
sundries
juxtapose
purplish
Fascism
46.______

peony
bayou
whoa
oho
Allah
loyally
nohow
oleo
Loyola
ahoy
47.______

Maya
Noel
boa
wooer
Peoria
melee
oriole
laity
alway
iota
48.______

splotch
rhymster
doldrums
dirigible
quint
Rothschild
crux
sludge
discus
hypnotist
49.______

disburse
splotch
rhymster
doldrums
dirigible
quint
Rothschild
crux
sludge
discus
50.______

juxtapose
purplish
Fascism
minstrelsy
bludgeon
asterisk
Ipswich
furbish
circumspect
disburse
51. _____

disburse
splotch
rhymster
doldrums
dirigible
quint
Rothschild
crux
sludge
discus
52. _____

laity
alway
iota
yaw
tiara
peony
bayou
whoa
oho
Allah
53. _____

loyally
nohow
oleo
Loyola
ahoy
aura
bylaw
aloha
oboe
Iliad
54. _____

bylaw
aloha
oboe
Tahiti
yowl
eel
payee
bah
ion
eon
55. _____

loyally
nohow
oleo
Loyola
ahoy
aura
bylaw
aloha
oboe
Iliad
56. _____

quint
Rothschild
crux
sludge
discus
hypnotist
shythesize
scathe
copiousness
cadmium
57. _____

whoa
aerie
oho
Allah
loyally
nohow
oleo
Loyola
ahoy
bylaw
58. _____

grubstake
portress
isthmus
stridulate
Hapsburg
vermiform
Coptic
bumpkin
wizened
digitalis
59. _____

Fascism
bludgeon
asterisk
furbish
circumspect
splotch
rhymster
doldrums
dirigible
quint
60. _____

Fascism
bludgeon
asterisk
furbish
circumspect
splotch
rhymster
doldrums
dirigible
quint
61. _____

peony
bayou
whoa
aerie
oho
loyally
nohow
oleo
Loyola
62. _____

yowl
eel
payee
ire
bah
Iago
ion
heighho
eon
Lorelei
63. _____

juxtapose
purplish
Fascism
minstrelsy
bludgeon
asterisk
Ipswich
furbish
circumspect
disburse
64. _____