An Investigation of the Relationship of Tongue Clicking to Mandibular Descent

Amy Louise Bricker

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AN INVESTIGATION OF THE RELATIONSHIP OF TONGUE CLICKING TO MANDIBULAR DESCENT

by

Amy Louise Bricker

A Thesis Presented to the Graduate Faculty of Western Michigan University in Partial Fulfillment of the Requirements for the Degree of Master of Arts

Western Michigan University
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AN INVESTIGATION OF THE RELATIONSHIP OF
TONGUE CLICKING TO MANDIBULAR DESCENT

CHAPTER I

Review of the Literature

Introduction. The movement of the tongue has been of concern for many years to the speech therapist. At one time tongue exercises were of prime importance in this field but due to the gross misuse of the exercises, they have now become of little importance. Only recently has the motor functioning of the tongue attracted renewed interest. Although the activity of the tongue has often been studied, none of the studies to our knowledge have included the control of jaw movement. Since the genio-glossus muscle serves as the bulk of the tongue and has its origin on the mandible, the importance of mandibular descent seems obvious. The purpose of this study is to investigate the diadochokinetic rate of tongue clicking under conditions controlling the jaw movement.

Anatomy and Function of the tongue in normal speech.
Judson and Weaver\(^1\), Travis\(^2\), and Van Riper and Irwin\(^3\) have


all stated that the tongue is probably the most important articulatory organ. In order to understand its importance a review of its anatomy and function is needed.

The tongue is often divided into a body and a root by the anatomist. The body is the part which is visible to the eye; the root the part which runs down to the hyoid bone. In considering the tongue, the speech therapist generally uses the following divisions; the _tip_, which is the pointed front portion of the tongue; the _blade_, which is the portion directly behind the tip and beneath the pre-maxilla; the _front_, which is beneath the hard palate; and the _back_, which is the portion below the soft palate.

According to Van Riper and Irwin\(^1\), the tongue is attached at three points: "the front of the jaw behind the chin; the skull (and soft palate) just in front of the ears; and the hyoid bone." Therefore, the tongue's relationship to these supporting structures is important in understanding its functions. The jaw attachment aids in pulling the tongue forward, in holding the tongue-tip down, and in retracting the tongue. The origin of the styloglossus on the skull draws the tongue upward and backward while the hyoid bone attachment pulls the tongue downward and backward by means of the hyo-glossus.

\(^1\) loc. cit., p. 376.
Van Riper and Irwin\textsuperscript{1} point out that: "The tongue, which is essentially a muscular organ, is capable of an almost infinite variety of positions and movements." The muscles of the tongue consist of two groups, the extrinsic and the intrinsic muscles. The former have their origins outside the tongue, the latter are contained entirely within it.

The extrinsic muscles consist of the genioglossus, the styloglossus, the palatoglossus, and the hyoglossus. In discussing the function of the genioglossus Van Riper and Irwin\textsuperscript{2} say: "The anterior or front fibers of this muscle run upward and forward to insert in the tongue tip and blade; they may act to retract the tongue tip or to pull down on the tongue tip and blade." The styloglossus has as its most important function the raising of the tongue. It also sends a branch of its muscles along the sides of the tongue which help to retract the tongue. The palatoglossus lifts the back portion of the tongue, while the hyoglossus lowers the tongue. Van Riper and Irwin\textsuperscript{3} state: "Since many of our consonants have acoustic features dependent upon the sudden lowering of the tongue to create a puff of air (as in the plosives), this muscle (the hyoglossus) has great importance in articulation."

\textsuperscript{1}loc. cit., p. 375.
\textsuperscript{2}loc. cit., p. 378.
\textsuperscript{3}loc. cit., p. 379.
The intrinsic muscles primarily shape the tongue. The lingualis superior muscle shortens the tongue and retracts the tip of the tongue. The lingualis inferior muscle pulls down and retracts the tip of the tongue. The lingualis transversus helps to groove the tongue. Van Riper and Irwin commented: "Most consonants that require tongue-tip lifting and grooving require its contraction." The last of the intrinsic muscles, the lingualis verticalis, grooves or flattens the middle portion of the tongue.

Judson and Weaver describe the muscular aspect of diadochokinesis in the following way:

"Muscles are always in pairs, right and left of the midline; further, every muscle (agonist) has its antagonist, and vice versa. Normally, contraction is produced by efferent (motor) impulses arriving via the nerve supply of the muscle. Muscles are never entirely relaxed; when not actively contracted they are always in a state of tonus (slight, steady tonic contraction). This provision, together with the mechanism of balanced antagonism permits a rapidity and smoothness of movement which could not otherwise be obtained."

West, Kennedy, Carr and Backus imply the importance of rapid diadochokinesis when they state that "speech involves extremely rapid shifts of muscular excitation and inhibition, and that varying defects result from slowness

1 loc. cit., p. 380.

2 Judson, L. S. and Weaver, A. T., op. cit., p. 190.

of muscular movement."

The importance of coordinated tongue movement in speech is evident from our discussion. In this study the speed of movement of the tongue in the process of a frontal tongue click will be used. This particular tongue click has been found to be representative of articulatory placement for most of the frontal consonants which cause difficulty in articulatory disorders. Stein\(^1\) suggests that the /l/ /r/ and /s/ develop from this click. These are the three most frequently misarticulated sounds.

The relationship of tongue movement to defective articulation. Because the tongue is considered the most important articulatory organ by most authors we need to consider the pertinent research. Speech requires a speed of movement which is very rapid. West, Kennedy, Carr and Backus\(^2\) state that probably the chief factor in the rate of diadochokinesis of the muscles of the face, tongue, and jaw is "the rate at which reciprocating impulses can be shifted from a given group of muscles to its antagonistic group and back again."


\(^2\) op. cit., p. 49.
Fairbanks and Spriestersbach\(^1\) found that the speech structures from fast to slow diadochokinesis ranked in the following order: "lips, mandible, tongue-alveolar, tongue protrusion." Berry and Eisenson\(^2\) state that within the articulatory organs themselves, there is a rate differential movement of from five to nine repetitions per second. Berry and Eisenson\(^3\) differ in order from Fairbanks and Spriestersbach\(^4\) in their finding that "...the tongue-tip is the fastest."

Diadochokinesis for movements of the tongue were reported by Fairbanks and Spriestersbach\(^5\) to be 4.84 per second; by Strother and Kriegman\(^6\) to be 6.53 per second; by Blackburn\(^7\) to be 4.59 per second; and, by Cross\(^8\) to be

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\(^3\) Ibid.


5.10 per second. Berry and Eisenson\(^1\) state that "85 per cent of our consonants are formed by raising the sides or tip-blade of the tongue." Therefore, it is apparent how markedly the disability in this function alone affects speech.

Tongue-tie has been thought to be an occasional cause of speech difficulties. Johnson\(^2\) describes this condition:

"The blade of the tongue is 'tied down' to the bottom of the mouth too far forward toward the tip. It is a simple operation to clip this cord, or frenum...but such an operation will not automatically remove the speech defect."

West, Kennedy, Carr and Backus\(^3\) in considering this point state:

"There are few demonstrable gross anomalies of the tongue causing speech defect, although there appear to be numerous instances of irregularities in arrangement of fibers of the various intrinsic muscles of the tongue which interfere with the production of the more complex articulatory adjustments."

Sarrett and Foster\(^4\) comment: "Usually...faulty articulation is the result of bad speech habits; inflexible lips and jaw, and a lazy tongue."

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\(^1\)Berry, M. E. and Eisenson, J., op. cit., p. 366.


Lundeen\(^1\) tested the diadochokinetic rate of several sounds, reporting the following order from fast to slow rates: /t/, /d/, /p/, /b/ were the fastest, with /f/ and /v/ occupying the medial position, and /s/, /z/, /k/, /g/ being the slowest. Poole's\(^2\) developmental order of sounds corresponds closely to Lundeen's\(^3\) diadochokinetic rank order of sounds.

In comparing seven, eight, and nine year old groups of children with abnormal articulation to children with normal articulation Maxwell\(^4\) says: "Groups of children with defective consonant sounds were inferior to children with normal speech at all three levels in their ability to repeat /pa - ta - ka/." The norms of his groups on this test were 9.23 productions per second for the seven year olds; 9.69 for the eight year olds; and 10.62 for the nine year olds.

\(^1\)Lundeen, D. J., "The Relationship of Diadochokinesis to Various Speech Sounds," Journal of Speech and Hearing Disorders, XV (March 1950), 57.


\(^3\)op. cit.

Ward\textsuperscript{1} found that the children with abnormal articulation did not differ significantly from the children with normal articulation in their amount of jaw movement during the production of /p\text{\textael} - t\text{\textael} - k\text{\textael}/. This may be accounted for by the fact that all of the sounds in this syllable require a close approximation of the maxilla and mandible plus the fact that the children with abnormal articulation in her study had had speech therapy previous to testing.

Irwin and Beckland\textsuperscript{2} report in a study of diadochokinetic rate of speech sounds that at the age fifteen boys could produce /t\text{\textael}/ 5.77 times per second and girls could produce it 5.38 times per second. Blomquist\textsuperscript{3} concluded from the evidence gathered in his study that: "The mean rate for this group of children (normal speakers) from nine through eleven in the production of the /t\text{\textael}/ sound was 4.9


\textsuperscript{2}Irwin, John V., and Beckland, Orville, "Norms for Maximum Repetitive Rates for Certain Sounds Established with the Syrlatest," Journal of Speech and Hearing Disorders, XVIII (June 1953), 159.

\textsuperscript{3}Blomquist, E., "Diadochokinetic Movements of Nine, Ten, and Eleven Year Old Children," Journal of Speech and Hearing Disorders, XV (June 1950), 132.
sounds per second." Lundeen$^{1}$ and Van Riper$^{2}$ found that adults could make the syllable /tə/ at the rate of seven per second.

The works of Pettit$^{3}$, Schlanger$^{4}$, Blomquist$^{5}$, and Jenkins$^{6}$ indicate that as chronological age increases, diadochokinetik ability increases until about the age eighteen. Jenkins$^{7}$ says: "...that diadochokinesis of the seven-year-old male is about two thirds that of the twenty-year-old male."

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$^{1}$Lundeen, D. J., op. cit., p. 56.


$^{5}$Blomquist, E., op. cit., p. 164.

$^{6}$Jenkins, R. E., "The Rate of Diadochokinetic Movement of the Jaw at the Ages from Seven to Maturity." Journal of Speech and Hearing Disorders, VI (March 1941). p. 19.

$^{7}$Ibid.
Diadochokinesis of articulatory movements has also been found to be in direct contradiction to the popular theory of female superiority in motor ability. Lundeen\textsuperscript{1}, Blomquist\textsuperscript{2}, Irwin and Beckland\textsuperscript{3}, Fairbanks and Spriestersbach\textsuperscript{4}, Neumayer\textsuperscript{5}, and Ream\textsuperscript{6}, all found that diadochokinetic sex differences exist in favor of the male. Although Fairbanks and Spriestersbach\textsuperscript{7}, qualify this finding by stating: "The general analysis showed significant sex variance in tongue protrusion and tongue-alveolar movement, but the difference between sex groups, ability constant, reached significance only in tongue protrusion."

\textsuperscript{1}Lundeen, D. J., op. cit., p. 59.

\textsuperscript{2}Blomquist, B., op. cit., p. 163.

\textsuperscript{3}Irwin, John V. and Beckland, Orville, op. cit., p. 158.

\textsuperscript{4}Fairbanks, G., and Spriestersbach, A. S., op. cit., p. 68.


\textsuperscript{7}Fairbanks, G., and Spriestersbach, A. S., op. cit., p. 69.
Several researchers commented that younger girls seemed to be superior to younger boys but that older boys were superior to older girls.

Considerable research has been carried out on the relationship of diadochokinesis to the various disorders of speech. Berry and Eisenson\(^1\) found the most frequent disability in the cerebral palsied's articulatory apparatus is "the failure of the tongue-tip and blade to rise to the alveolar ridge without approximation of the mandible." Travis\(^2\) found "a reduced activity of the anterior tongue and tongue-tip" in cleft palate children. West, Kennedy, Carr and Backus\(^3\) refer to one of the positive signs of spastic paralysis as being unable to produce five movements of the jaw per second.

Mase\(^4\) in comparing fifty-three pairs of boys with articulatory defects to boys with normal speech found no significant differences between the two groups in the following abilities:

\(^1\)Berry, M. F., and Eisenson, J., op. cit., p. 366.


\(^3\)West, R. E., Kennedy, L., Carr, A., and Backus, O., op. cit., p. 175.

\(^4\)Mase, Darrel J., Etiology of Articulatory Speech Defects. Teacher's College, Columbia University, Contributions to Education, No. 921, 1946, p. 79.
moving tongue from corner to corner of mouth, opening mouth and closing lips alternatively, touching a tongue depressor with the tongue tip, stretching and rounding the lips alternately, and repeating "daddy" rapidly. Fairbanks and Spriestersbach\(^1\) in their study of young adults with superior and inferior articulatory ability found no significant difference between the two groups. Fairbanks and Bebout\(^2\) report very little difference between articulatory and normal speaking adult subjects in maximum tongue force. Palmer and Osborne\(^3\) concluded in their study that: "Speech defective individuals have, in general, a low muscular strength of the tongue." Karlin, Youtz, and Kennedy\(^4\) in a series of experiments found that children with normal speech made higher rates in tests of articulatory speech than those with "distorted speech".

\(^1\)Fairbanks, G. and Spriestersbach, A. S., op. cit., p. 68.


\(^3\)Palmer, M. F. and Osborne, C. D., "Study of Tongue Pressures of Speech Defectives and Normal Speaking Individuals." Journal of Speech and Hearing Disorders, V (June 1940), 139.

\(^4\)Karlin, L., W., Youtz, A. C., and Kennedy, L., "Distorted Speech in Young Children." American Journal of Diseases of Children, LIX (June 1940), 1217.
Most of the research seems to indicate that diadochokineti
movements of the tongue of individuals with
articulatory disorders is significantly lower than those
of individuals with normal speech.

Differentiation of tongue movement from mandibular
movement. In speech the jaw and tongue must be able to work
together in perfect coordination, and yet must also be able
to function independently from the other. In the basic
function of the oral structures, that of mastication, the
tongue moves with the jaw. In speech the tongue must be
able to move independently of the jaw.

For example, the most obvious and frequent disability
in the cerebral-palsied's articulatory apparatus is the
failure of the tongue-tip and blade to rise to the alveolar
ridge without approximation of the lower jaw. Van Riper\(^1\)
and Crickmay\(^2\) suggest that a possible reason for a child to
articulate the more difficult sounds incorrectly is due to
the failure to differentiate the tongue from a concomitant
movement of the jaw.

\(^1\)Van Riper, C. op. cit., p. 173.

\(^2\)Crickmay, Marie C., "An Exploratory Study of Dif-
ferential Diadochokinesis." Unpublished master's thesis,
Western Michigan College of Education, Kalamazoo, Michigan,
January 1956. p. 22.
Berry and Eisenson\(^1\) point out the significance of the differentiation of tongue from jaw movement in suggesting the following: "If the tongue-tip can be raised to the gumline behind the upper front teeth seven or eight times in ten seconds without moving the lower jaw, its action may be considered to be adequate for developing speech." West, Kennedy, Carr and Backus\(^2\) suggest the following exercise: "Take the relaxed jaw position with the velum elevated. Keeping the jaw, lips, and velum in this position, elevate the tongue until the tip comes into contact with the gum ridge." Therefore, if these suggestions be true, it appears important to find out the rate at which the tongue can move if the mandible is stabilised, or at what approximation of the jaw is tongue diadochokinesias most easily coordinated.

Lundeen\(^3\) reports "an increase in rate of speech tends to be accompanied by a decrease in the amount the mandible

\(^1\)Berry, M. F. and Eisenson, J., op. cit., p. 367.


is lowered." Heffner suggests that a variety of mandibular positions may be assumed during speech. He continues:

"Consonantal sounds are produced by a complete or partial closure of the channel by which the breath flows from the larynx to the lips."

Grey and Wise believe too narrow a separation of the jaws is a common cause of nasality. They state: "...constriction at the front of the mouth reduces the normal amount of oral resonance, allowing any nasal component present to assume greater prominence." Kelly found that non-nasal speakers separated their jaws to a significantly greater degree than did nasal speakers. Hixon and Smith discovered no significant differences between the two groups.

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Fartridge\(^1\), in his observations of a patient whose lower and upper jaws were wired together, comments: "Both voice quality and articulation were correct in this person's speech."

It was indicated earlier in the results of the investigations of norms for the speed of movement of the tongue by Fairbanks and Sprietersbach\(^2\), Karlin, Youtz and Kennedy\(^3\), Maxwell\(^4\), and Raine\(^5\) that children with articulatory defects have been found to fall below the norms.

The rate of tongue movement to our knowledge in relation to fixed jaw positions has received little interest. It, therefore, seems relevant to conduct a study which would measure the diadochokinetic rate of tongue movement with the mandible stabilized, due to the observed importance of differentiation of tongue movement from mandibular movement.

\(^1\)Fartridge, L., M., "Oral Deformations and Dyslalias," *Journal of Speech and Hearing Disorders*, XII (June 1947), 165.


\(^3\)Karlin, I. W., Youtz, A. C., and Kennedy, L., op. cit., p. 1218.

\(^4\)Maxwell, K. J., op. cit., p. 214.

Mal-coordination as a factor in articulation speech disorders. Many articulation cases have been considered to have speech problems because of poor motor coordination. Cypreansen, Wiley and Laase\(^1\) state: "Adequate speech in most cases calls for normal functioning of the muscles of the larynx, throat, palate, tongue, lips, jaws, and of the muscles related to breathing."

According to Grinker\(^2\) dysdiadochokinesis may be due to faulty innervation of the muscles which fix the neighboring joint. He found the movements were slower and more irregular. In discussing specialization of movement West, Kennedy, Carr and Backus\(^3\) stated: "The functions of speech require such definite localized movements of the muscles of the face, tongue, throat, larynx, and respiratory apparatus that development of speech must wait upon the ability of the child to cause one muscle or group of muscles to act and others to remain inactive."


\(^3\) West, R. S., Kennedy, L., Carr, A., and Backus, O., *op. cit.*, p. 50.
Cole\textsuperscript{1} feel that a delay in the myelination of the nerve tracts at the onset of parental training in speech prevents speech development, and that the errors are stabilized by the time myelination occurs. Berry and Eisenson\textsuperscript{2} suggest in relation to speech defectives the supposition that "the threshold of excitation of the nerves controlling the speech organs is high and the rate of conduction slow." Cypreansen, Wiley and Laase\textsuperscript{3} suggest that for normal speech to develop there must be no interference with the muscular activities of the speech organs which means "no interference with the central or peripheral nervous systems that innervate the speech mechanism."

A review of several studies will help to bring out the areas of agreement and disagreement in regard to the motor development and motor abilities of the defective in speech. Bilto\textsuperscript{4} administered a series of tests measuring


\textsuperscript{2}Berry, M. F. and Eisenson, J., op. cit., p. 42.


large-muscle abilities of a group of speech-defective children ranging in age from nine to eighteen years and a control group with normal speech. In the elements of rhythm, coordination and strength necessary for performance of the tests he found two-thirds of the speech-defective children were inferior to the children with normal speech. Carrell\textsuperscript{1}, Karlin, Youtz, and Kennedy\textsuperscript{2}, Patton\textsuperscript{3}, and Albright\textsuperscript{4} tend to support the view that poor speech, especially poor articulation, is associated with poor motor performance.

Several studies, which seem to contradict this point of view, were done by Fairbanks and Bebout\textsuperscript{5}, Fairbanks and Spriestersbach\textsuperscript{6}, Reid\textsuperscript{7}, and Mase\textsuperscript{8}.

\begin{enumerate}
\item Karlin, I. W., Youtz, A. C., and Kennedy, L., op. cit., p. 1207.
\item Albright, R. W., "The Motor Abilities of Speakers with Good and Poor Articulation," Speech Monographs, XV (April 1948), 170.
\item Fairbanks, G., and Bebout, B., op. cit.
\item Fairbanks, G., and Spriestersbach, A. S., op. cit.
\item Reid, G., "The Etiology and Nature of Functional Articulatory Defects in Elementary-School Children," Journal of Speech Disorders, XII (1947), 149.
\item Mase, D. J., op. cit.
\end{enumerate}
A review of the studies of motor coordination of the articulatory mechanisms also shows discrepancies. Neither Fairbanks and Spiestersbach\(^1\) nor Albright\(^2\) found a significant difference between poor and normal speech groups in these functions. Mason\(^3\) and Fairbanks and Spiestersbach\(^4\) found no difference for any type of nonspeech tongue movement, speed or protrusion. Both studies did find slight differences between ability groups in lip movements only.

Blomquist\(^5\), Albright\(^6\) and Maxwell\(^7\) reported significant differences between speech-defectives and normal speakers for rapid repetition of syllables. In regard to tongue pressure or force, the results of Palmer and Osborne\(^8\) and of Fairbanks and Bebout\(^9\) are contradictory. The former found a significant difference, the latter did not.

\(^{1}\)Fairbanks, G., and Spiestersbach, A. S., op. cit.
\(^{2}\)Albright, R. W., op. cit.
\(^{3}\)Mason, D. J., op. cit.
\(^{5}\)Blomquist, B., op. cit., p. 161.
\(^{6}\)Albright, R. W., op. cit., p. 172.
\(^{7}\)Maxwell, K. J., op. cit.
\(^{8}\)Palmer, M. F. and Osborne, C. D., op. cit.
\(^{9}\)Fairbanks, G., and Bebout, B., op. cit.
The literature concerning diadochokinesis of articulatory mechanisms seems to point to poor motor coordination factors most specifically in the case of the dyslalic or the dysarthric. Lundeen\textsuperscript{1} states: "The observation was made that articulation cases who can produce a newly learned sound only at a relatively slow rate usually have more difficulty incorporating that sound into casual conversation than do those who can produce the newly learned sound at a relatively fast rate." Albright\textsuperscript{2} says "the test of speech rate showed marked superiority on the part of the subjects with good articulation" in relation to those with poor articulation. Palmer and Osborne\textsuperscript{3} commented "there was a significant difference in the tongue strength of speech defective individuals and their controls."

Heltman and Peacher\textsuperscript{4} suggest: "In view of the fact that diminished diadochokinesis bears a definite relationship to defective speech in the spastic, diadochokinetic exercises of the tongue, lips, jaw, and velum palatinum are

\textsuperscript{1}Lundeen, D. J., "The Relationship of Diadochokinesis to Various Speech Sounds," \textit{op. cit.}, p. 58.

\textsuperscript{2}Albright, R. W., \textit{op. cit.}, p. 171.

\textsuperscript{3}Palmer, M. P. and Osborne, C. D., \textit{op. cit.}, p. 135.

indicated." Palmer and Osborne support direct attempts to improve the muscular strength of the tongue. Tongue exercises, including the differentiation of jaw movement from tongue movement, are recommended by Van Riper, Van Riper and Irwin, West, Kennedy, Carr and Backus and Berry and Eisenson.

Even though the significance of tongue movement which is independent of jaw movement for speech has been recognized by several researchers, little research has been conducted in this area. The inability to differentiate the movement of the tongue from that of the jaw seems to be a major problem for many speech defectives. The prime purpose of this study is to measure the relationship of tongue clicking to mandibular descent and thereby to provide essential information on this important aspect of articulatory ability.

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1 Palmer, M. F. and Osborne, C. D., op. cit., p. 140.
2 Van Riper, C., op. cit., pp. 216-220.
CHAPTER II

Statement of the Problem

Contradiction, concerning mal-coordination as a factor in articulation speech disorders, seems to prevail in the findings of the researches reviewed in the last chapter. It would appear from the survey of these and from accounts of therapeutic procedures, especially in the case of the dyslalic or the dysarthric individual, that many articulation defects are the results of or include deficiency of tongue movement. Crickmay\textsuperscript{1} has suggested: "...that a lack of differentiation of the fine movement of the tongue from the gross movements of the jaw might be one of the original or maintaining causes of defective articulation."

According to Ward\textsuperscript{2} children with articulatory disorders open their mouths wider in their normal and their abnormal speech, than children with normal speech in the utterance of consecutive speech. She continues: "This suggests that the movement of the tongue is failing to differentiate sufficiently from the movement of the jaw. If this is true, it may be that we are in error to emphasize larger mouth movements in the treatment of these children."

\textsuperscript{1}op. cit., p. 21

\textsuperscript{2}op. cit., p. 62

24
The basic problem of this present research is to see if the normal adult speaker is able to perform faster coordinated movements of the tongue at narrow openings of the jaw in comparison to wider openings of the jaw, to determine whether or not Ward's\(^1\) observation has experimental support.

**Justification of this research.** Speech therapy, for most of its history, has emphasized the use of tongue exercises. Many studies have been conducted concerning the speed of tongue movement and jaw movement during the past twenty-five years. However, our review of literature indicates that little or no research has been done which controlled the jaw opening and movement while measuring the diadochokinetic rate of the tongue movements.

Practicing speech therapists have noted that many articulation cases fail to elevate the tongue-tip to the alveolar ridge. Critchmay\(^2\) observed in the children with abnormal articulation that "it was obvious that some of the children used smaller tongue liftings in producing the syllable /\'æ/ than did others." Dysarthrias and dysalalies tend to use gross movements of the jaw and larger mouth openings in an attempt to produce the tongue-tip and blade

\(^1\)op. cit., p. 63.

\(^2\)op. cit., p. 39.
sounds such as /s/, /l/, and /r/.

In view of these factors it would seem justifiable to undertake a study to determine whether or not normal speaking adults would have a faster diadochokinetic tongue-clicking rate when the mandible closely approximated the maxilla than during a larger separation of these two structures.

The present research. This investigation concerned the relationship of tongue-clicking to varied vertical distance, mandibular descent, between the incisors of normal speaking college adults of both sexes. This group of adults, between the ages of eighteen and twenty-four, formed the experimental group. Sixteen of the group were males and sixteen were females, making a total number of thirty-two subjects. All thirty-two of the adults were tested by means of vernier caliper which locked the jaw open at varying widths. The clicks were tape recorded and subjected to an analysis of variance to see what differences occurred in frequency. Comparisons were made, conclusions drawn and suggestions for further research and implications were discussed.
CHAPTER III

Procedure

The Experimental Subjects. The subjects for this investigation were white college age adults from Western Michigan University.

The age range was from eighteen years to twenty-four years of age. This particular age group was used to provide comparative data with discussed research of Pettit\(^1\), Schlanger\(^2\), Blomquist\(^3\), and Jenkins\(^4\). There were a total of thirty-two subjects, sixteen males and sixteen females.

The subjects were limited to those who exhibited no pronounced voice quality, rhythm, articulatory, or hearing deviations. The frenum, tongue size, alignment and occlusion of the teeth and the symmetry of the jaw were examined for each subject to ensure that no organic involvements were present. A developmental history was taken to ascertain if the following items had any bearing on the findings of the experiment. The items included were: thumb sucking, tongue sucking, accidents to the tongue, breast feeding, tongue thrusting, mouth breathing, nose breathing, presence

\(^1\) op. cit., p. 42.
\(^2\) op. cit., p. 38.
\(^3\) op. cit., p. 163
\(^4\) op. cit., p. 21
or absence of adenoids and tonsils, pipe smoking, and ability to trill the tongue.

The Apparatus. A vernier caliper (Buffalo Dental Mfg. Co., 2911-23 Atlantic Ave., Brooklyn, N. Y.; No: 3-605-900.), which was held by the subject, was used to measure the width of mouth opening and to lock the jaw open at varying widths. In order to lock the caliper at the desired measurement a "C" clamp was used. A tape recording was made of each subject's tongue clicking for later compilations. The microphone was placed horizontally six inches from each subject's mouth. An electric metronome produced one beat per second. A signal light, at eye level, was the starting device.

Experimental procedure. Each subject was required to lower the mandible to its greatest extent. A measurement of the vertical distance between the maxillary incisors and the mandibular incisors (maximum incisor descent) was taken. The average measurement of five trials was used to determine the extreme range of mandibular descent. The metric system of measurement was employed.

This average was then divided by eight in order to determine the three experimental jaw openings used in this study. They were those of one-eighth, two-eighths and three-eighths of the averaged greatest incisor descent.
Since in the pilot study it was found that the average speaker cannot click the tongue more than once when the mandible is lowered over one-half the maximum incisor descent, the one-eighth, two-eighths and three-eighths openings were used.

The subjects were then given a description and demonstration of the type of tongue click /l/ needed. A three second practice period of tongue clicking from the alveolar-premaxillary ridge of the maxilla to the area immediately posterior to the alveolar ridge in the mandible followed to ensure comprehension of the directions.

The vernier caliper was then placed in the subject's mouth, between the upper and lower incisors and the subject was instructed to maintain continuous contact with both of its blades. The subjects were told to make the tongue click as rapidly as possible during the two trials for for each of the three compiled distances.

For each subject the number of tongue clicks produced in a five-second period for each jaw opening were tape recorded. An electric metronome was placed near the microphone so that the beat per second was recorded. The subjects were signalled by means of a light going on and off at the beginning and termination of the five-second period. The initial and final second were eliminated due to the time lapse factor between signalling and the initiation and termination of the tongue clicking. The clickings were
recorded at fast speed (seven and one-half inches per second) and then counted on slow speed playback (one and one-sixth inches per second). A two minute rest period was given between each of the six trials in order to decrease fatigue variability.

Despite the fact that the previous work of Ream\(^1\), Blomquist\(^2\), and Lundeen\(^3\) has indicated that neither practice nor order of presentation has appreciable effect upon the rate obtained, for one-half the group the order was reversed.

The order for eight of the men and eight of the women was as follows:

1) One-eighth the distance.
2) Two-eighths the distance.
3) Three-eighths the distance.
4) Three-eighths the distance.
5) Two-eighths the distance.
6) One-eighth the distance.

\(^1\) op. cit.

\(^2\) op. cit., p. 164.

\(^3\) Lundeen, "An Investigation of the Relationship of Vertical Mandibular Movement to Loudness and Rate of Speech and to Aspects of Individual Variation," op. cit., p. 140.
The order for the other eight men and eight women was as follows:

1) Three-eighths the distance.
2) Two-eighths the distance.
3) One-eighth the distance.
4) One-eighth the distance.
5) Two-eighths the distance.
6) Three-eighths the distance.

The results of the investigation were obtained by counting the tongue-clicks for the median three seconds for each subject. The reliability of the measurements were found to be accurate by an independent observer who scored a sample record selected at random. All records which were not qualitatively complete were eliminated.

**Justification for the use of tongue-clicking. Stein¹**

states:

"There are many primitive languages in which, in spite of the very long history they have behind them, clicks are still preserved, for instance, in the subbranches of Athapaskan, Haida and Tlingit of the American languages, and in some African languages such as Bushman, Hottentot, Sandawe, Bantu-Ngoni (Zulu, Xhosa, Swazi) and sporadically the Bantu-Sotho languages."

¹Stein, op. cit., p. 70.
Gimnokin\textsuperscript{1} describes the three clicks involved in suction as "nämlich, a labial, a medial, and a velar one, which can be well discriminated acoustically." In speech development the original utterances are a continuous stream of voice integrated by movements which result in noises such as clicks. The frontal click is represented thusly /\textipa{t}/. These clicks are initially made on inhalation, but gradually the child learns to produce the clicks during exhalation, changing them to the consonantal sounds.

Stein\textsuperscript{2} describes this process thus:

"The amalgamation of two essentially antagonistic functions necessitates in its course the abandonment of impeding characteristics. Thus, for the sake of a unified pattern the rarefaction of air implied in the clicks gradually comes to be replaced by expulsion of air. At first the sounds so produced are half clicked and half explosive, until in the end they are entirely expiratory."


Leopold\textsuperscript{1} and Cypreansen, Wiley, and Laase\textsuperscript{2} in their discussions of the imitative period of speech acquisition suggest that the preceding practice of sucking and chewing produce better coordination of the muscles used in speaking. Proeschels\textsuperscript{3} advocates chewing in all of his therapy.

Most consonantal motions, with the exception of those made by the lips, involve an upward movement of the tongue. Thus the diadochokinetic measurement of a frontal tongue-click \textsuperscript{4} which involves the above movement, is closely related to speech. It has been shown that precision and speed in motor movement are based upon a fundamental tonicity of the efferent systems.

Treatment of data. The data in this study was treated statistically in the following way. The arithmetic mean and standard deviation were computed for each of the three distances for the females, males and the total group.

\textsuperscript{1}Leopold, W. F., "Patterning in Children's Language Learning." Language Learning, V (1953-54), 10.


\textsuperscript{3}Proeschels, E., "Dysarthrias Due to Certain Cerebral Lesions." Journal of Speech and Hearing Disorders, VIII (December 1943), 320.

\textsuperscript{4}Clicks are represented by the inverted symbols for the consonants derived from them.
It was felt necessary to determine through an analysis of variance, whether the differences between means were significant or not. For this purpose, t-scores were procured for all three distances for the females, males and the total group. The t-score is defined as the ratio of a deviation to a standard error. It measures the validity of the difference of two means by taking into account the probable amount of variation from those means which might be expected to occur. We can, therefore, determine by use of the t-scores whether the differences between the means of one-eighth and two-eighths the distance, one-eighth and three-eighths the distance, and two-eighths and three-eighths the distance was statistically significant or not for the three groups.

The confidence level determines the degree of significance. The higher the t-score the more sure we can be that there is a significant difference between the means and that this difference has not occurred by random sampling. If the t-score reaches a five per cent level of confidence this means that the difference between the means is significant and that we would probably find this result again in ninety-five cases out of a hundred, were we to repeat the experiment. When the t-score is larger and reaches the one per cent confidence level this indicates that there is even a greater significant difference between the
means, that is, that only in one case out of a hundred (one per cent), is there likely to be no difference. Therefore in ninety-nine cases out of a hundred with a t-score that reaches the one per cent confidence level the difference would probably occur again if the experiment were repeated.

The greater the number of cases used in an experiment, the lower the t-score would be needed to be significant. This is because a greater freedom of variation in the differences is allowable. This "freedom to vary" is called a degree of freedom and it is the number of subjects used in the experiment minus one. The greater the degree of freedom (the greater the number of cases) the more the deviations can be scattered around the mean and still be significant. In this particular experiment fifteen degrees of freedom are used for the male and female groups. The t-score must then reach 2.131 to be significant at the five per cent level of confidence and 2.947 at the one percent level of confidence. For the total group, thirty-two subjects, thirty degrees of freedom are used making the t-score significant at the five per cent level of confidence if it reaches 2.042 and at the one per cent level of confidence if it reaches 2.750.
Fisher's\textsuperscript{1} technique for deriving t-values was used because the means of paired samples were not independent but correlated. His formula,
\[ t = \frac{M_1 - M_2}{\sqrt{\frac{\sum x_1^2 + \sum x_2^2}{N_1 (N_1 - 1)}}} \]
was applied to all three of the distances for males, females and the total group. The confidence levels are expressed according to Table D in Guilford\textsuperscript{2}.


\textsuperscript{2}loc. cit., p. 609.
CHAPTER IV

Results and Conclusions

In Tables I-IX are presented the sums of the raw scores, sums of the mean deviations squared, means, standard deviations, mean differences, and t-values of tongue clicking for each of the compiled distances of one-eighth and two-eighths, two-eighths and three-eighths, and one-eighth and three-eighths of the total mandibular descent for females, males and the total group. The raw scores are stated in terms of the number of tongue clicks per second.

In Tables I-III the evaluations of the scores for the sixteen females are presented. No significant difference was found for diadochokinetic rate of tongue clicking when jaw openings of one-eighth the total excursion of the mandible were compared with jaw openings of two-eighths (Table I). The comparison between two-eighths and three-eighths of the distances (Table II) showed a t-value of 2.962 which is significant at the one per cent level of confidence. This means that tongue clicking at two-eighths of the total mandibular descent is much easier and faster than at three-eighths of the total excursion. Between one-eighth and three-eighths the total distance of mandibular descent (Table III) a t-value of 4.260 showed significance at the one per cent level of confidence. At an opening of one-eighth the distance tongue clicking is
### Table I

**A Statistical Evaluation of One-Eighth and Two-Eighths the Distance for Females**

<table>
<thead>
<tr>
<th>Distance</th>
<th>$\bar{X}$</th>
<th>$\overline{X_f}$</th>
<th>Mean</th>
<th>S.D. Difference</th>
<th>$t$-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-eighth</td>
<td>65.62</td>
<td>11.65</td>
<td>4.10</td>
<td>.85</td>
<td></td>
</tr>
<tr>
<td>Two-eighths</td>
<td>55.55</td>
<td>10.49</td>
<td>3.47</td>
<td>.81</td>
<td></td>
</tr>
<tr>
<td>One-eighths and two-eighths</td>
<td>.63</td>
<td></td>
<td></td>
<td>2.074</td>
<td></td>
</tr>
</tbody>
</table>
TABLE II

A STATISTICAL EVALUATION OF TWO-EIGHTHS AND THREE-EIGHTHS THE DISTANCE FOR FEMALES

<table>
<thead>
<tr>
<th>DISTANCE</th>
<th>$z$</th>
<th>$z_{.05}$</th>
<th>MEAN</th>
<th>S.D.</th>
<th>MEAN DIFFERENCE</th>
<th>$t$-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-eighths</td>
<td>55.55</td>
<td>10.149</td>
<td>3.47</td>
<td>.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three-eighths</td>
<td>38.37</td>
<td>20.84</td>
<td>2.40</td>
<td>1.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-eighths and three-eighths</td>
<td></td>
<td></td>
<td>1.07</td>
<td>2.962*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

"Significant at the 1 per cent level of confidence."
<table>
<thead>
<tr>
<th>DISTANCE</th>
<th>$\leq \xi$</th>
<th>$\xi_{16}$</th>
<th>MEAN</th>
<th>S.D.</th>
<th>DIFFERENCE</th>
<th>$t$-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-eighth</td>
<td>65.62</td>
<td>11.65</td>
<td>4.10</td>
<td>.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three-eighths</td>
<td>38.37</td>
<td>20.84</td>
<td>2.40</td>
<td>1.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-eighth and three-eighths</td>
<td>1.62</td>
<td></td>
<td></td>
<td></td>
<td>4.620&lt;sup&gt;5&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

<sup>5</sup>Significant at the 1 per cent level of confidence.
much faster than at three-eighths of the total excursion of the jaw.

In Tables IV-VI the comparisons for the sixteen males are found. In the evaluation (Table IV) of tongue clicking at one-eighth and two-eighths of the total mandibular descent a t-value of 1.713 was procured showing a lower degree of significance. This means that the diadochokinetic rate of the tongue was only slightly faster at one-eighth the distance than it was at two-eighths the total distance. Comparison of the means shows that the trend of smaller openings leading to faster clicks is sustained, though not as clearly. The t-value for the distances of two-eighths and three eighths (Table V) was 2.712. For the distance of one-eighth and three-eighths (Table VI) the t-value was 4.123. The latter two t-scores were significant at the one per cent level of confidence. The subjects could click their tongue faster at jaw openings of two-eighths the distance than at jaw openings of three-eighths the total distance. Tongue clicking, when the jaw was open at one-eighth the total mandibular descent, was much faster in comparison to the rate of tongue clicking at three-eighths the total excursion.

Tables VII-IX show the statistical evaluations of tongue clicking for the total group. The t-score of 2.558
TABLE IV
A STATISTICAL EVALUATION OF ONE-EIGHTH
AND TWO-EIGHTHS THE DISTANCE FOR MALES

<table>
<thead>
<tr>
<th>DISTANCE</th>
<th>$E$</th>
<th>$E_X^2$</th>
<th>MEAN</th>
<th>S.D.</th>
<th>DIFFERENCE</th>
<th>t- VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-eighth</td>
<td>75.30</td>
<td>17.74</td>
<td>4.71</td>
<td>1.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-eighths</td>
<td>65.54</td>
<td>12.67</td>
<td>4.10</td>
<td>.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-eighth and two-eighths</td>
<td>.61</td>
<td>1.713</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table V

A Statistical Evaluation of Two-Eighths and Three-Eighths as the Distance for Males

<table>
<thead>
<tr>
<th>Distance</th>
<th>$\xi$</th>
<th>$\xi^2$</th>
<th>Mean</th>
<th>S.D.</th>
<th>$t$- Differences</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-eighths</td>
<td>65.54</td>
<td>12.67</td>
<td>4.10</td>
<td>89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three-eighths</td>
<td>50.62</td>
<td>16.16</td>
<td>3.16</td>
<td>1.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two eighths and three-eighths</td>
<td>.94</td>
<td></td>
<td></td>
<td>2.712</td>
<td>$^*$</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the 5 per cent level of confidence.*
Table VI
A Statistical Evaluation of One-Eighth and Three-Eighths the Distance for Males

<table>
<thead>
<tr>
<th>Distance</th>
<th>$ \bar{x} $</th>
<th>$ \bar{x}^2 $</th>
<th>Mean</th>
<th>S.D. Differences</th>
<th>$ t $</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-eighth</td>
<td>75.30</td>
<td>17.74</td>
<td>4.71</td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td>Three-eighths</td>
<td>50.62</td>
<td>16.16</td>
<td>3.16</td>
<td>1.02</td>
<td></td>
</tr>
<tr>
<td>One-eighth and three-eighths</td>
<td>1.55</td>
<td></td>
<td></td>
<td>$ 4.123^a $</td>
<td></td>
</tr>
</tbody>
</table>

$ ^a $Significant at the 1 per cent level of confidence.
TABLE VII
A STATISTICAL EVALUATION OF ONE-EIGHTH AND TWO-EIGHTHIES
THE DISTANCE FOR THE TOTAL GROUP

<table>
<thead>
<tr>
<th>DISTANCE</th>
<th>$\xi$</th>
<th>$\xi_k^2$</th>
<th>MEAN</th>
<th>S.D.</th>
<th>DIFFERENCE</th>
<th>t-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-eighth</td>
<td>140.92</td>
<td>32.17</td>
<td>4.40</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-eighths</td>
<td>121.09</td>
<td>26.24</td>
<td>3.78</td>
<td>.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-eighth and two eighths</td>
<td>.62</td>
<td>2.558*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the 5 per cent level of confidence.
**TABLE VIII**

A STATISTICAL EVALUATION OF TWO-EIGHTHS AND THREE-EIGHTHS
THE DISTANCE FOR THE TOTAL GROUP

<table>
<thead>
<tr>
<th>DISTANCE</th>
<th>$\xi$</th>
<th>$\xi^2$</th>
<th>MEAN</th>
<th>S.D.</th>
<th>DIFFERENCE</th>
<th>MEAN</th>
<th>t-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-eighths</td>
<td>121.09</td>
<td>26.24</td>
<td>3.78</td>
<td>.91</td>
<td>1.00</td>
<td></td>
<td>3.821**</td>
</tr>
<tr>
<td>Three-eighths</td>
<td>88.99</td>
<td>41.70</td>
<td>2.78</td>
<td>1.13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two-eighths and three-eighths</td>
<td>1.00</td>
<td></td>
<td>3.821**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Significant at the 1 per cent level of confidence.**
**TABLE IX**

A STATISTICAL EVALUATION OF ONE-EIGHTH AND THREE-EIGHTHS
THE DISTANCE FOR THE TOTAL GROUP

<table>
<thead>
<tr>
<th>DISTANCE</th>
<th>( \bar{x} )</th>
<th>( s^2 )</th>
<th>MEAN</th>
<th>S.D.</th>
<th>DIFFERENCES</th>
<th>t-VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>One-eighth</td>
<td>4.17</td>
<td>32.17</td>
<td>4.40</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Two-eighths</td>
<td>8.99</td>
<td>41.70</td>
<td>2.78</td>
<td>1.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two eighths and three-eighths</td>
<td>1.62</td>
<td>5.936*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the 1 per cent level of confidence.
for one-eighth and two-eighths the total excursion (Table VII) was significant at the five per cent level of confidence. This means that for the total group the diadochokinetic rate of tongue clicking was faster at one-eighth the distance when jaw openings of one-eighth the distance were compared with jaw openings of two-eighths the total mandibular descent. For the comparison of two-eighths and three-eighths the total distance (Table VIII) a t-score of 3.821 was procured, showing significance at the one per cent level of confidence. Here again we find that the subjects clicked their tongue faster at two-eighths the total distance in comparison to three-eighths the total distance. The highest t-score of 5.936, significant at the one per cent level of confidence, was computed for one-eighth and three-eighths the total mandibular descent (Table IX). This score indicates that tongue clicking at one-eighth the total mandibular descent is much faster than the tongue clicking at three-eighths the total distance and in less than one out of one-hundred cases would the finding be likely to be reversed.

The t-scores comparing the performances at two-eighths and three-eighths the total distance, and one-eighth and three-eighths the total jaw descent all showed a very high degree of significance. We can be fairly certain, therefore, that the ability to click the tongue while the
mandible is stabilized shows a greater degree of motor coordination and ease in clicking at one-eighth the distance of the total mandibular descent than the ability to click at the other distances of two-eighths and three-eighths mandibular excursion.

The standard deviations show a change which is significant of a leptokurtic curve. Fisher's1 t-score formula, previously discussed, corrects this change in kurtosis.

Only one subject (LM-Appendix B) showed an increase in the number of clicks per second from one-eighth to three eighths the total jaw excursion.

The mean scores for the tongue clicks per second of the males for all three distances were higher than the scores of the females. This finding supports the results of Lundeen2, Blomquist3, Irwin and Beckland4, Fairbanks and Spristersbach5, and Neumayer6 that diadochokinetic sex differences exist in favor of the male.

1 loc. cit.
2 Lundeen, op. cit., p. 59.
3 Blomquist, op. cit., p. 163.
4 Irwin and Beckland, op. cit., p. 158.
5 Fairbanks and Spristersbach, op. cit., p. 68.
6 Neumayer, op. cit., p. 140.
Qualitative observations. From our qualitative observations of the subjects during the test, it appeared that difficulty in tongue clicking increased as the mandible descended to a greater degree.

Only one of the items in the developmental history, the ability to trill the tongue, appeared to show any degree of relationship to the ability to click the tongue. Out of the eight females who could not trill their tongue, five (CP, DF, CF, KP, NF) were below the means of tongue clicking at all three distances, and three (AF, PF, JP) were only slightly above the means at one or more distances. The two males (KM, MM), who also showed this inability, were above the means of tongue clicking at one-eighth and two-eighths the total mandibular descent but one subject (KM) was below the mean at three-eighths.

The mean jaw opening for males was 5.145 cm and 4.85 cm for females (Table X). In a comparison of tongue clicking

<table>
<thead>
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<td>THE MEAN JAW OPENINGS FOR MALES AND FEMALES</td>
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<table>
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<td>Males</td>
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</tr>
<tr>
<td>Females</td>
<td>4.830 cm</td>
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to jaw opening the following was found. Females who were
delay below the female mean for jaw opening were above the mean
for tongue clicking; i.e., females who have smaller mouth
openings can click their tongue faster than those with
larger mouth openings. The reverse was true for the males.
Those who were above the male mean for jaw opening, click
their tongue faster than males who have small mouth open-
ings. We are unable to explain these differences.

Summary. An analysis of the results indicates that
there is a very significant difference between tongue
clicking and mandibular descent at one-eighth and three-
eighths the total distance, and two-eighths and three-eighths
the total distance for males, females and the total group.
For the total group there was a significant difference
between tongue clicking and mandibular descent at one-
eighth and three-eighths the total distance. It would
seem, from these results, that the smaller mouth opening
greatly facilitates the ability to click the tongue.
CHAPTER V

Discussion of Results

The relationship of larger and smaller mouth openings to diadochokinesis. This study indicates that the wider mouth openings decreased the diadochokinetic rate of tongue clicking, while the narrower mouth openings increased the rate. The previously discussed findings of Fairbanks and Spriestersbach\(^1\), Strother and Kriegman\(^2\), and Cross\(^3\) show a diadochokinetic rate for movements of the tongue which are slightly faster than the findings of this study. Our findings appear to correlate most closely to those of Blackburn\(^4\). It must be kept in mind, however, that none of these studies controlled the amount of mandibular movement, which may signify that fixation of the mandible decreased diadochokinetic rate of tongue clicking slightly.

Analysis of the scores on tongue clicking. In the case of one-eighth the total mandibular descent the mean for tongue clicking was the fastest for all groups. At one-eighth the distance in comparison with two-eighths and

\(^1\)Fairbanks and Spriestersbach, op. cit., p. 69.
\(^2\)Strother and Kriegman, op. cit., p. 67.
\(^3\)Cross, op. cit., p. 66.
\(^4\)Blackburn, op. cit., p. 324.
especially with three-eighths the distance the differences in speed of tongue clicking were very significant. This implies that a smaller mouth opening, when the mandible is fixed, facilitates a finer degree of coordination of the tongue muscles than that of a wider mouth opening.

All but one of the subjects commented after the testing that the three-eighths distance was the most difficult to perform. Since mandibular movement and movement of the tongue are interrelated in that the mandible is the carrier of the tongue, if the tongue is taken further away from its contact points for clicking, it would necessarily take longer to make successive contact with these. It must be noted that on the three-eighths trials, the subjects found the greatest difficulty in maintaining continuous contact with the blades of the caliper. Therefore, it may be said that movement of the tongue in clicking is most easily differentiated from mandibular movement at narrow jaw openings.

Implications for Therapy. The results of this study indicate that wider mouth openings markedly decrease the diadochokinetic rate of tongue clicking. If this is true, it would appear in the case of the dysarthric or dyslalic individual, that they would profit from training to improve the speed of the tongue activity independently of mandibular movement. The click used in this study /τ/ may
perhaps be considered as an infantile or primitive fore-
runner of the /l/ which is one of the most frequently
misarticulated phonemes. This conclusion appears to be
supported by Lundeen's\(^1\) finding that with faster rates of
speech the mandibular descent is less than mandibular descent
during slower rates of speech.

It has been observed that the mandible is generally
very closely approximated during chewing, swallowing and
other basic functions of the tongue. If speech requires
finer muscular coordination of the tongue than the above
functions, it would seem that a closer approximation of
the maxilla and mandible during these functions would
facilitate these movements.

The results of this study lead us to suggest that
therapists might possibly be in error when they emphasize
larger mouth movements or openings in the treatment with
articulatory cases. By such training they, in fact, are
increasing the difficulty in differentiation of tongue
movement from that of jaw movement and decreasing the rate
of diadochokinesis.

Moreover, it would appear then that if such articulatory
cases produced a newly learned sound, such as /l/, at a slow

\(^{1}\)Lundeen, "An Investigation of the Relationship of
Vertical Mandibular Movement to Loudness and Rate of Speech
and to Aspects of Individual Variation," op. cit., p. 240.
rate, it would be very difficult to incorporate it into the relatively fast rate of consecutive speech due to the gross jaw movements which would tend to become habitual.

**Suggestions for future research.** The review of research indicated that little or no research has been undertaken with respect to the function of the tongue with mandibular movement controlled. The results of this study indicate that tongue movement is faster when narrower mouth openings are used.

In view of the importance of the function of the tongue in the production of speech sounds and the considerable importance to speech therapy, it would seem appropriate that further investigations be carried out in this area. It would appear that investigations into the independent activity of the tongue in both normal and abnormal production of speech sounds, especially the consonants, and also in consecutive speech would be useful in the diagnosis and therapy of speech disorders.

This relatively unexplored area offers many possibilities for future research. It is tentatively suggested that a wider range of age groups be investigated with comparisons between them. It is recommended that the children who are dyslalic or dysarthric be investigated in terms of this function. The question asserts itself as to whether or not the dysarthric adult would vary from the tentative
norms of this study. From qualitative observations of these individuals in therapy we would tend to believe that the tongue shows a low degree of activity independent from that of the jaw for the dysarthric in comparison to the normal speaking adult.

Finally, it is suggested that future investigations should emphasize the function of the tongue in developmental speech as a basis for speech therapy. It seems relevant to find the degree of opening of the jaw at which diadochokinesis of the tongue, independent of jaw activity, is the fastest.
CHAPTER VI

Summary

The problem. The purpose of this study was to determine whether or not normal speaking adults would have a faster diadochokinetic tongue clicking rate when the mandible closely approximated the maxilla than during a larger separation of these two structures.

The procedure. The thirty-two subjects used in this study were adults with an age range from eighteen to twenty-four years. Sixteen of the total group were males, and sixteen were females. The subjects were limited to those who exhibited no pronounced speech, hearing, or organic deviations.

The jaw was locked open at one-eighth, two-eighths, and three-eighths the total mandibular descent by means of a vernier caliper. The raw scores for tongue clicks per second were based on the average score of the two tongue clicking trials at each of the compiled distances.

Results. Statistically significant differences were found for males, females and the total group between one-eighth and three-eighths, and two-eighths and three-eighths of the total mandibular descent for tongue clicking. At the one-eighth distance the diadochokinetic rate of tongue clicking was the fastest for all groups.
There was no significant difference for tongue clicking between the one-eighth and two-eighths openings for the males and females. The total group showed significance at the five per cent level of confidence at this degree of opening. Qualitative differences, and implications for speech therapy and future research were discussed.
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APPENDICES
### APPENDIX A

**RAW SCORES OF TONGUE CLICKS PER SECOND FOR FEMALES**

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<thead>
<tr>
<th>Subject</th>
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**APPENDIX B**

**RAW SCORES OF TONGUE CLICKS PER SECOND FOR MALES**

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### Average Scores of Jaw Openings for Males and Females

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