An Exploratory Study of Differential Diadochokinesis

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AN EXPLORATORY STUDY
OF
DIFFERENTIAL DIADOCHOKINESIS

by

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Arts

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Chapter I

Review of Literature

Introduction. In speech man is forced to use organs, muscles and groups of muscles whose basic function is to serve other purposes, namely, to chew, to suck and swallow, movements which are relatively slow and primitive in execution. But in articulate speech it is necessary to manipulate these same organs and muscles at a faster speed, and with far greater precision than was required of them in the performance of their basic function.

The speed of muscle movements in relation to articulate speech, with which this study is concerned, is attracting an increasing amount of attention from speech pathologists, for it is realised that diadochokinesis, that is the ability to perform regular repetitive movements under conditions of speed, such as lowering and raising the tongue or opening and closing the jaw, has an important bearing on the speech performance of the individual. If such a person is able to move the muscles of his jaws, tongue and lips quickly and smoothly even under pressure, then he is likely to produce the vowel and consonant sounds of spoken language with ease and precision. If he is not able to do this he may find it hard to master some of the more difficult consonant sounds and blends, and to coordinate them into his speech.
The chief factor in diadochokinesis, according to West, Kennedy and Carr (50), is the "rate at which reciprocating impulses can be shifted from a given group of muscles to its antagonistic group and back again" and they conclude that "the person who can negotiate rapid shifts of inhibition of muscle contraction is, generally speaking, possessed of a high rate of diadochokinesis, and correlatively, of the ability to make rapid articulatory movements".

Research on diadochokinesis. Research has shown that diadochokinetic ability is not static, but varies, amongst other things, with age. West, Kennedy and Carr (50) state that "as the child advances year by year his rate of diadochokinesis increases, as does also his speed of articulation". This contention is also borne out by Schlanger (39) Pettit (33) and Jenkins (22) who set themselves the task of establishing norms for the ages 7-19 years in the diadochokinetic movement of opening and closing the jaws. As a result of these studies Jenkins (22) was able to state conclusively that "there seems to be an increase in the rate of diadochokinesis of the jaw from the ages of 7 to the age of 18 years", but he found no correlation with age after 18 years. "At this latter age" he states "the person seems to be diadochokinetically mature". Blomquist (5), in her study of the "Diadochokinetic Movements of 9, 10 and 11 year Olds" found that the number of sounds produced per second increased with age for each of the three sounds tested, which in this case were [p t k]
Diadochokinesis has also been found to vary with sex, although research on this score is contradictory. Ream (37) in his tapping test found that males excelled females. Lundeen (27) in his study of diadochokinesis as related to the focal articulation points of various speech sounds found that males were "significantly faster" than females. In connection with these findings it is interesting to note that they are in direct contradiction to the popular theory of female superiority in motor ability.

Supporting this latter theory Schlanger (41) and Pettit (34) in the studies already referred to, found that in diadochokinetic movements of the jaw girls were superior to boys. Jenkins (22) also found that the female norm was greater than the male, although, as Lundeen (27) points out, these findings may be due to the fact that girls mature faster than boys. Indeed, Jenkins (22) himself bears out this statement when he writes that "one of the determiners of the rate of diadochokinesis is the degree of maturity".

Johnson (23) in his studies on practice and habit found that diadochokinesis is also affected by both physical and emotional habits. The physical condition of the individual and his attitudes and reactions not only to the test but to his environment at that moment have an important bearing on his diadochokinetic ability.

Considerable research has been carried out on the relationship of diadochokinesis to the various disorders of speech. Studies have been undertaken to try to ascertain
whether there is any significant differences in the diadochokinetic ability of individuals with speech abnormalities and individuals with normal speech. The results of this research can be summarized briefly as follows:-

**Diadochokinesi and Stuttering.** West (51) tested stutterers and non-stutterers on their ability to open and close their jaws, and raise and lower their brows. As a result of these tests he reached the conclusion that stutterers as a group were significantly slower in performing these acts than non-stutterers. Blackburn (4) tested stutterers and non-stutterers on movements of the jaw, lips, tongue and diaphragm, and he also found stutterers inferior to normal speakers in these movements. Arps (2) tested the same two groups in gymnastic exercises calling for rhythm and coordination and found that the motor ability of stutterers much lower than that of non-stutterers. Hunsley (19) tested the jaw, lip and tongue movements of stutterers and non-stutterers and reported the former as being significantly slower than the latter. Rotter (37) tested stutterers and non-stutterers on card-sorting and finger tapping and also found the stutterers significantly slower than the non-stutterers.

Against this one must place the fact that Westphal (52) testing a group of stutterers and non-stutterers in bean bag and the Seguin Board Tests found "no measurable differences" between the two groups in motor ability. Seth (42) repeated Blackburn's (4) experiments and found non-significant
differences in the mean variation of the diaphragm. Wulff (55) investigating the movements of the lips, tongue and jaw came to the conclusion that the diadochokinetic ability of stutterers was not inferior to non-stutterers in respect to these movements. Cross (9) examined groups of stutterers and non-stutterers in unimanual activity, as measured by the Motor Rhythm and Tapping Tests of the Stanford Motor Skills Battery, and found no significant difference between the two groups. But she did obtain a significant difference in a unimanual task, the Brown Spool-Packing test. Spriestersbach (45) found no statistically significant difference between stutterers and non-stutterers in the ability to move the jaw, brow, tongue and lips. Strother and Kriegman (46) tested the hypothesis that "stutterers do not differ significantly from non-stutterers with respect to the rate of diadochokinetic movements of the lips, mandible, tongue and finger". The results of their experiments proved this hypothesis to be correct.

From this brief summary it will be seen that the conclusion pointing to a difference in the diadochokinetic ability of stutterers and non-stutterers is just about balanced by conclusions to the contrary. It would seem that further research is needed in this area.

Diadochokinesis and Cerebral Palsy. As yet there has not been so much research on the relationship of diadochokinesis to cerebral palsy, or other types of brain injury as there has been on the relationship of diadochokinesis to
stuttering, for it can be readily understood that any injury to the brain is likely to have considerable effect on the diadochokinetic ability of the individual concerned.

Heltman and Peacher (17) made a study of the rates of diadochokinesis in 102 children with spastic paralysis, and found that the rate for spastics was considerably lower than those reported by Jenkins (22) for non-spastics.

Froeschels (13) states that "in dysarthrias due to lesions of the pyramidal tract movements of articulation are sluggish and clumsy". In injuries to the frontal brain, or of the pathways leading to the frontal brain, he points out that the "impulse of the movements is inhibited and the movements stop before they are completed". Zentay (56) in his studies found that dysarthrias of speech as a result of cerebellar lesions may result in a-diadochokinesis, and in his description of this condition he reports that the "repeated movements gradually decrease in intensity and finally cease".

Wolfe (54) in his studies of cerebral palsied children found that 70% of the subjects he examined had inadequate articulation. He also found that the organs most affected were, in order of severity, the lips, tongue, velum, larynx and mandible.

**Diadochokinesis and disorders of articulation.** A number of studies have been made to try to determine the relationship, if any, between diadochokinesis and disorders of articulation. The results of these studies have again been somewhat contradictory.
Mase (28) made a series of experiments between groups of boys with articulatory defects and groups of boys with normal speech. He tested, amongst other things, the coordination of muscles controlling the articulation, using for this purpose diadochokinetic movements of his own devising. He found no significant differences between the two groups. Fairbanks and Spriestersbach (12) tested 60 young adults with superior and inferior articulatory ability, the latter group having a mean of two consonant errors. Diadochokinetic movements of the lips, jaw, tongue protrusion and eye brow lifting were tested, and the result also showed no significant difference between the two groups. Fairbanks and Bebout (11) found no significant difference in maximum tongue force between subjects with articulatory errors and subjects with normal speech.

As against this, however, Palmer and Osborne (32) also made a study of the relative tongue pressure of individuals with defective speech and individuals with normal speech. They found that tongue strength of those with defective speech was significantly weaker than the tongue strength of the control group. They reported that this deviation from the normal was found "to lie mainly in the articulatory group, although there was some indication that some stutterers also have low tongue strength".

Karlin, Youtz and Kennedy (25) in a series of experiments found that children with "distorted speech" made lower rates in tests of articulatory speech than those
with normal speech. Maxwell (29) studied the difference in motor ability of children with articulatory defects of two or more consonant sounds and children with normal speech. The test was confined to the repetition of nonsense syllables \[ p\, t\, k \] at varying speeds, and it showed that children with defective consonant sounds were inferior to the control group in their ability to do this.

The results of this particular field of research seems to indicate that the diadochokinetic movements of the tongue, lips and jaw and the production of consonant sounds of individuals with articulatory disorders is significantly lower than that of individuals with normal speech.

**Relationship of motor ability to defects of speech.** Simultaneously with research on the relationship of diadochokinesis to the various disorders of speech, studies were being carried out on the possible correlation between motor ability and defects of speech.

Borovikov (7) using the Oseretsky Scale tested the motor abilities of children with speech defects and children with normal speech. The test showed that "motor abilities are not so well developed in children with speech defects as in other children of the same age". Arps (2) also found that the motor abilities of speech defective children were much lower than those of children with normal speech. Bilto (3) made a comparative study of certain physical abilities of children with speech defects and children with normal speech. He tested both groups in a series of activities involving
gross motor coordination and found that two thirds of his subjects with articulatory defects scored lower than his subjects with normal speech. He noted that "in play activities and classes in rhythmic drills children with speech defects appeared to have less adequate large muscle coordination than children whose speech was normal". Wightman (53) tested only ten subjects with delayed speech (cerebral palsy cases excluded) without any etiological factor to account for the delay. Using an adaptation of the Oserestsky test he found that the motor age of the children was nearly two years behind their chronological age. When he validated his findings against normal speaking children he found that their motor age score was equivalent to their chronological age.

**Relationship of developmental factors to defects of articulation.** This is a field which promises to yield interesting information in that further research may point to the fact that a delay in maturation may be a contributory cause in the development of defects of articulation. It is a field, however, which has not yet been adequately investigated.

Schiefelbusch (40) investigated the developmental characteristics of children with speech retardation and children with normal speech and found that the "investigations show a relationship between motor proficiency, intelligence, social maturity and delayed speech". Everhard (10) carried out research to "determine the
importance of various growth and developmental factors in the maturation of speech articulation for elementary children grades one to six. The particular developmental factors chosen for investigation were onset of holding up head: onset of sitting alone: onset of crawling: onset of walking: onset of talking: onset of voluntary bladder control: eruption of first tooth: handedness: grip: height: intelligence: reading: arithmetic. 110 children with articulatory deviations were studied and matched against 110 children with normal speech. The result of the investigations showed that there were no significant differences between the two groups in respect to the above information.

In connection with the possibility that further research in this area may reveal a relationship between maturation and defects of articulation, Maignant (31) has suggested that the correlation may be due to a delay in the myelinization of the nerve tracts at the time that attempts are being made to teach the child to talk. He states that "since speech required the highest type of motor integration it could be most susceptible to a delay in the myelinization of certain nerve fibers". Van Riper (47) points out that "the fact that more boys than girls have speech defects and that myelinization is completed earlier in the female tends to add support to this hypothesis".

On the other hand Sperry (44) feels that the "addition of myelin to nerve fibers has little or no direct influence upon the formation of proper reflex connections".
He goes on to say, however, that a "general correlation between the order of the appearance of stainable myelin, and the order in which the nerve becomes functional has suggested a causal relation. "But" he points out, "the relation is not simple, and it appears to be reciprocal in nature". This latter view is supported by Langworthy (26). He states that "fairly complex activity can be carried out prior to myelinization". But he goes on to say that although "functions in general show considerable improvements in speed, strength, steadiness and precision co-incident with the laying down of myelin...it is not entirely a matter of myelinization acting to improve function, because, conversely, the laying down of myelin is stimulated and accelerated by function."

It is apparent that no definite conclusions can be reached on this point, for as Van Riper (45) emphasizes, there has not been sufficient research to either support or refute the myelinization theory.

The development of motor skills. "Behaviour growth" says Gesell (15) "is a process which produces a progressive organization of behaviour forms". The most outstanding characteristic of this organization is that it follows well ordered patterns, and that it always proceeds from the general to the specific. Never under any circumstances is the reverse the case. Hurlock (20) points out that in both pre-natal and post-natal development general activity precedes specific activity, and goes on to say "this is apparent first in
muscular responses. The newborn infant moves his whole body at one time, instead of moving any one part of it. The baby waves his arms in general, random movement before he is capable of so specific a response as reaching. Likewise his legs are used for random kicking before he can coordinate the leg muscles well enough to crawl, creep or walk.

This evolution of motor patterns can be attributed to the gradual development of inhibition which has the power to suppress all but the required part of any intended movement. Bobath (6) points out that at the lowest spinal level of the central nervous system the movements elicited as a response to stimulation are widespread, involving large parts of the body, and automatic in that they show the influence of primitive reflex patterns. When in the process of maturation the higher centers of the central nervous system gradually take control. Bobath (6) states that "movements become more variable and selective, and involve ever smaller segments of the body". Thus in the ascent from the spinal to the cortical, the highest level of integration of movement, the "lower, simple widespread patterns are broken up and elaborated by......the increasing use of inhibition". He goes on to say that "this process reaches its climax at the cortical level, where inhibition has given us the ability to move small parts of the body independantly in the most varied ways". But even at this level inhibition is relative rather than absolute, for as Walshe (49) points out we are unable to flex one finger without at least producing
some tension in the rest of the hand. With practice, however, it is possible to improve the capacity to differentiate one movement pattern from another, as is evidenced by the difference in the finger movements of a skilled violinist and an ordinary individual.

This process of differentiation, that is the development of finer movements from grosser ones, is beginning to attract an increasing amount of attention from speech pathologists, for it is realised that it may have an important bearing on the therapeutic handling of many speech disorders. The differentiation of the finer movements of the tongue from the grosser movements of the jaw in diadochokinetic movements of the tongue is the key-note of this study. The term "differential diadochokinesis" is used to describe this process.
Chapter II

Statement of the Problem

In order to understand this study it is necessary to return to the introductory statement that the basic function of the organs and muscles used in speech, namely, the jaw, tongue, lips and teeth, is to chew, suck and to swallow. In the performance of these movements the action of the jaw and tongue, in particular, is very different from that required of them in speech.

In the chewing movement the muscles of mastication bring the teeth of the two jaws together in firm contact with a piece of food. Speech, however, does not call for such a crude jaw movement. Judson and Weaver (24) state that "in speech... there is a multitude of part-way movements and retreating movement, most of which are practically in mid-air, and there is no solid contact movement". They conclude that "this seems to mean that speech movements will require a greater fineness than will mastication movements".

The same can be said of the action of the tongue. Shohara (43) describes the "rather crude movements of the larger chewing muscles in contrast with the highly specific movements of the tongue" as required in speech.

Thus it can be seen that in the performance of their basic function the jaw, tongue and lips are required to use gross muscular movements. But, in what has been called their "over-laid" function of speech, they are required
to use finer and more specific movement. In speech the jaw, lips and tongue work together in subtle coordination, and yet each must be able to work independently of the other.

This latter point is of particular importance in the relationship of the tongue to the jaw. The salient point of difference between the action of the tongue in chewing and in speaking is that in chewing the tongue moves with the jaw, whereas in speech it is necessary for it to move independently of the jaw.

It is this inability to dissociate the movements of the tongue from those of the jaw that may be one of the causal factors in certain articulatory disorders, such as lalling. When a laller speaks his tongue moves in conjunction with the movement of his jaw, with the result that his speech sounds abnormally slow and clumsy. It would seem that in such an individual the finer movements of the tongue necessary for speech have not yet been differentiated from the grosser movement of the jaw. But as Van Riper (48) points out "the tongue seems to be of greater importance in articulation than the jaw", therefore, it is on the movement of the tongue that attention must primarily be fixed.

In the past individuals with this type of articulatory disorder would have been subjected to a rigorous course of tongue exercises, for as Van Riper (48) says "in earlier speech correction tongue exercises had the status of a religious ritual". Cotrel and Halsted (8) bear out this contention when they say "the question might arise
as to the need of mouth gymnastics......if the golfer wishes to perfect his game, he practises each individual stroke, thus developing the muscles necessary for that particular stroke. The singer picks out the difficult phrases in a selection and practises them diligently.... just so, must the elements of speech be perfected, and the muscles used in their production be well trained". However, in spite of this high therapeutic value placed on tongue exercises in the past, Van Riper (48) rightly says that "in modern speech correction, the emphasis on tongue exercises has almost disappeared."

This swing away from tongue exercises may be due, in part at least, to the fact that the "mouth gymnastics" prescribed so freely for individuals with articulatory disorders had little relation to the neuro-muscular movement patterns demanded of the tongue in actual speech. The natural result of this was that although the individual was able to perform intricate movements of the tongue without speech, there was very little, if any, carry-over into speech itself.

But at times the speech pathologist is confronted with articulation cases who, as Van Riper (48) says can truly be described as being "slow of tongue". He describes these individuals as being scarcely able "to protrude the tongue......without having it lall around and droop over". With some individuals, he goes on to say, the "poorly coordinated movement seems to be localized about the mouth.... the tongue, jaw, soft palate all are sluggish", but with
others the muscular coordination of the whole body is affected". "These cases" Van Riper concludes "need tongue exercises".

However, the tongue exercises he recommends are not based on tongue gymnastics, but on an understanding of the basic cause of the speech difficulties, that is, the individuals' inability to differentiate the movement of his tongue from that of his jaw. He lays down the following basic principles governing his use of tongue exercises:

"1. Learn to recognize the movement as part of some familiar biological movement, such as chewing, swallowing, coughing. Practice these basic activities.

2. The finer movements should be taught first in conjunction with larger movements, then alone.

3. The movements should be used with increasing speed, strength and accuracy.

4. The movement should be combined with other movements, such as breathing and phonation, used in speech.

5. The emphasis in this training should be on the activities... and the contacts... and the positions actually used in speech, rather than random generalized tongue movements".

West, Kennedy and Carr (50) also recommend tongue exercises for articulatory cases that recognize the principle of dissociating the movement of the tongue from that of the jaw. Amongst other things they recommend that the subject be trained to "drop the jaw to the [a] position... keep the lips
and jaw inactive, and bring the sides of the tongue into contact with the upper teeth". They also advise the subject to "take the [a] position, and repeat [at]" and they lay special emphasis on the fact that this syllable must be said "by moving only the tongue".

Thus it can be seen that in relation to the movement of the tongue and jaw the principle of the differentiation of finer movements from grosser ones is recognized. However, in spite of this recognition very little research has been carried out in this particular field. The diadochokinetic movements of the tongue and jaw have been investigated, as we have seen, in regard to the rate of the movements concerned, and as a result of this research it has been possible to establish norms for the movement. Jenkins (22) found that the means for the number of jaw bites per second of twenty-one males and nineteen females, twenty years of age and over, were 5.43 and 5.50 respectively. Strother and Kriegman (46) found norms of 4.78 for the same movement. Diadochokinesis for movements of the tongue were reported by Strother and Kriegman to be 6.53; by Spriestersbach (45) to be 4.84; by Cross (9) to be 5.10; and by Blackburn (4) to be 4.59.

Blomquist (5) in the studies already mentioned found that children of nine years averaged 4.6 jaw movements per second for the syllable [tuh] 4.6 for the syllable [puh] and 4.0 for the syllable [kuh]. The corresponding figures for children of eleven years were, p: 5.3, t: 5.2, and k: 4.7. When the syllables were combined in the nonsense word [puhtuhkuh] children of nine years could say the word 4.5 times per second.
Lundeen (27) in testing the diadochokinetic rate for certain consonant sounds found that the order in which they could be repeated most quickly was: t, d, p, b, f, v, s, g, z. This, according to Poole (35), roughly correlated with the ease of mastery of these sounds by normal children. Rainey (36) in her study of the diadochokinetic ability of children from seven to nine years, found that the nonsense syllable \([p \rightarrow t \rightarrow k]\) was said more rapidly than the nonsense syllable \([k \rightarrow p \rightarrow t]\) and that children with normal speech were able to say it significantly faster than children with defective articulation. She offered no explanation for this finding. Irwin (21) using a new instrument, the sylrater, established tentative norms for the diadochokinetic repetition of the syllable \([p \rightarrow t \rightarrow k]\) for the ages six, seven, nine, eleven, thirteen and fifteen years for normal speaking boys and girls. In this study the mean varies from 3.18 per second for \([k]\) for boys at the age of six years to 5.86 per second for \([p]\) for boys at age of fifteen years. Irwin states that "insofar as the data are comparable these means show general agreement with those found in the studies of Blomquist (5) and Jenkins. (22)

Thus it will be seen that norms have been established for both adults and children in diadochokinetic movements of the tongue and jaw. Blomquist, (5) Lundeen, (27) Rainey (36) and Irwin (21) have related these movements to the utterance of nonsense syllables incorporating the sounds of \([p, t, k]\). As a result of this research it has been
established that the sounds $[p]$ and $[t]$ are pronounced more quickly than the sound of $[k]$.

The data collected on the rate of the diadochokinetic movements of the jaw and tongue has been shown to be fairly extensive. But, as far as we can ascertain, no research has been carried out on the amplitude of the concomitant jaw movements in diadochokinetic movements of the tongue, in other words, on the degree of jaw involvement in such tongue movements. Yet, as Gesell and Halverson (14) have shown in their studies of a baby's hand development, the speed of any movement is determined by its differentiation from associated movements which tend to interfere with, and prevent its fast performance. For example, at a later stage of neuro-muscular maturity the speed of finger tapping is determined by the differentiation of this movement from the associated movements of the whole hand or wrist, which tend to interfere and prevent a fast finger tapping performance. The reason for this is that a fine movement can be performed much more quickly when it is differentiated from a gross movement associated with it. Thus in diadochokinetic movements of the tongue the speed of the tongue is determined by its differentiation from the associated movement of the jaw, which tends to interfere with and prevent a fast tongue movement.

If this is true, then the greater the amplitude of the jaw movement the greater its effect on the movement of the tongue. If the amplitude of the jaw is great, then the
movement of the tongue may be correspondingly slow; if the amplitude of the jaw is small then the tongue movement may be correspondingly fast. Thus it seems probable, or even tenable, that in diadochokinetic movements of the tongue a continuum of decreasing amplitude is related to a continuum of increasing differentiation of the tongue movements from those of the jaw.

The purpose of this study is to investigate and compare the amplitude of concomitant jaw movements in diadochokinetic movements of the tongue in children with articulatory defects and children with normal speech. The diadochokinetic tongue movements used in this study consist of the nonsense syllable [la] repeated at the speed of two [la]'s per second: three [la]'s per second: and four [la]'s per second.

Importance of the study. If it could be shown that children with articulatory defects of one or more consonant sounds have a greater amplitude of concomitant jaw movements in diadochokinetic movements of the tongue than children with normal speech, it would indicate, first, that a lack of differentiation of the fine movements of the tongue from the gross movements of the jaw might be one of the original or maintaining causes of defective articulation. Such a lack of differentiation would mean that in speech the tongue would be moving with the jaw, as in chewing, instead of moving independently of the jaw as it is required to do in speech. A close association of the movement of the
tongue with that of the jaw should account for the fact that individuals with articulatory defects often have difficulty in making the consonant such as the [l] and [r] sounds which are produced by the upthrust tongue with the tip either in contact with, or in close proximity to the hard palate. For the proper production of these sounds the jaws need to be slightly apart, while the tongue tip, in a movement independent of that of the jaw, reaches up behind the upper front teeth to, or towards, the alveolar ridge and palate. If an individual has not yet learned to dissociate the movements of his tongue from that of his jaw he would tend to find difficulty in making this independent tongue movement, with the result that he would attempt to make these sounds with the blade, or mass, of tongue, while the tongue tip remains anchored behind his lower front teeth. The tongue, in this performance, moves only as the jaw moves. This behaviour according to West, Kennedy and Carr (50) and Van Riper (48) is characteristic of the misarticulation of individuals with lalling or defective [l] and [r] sounds.

Second, if it is found that a relationship exists between the amplitude of the concomitant jaw movement in diadochokinetic movements of the tongue and articulatory defects it would indicate that one of the primary aims in the therapeutic handling of cases of articulatory defects would be to dissociate the movement of the tongue from that of the jaw. It has already been pointed out by Hurlock (20)
that the development of specific responses from general responses is largely a matter of maturation, depending upon the increasing use of inhibition exerted at various levels of the central nervous system. However, Bobath (6) states that "inhibition can be greatly improved by practice", and, as already stated, he cites as evidence of this the difference between the finger movements of a skilled violinist and those of an ordinary man. It would seem, then, that training a child to dissociate the movement of his tongue from the movement of his jaw would help him to develop the automatic inhibitory control necessary for the successful performance of such movements in speech.

The specific questions asked in this study are:
(1) Do articulatory cases use more jaw movement concomitantly with their tongue movement than their normal speaking controls in the utterance of the nonsense syllable [la] at speeds of two [la]s per second: three [la]s per second: and four [la]s per second? (2) Does the amplitude of the concomitant jaw movement increase proportionately with the speed of the tongue movement?
Chapter III

Procedure

The Experimental Subjects. The subjects chosen for this investigation were all elementary children from the public schools of Greater Victoria, British Columbia, Canada.

All were nine years of age and in the fourth grade. This particular age group was selected as it was felt that if the articulatory defects had not become corrected by the time the children had reached nine years of age, and had passed through the primary grades, the possibility of these defects being due only to immaturity could be discounted. This supposition was based on the findings of Roe and Milisen (38). In investigating the speech of 1989 children from grades one to six in the public schools of nine Indiana cities, they reached the following conclusions:-

1). the mean number of errors decreased as the grade level increased.

2). there was a statistically significant difference between the mean number of errors in grades one to two, two to three and three to four to indicate that "growth and maturation eliminate many sound errors in these grades".

3). the lack of a significant difference between grades four to five, and five to six indicated that "maturity does not affect any noticeable improvement in the speech sounds of higher grades".
Mills and Streit (32) also investigated the speech of 4685 children in the schools of Holyoke, Massachusetts, and found that a large percentage of the articulatory defects in the younger children "disappear with the maturation process".

In the investigation under discussion there was a total of forty subjects, twenty children with articulatory defects of one or more consonant sounds, and twenty children with normal speech. Each child with defective articulation was matched in terms of sex, age and intelligence with a child of normal speech.

The subjects with articulatory errors were selected by the experimenter. Owing to the fact that the total school population of Greater Victoria did not exceed 14,000, and that a speech therapy program had been in operation in the schools for over ten years it was not possible to find twenty children with severe articulatory defects at the grade four level. The children selected, therefore, had relatively minor articulatory errors, consisting of substitutions, distortions and omissions of consonant sounds. The errors ranged from four to one per child, with an average of two per child.

The subjects with normal speech were selected by the experimenter in consultation with the class-room teacher concerned.

The apparatus. The apparatus used in the investigation was a cardo-pneumo polygraph (C.H. Stoelting Company, Chicago, Ill., serial no. 49003); a tambour (diameter two inches) with a piece of rubber tightly stretched across the
top; a piece of heavy rubber tubing approximately twelve inches in length attaching the tambour to the polygraph; an adjustable iron stand, the top of which was soldered on to the base of the tambour cup in order (1) to hold the tambour firmly in position, and (2) to adjust the tambour to the required height for each child. The timing device consisted of an R. C. A. phonograph playback calibrated to insure constant speed. The turn-table of this phonograph was removed, and in its place three metal discs were fitted to the spindle, one above the other with half inch spaces between. Two teeth one hundred and eighty degrees apart were cut in the first disc; three teeth one hundred and twenty degrees apart were cut in the second disc; and four teeth ninety degrees apart were cut in the third disc. A spring arm was pivotted to bear on each disc as required. The spindle revolved at sixty revolutions per minute giving a decisive beat of two, three and four clicks per second. This set the rate of utterance of the syllable spoken by the subject. Figure I illustrates the apparatus.
The apparatus

Experimental procedure. Each subject tested was required to rest his chin on the rubber stretched across the tambour and to say the series \( \text{[la la la la]} \) twice at each of three different speeds. The slowest speed was timed at the rate of two \( \text{[la]} \)'s per second: the medium speed at the rate of three \( \text{[la]} \)'s per second: and the fast speed at the rate of four \( \text{[la]} \)'s per second.
The reason for the choice of this particular nonsense syllable was that in the production of the initial consonant sound of [l] there is an upthrust movement of the tongue tip to the alveolar ridge, and in the production of the vowel sound [a] the tongue tip rests behind the lower front teeth. Thus the syllable as a whole provides for a maximum movement of the tongue tip which was required in this test. The sound of [l] was chosen in preference to the sounds of [t, d, n] also produced by the tongue tip, because it calls for a greater upthrust of the tongue tip towards the alveolar ridge than the latter sounds, which can be produced with the tongue tip forward towards the front teeth rather than upward towards the alveolar ridge.

The test was given at three different speeds in order to find out whether the amplitude of the concomitant jaw movement increases proportionately with the speed of the tongue. The three speeds chosen were selected as a result of the research on the diadochokinetic movements of the tongue undertaken by Blomquist (5). These findings have already been cited.

The timing device, already described, was adjusted to give the required beat for each double group of four and before the test each child was instructed to listen carefully to the beat, and to synchronize his speech as closely as possible with it. A slight pause (five seconds) was made between the [la]s at the same speeds, and a relatively long pause (sixty seconds) was made between the
at different speeds, thus minimizing the possibility of fatigue.

The tambour was adjusted to suit the individual height of each child, and care was taken that the symphysis of the mandible rested on the center of the rubber stretched across the tambour. Care was also taken to ensure that the pen of the polygraph was moving freely before each recording was made.

The results of the investigation were obtained by measuring the amplitude of each wave length recorded by the polygraph. The wave lengths were measured by a ruler in millimeters, and to ensure maximum accuracy a magnifying glass was used. A sample polygraph record is given in Figure II.

FIGURE II

![Sample Polygraph Record]
Chapter IV

Results and Conclusions

In Figure III are presented the mean differences in amplitude of the concomitant jaw movement at slow, medium and fast speeds for both the articulation cases (the experimental group) and their matched controls (the normal speaking group).

FIGURE III

MEAN DIFFERENCES IN AMPLITUDE OF JAW MOVEMENT IN THE UTTERANCE OF THE SYLLABLE

The raw data of this experiment are presented in Table I. The numerical values are the displacement of the polygraph pen expressed in millimeters, and reflect the
average amplitudes of four concomitant jaw movements in the utterance of the syllable \( [\text{la}] \) for each subject under the three conditions of speed.

The means and standard deviations of these measurements are given for all twenty subjects in the experimental (the articulation cases) and for the twenty subjects in the control group (the matched normal speakers). As the table indicates, the articulation cases as a group had mean amplitudes of concomitant jaw movements which were larger than the mean amplitudes of the control group under all conditions of speed. At low, at medium and at fast speeds the mean amplitudes of the experimental group exceeded those of the controls. The standard deviations, however, are large in comparison with these means and so an analysis of variance was done to evaluate the significance of these mean differences. Using the technique for procuring \( t \) values outlined in Guilford (16) the formula \( t = \frac{M - M}{\frac{5}{d_m}} \) was applied to the values in Table I and these \( t \)-scores are given in Table II.
TABLE I

<table>
<thead>
<tr>
<th>Subject</th>
<th>Slow A</th>
<th>Medium B</th>
<th>Fast C</th>
<th>Subject</th>
<th>Slow X</th>
<th>Medium Y</th>
<th>Fast Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>11.0-17.40</td>
<td>8.0-17.00</td>
<td>13.0-21.10</td>
<td>1.</td>
<td>0.5-24.02</td>
<td>7.0-14.00</td>
<td>6.0-21.30</td>
</tr>
<tr>
<td>2.</td>
<td>13.0-15.40</td>
<td>14.0-11.00</td>
<td>15.0-19.10</td>
<td>2.</td>
<td>8.0-16.52</td>
<td>9.0-12.00</td>
<td>8.0-19.30</td>
</tr>
<tr>
<td>3.</td>
<td>14.0-14.40</td>
<td>15.0-10.00</td>
<td>17.0-17.10</td>
<td>3.</td>
<td>8.0-16.52</td>
<td>10.0-11.00</td>
<td>11.0-16.30</td>
</tr>
<tr>
<td>7.</td>
<td>20.0-8.40</td>
<td>19.0-6.50</td>
<td>23.0-11.10</td>
<td>7.</td>
<td>10.0-14.52</td>
<td>14.0-7.00</td>
<td>17.0-10.30</td>
</tr>
<tr>
<td>8.</td>
<td>20.0-8.40</td>
<td>20.0-5.00</td>
<td>29.0-5.10</td>
<td>8.</td>
<td>11.0-13.52</td>
<td>14.0-7.00</td>
<td>18.0-9.30</td>
</tr>
<tr>
<td>10.</td>
<td>24.0-4.40</td>
<td>21.0-4.00</td>
<td>33.0-1.10</td>
<td>10.</td>
<td>20.0-4.52</td>
<td>14.0-7.00</td>
<td>20.0-7.30</td>
</tr>
<tr>
<td>11.</td>
<td>24.0-4.40</td>
<td>22.0-3.00</td>
<td>34.0-0.10</td>
<td>11.</td>
<td>20.0-4.52</td>
<td>16.0-5.00</td>
<td>25.0-2.30</td>
</tr>
<tr>
<td>12.</td>
<td>25.0-3.40</td>
<td>22.0-3.00</td>
<td>35.0-0.90</td>
<td>12.</td>
<td>22.0-2.52</td>
<td>18.0-3.00</td>
<td>27.0-0.30</td>
</tr>
<tr>
<td>13.</td>
<td>31.0-2.60</td>
<td>28.0-3.00</td>
<td>36.0-1.90</td>
<td>13.</td>
<td>24.0-0.52</td>
<td>19.0-2.80</td>
<td>35.0-7.70</td>
</tr>
<tr>
<td>14.</td>
<td>32.0-3.60</td>
<td>28.0-3.00</td>
<td>44.0-9.90</td>
<td>14.</td>
<td>29.0-4.48</td>
<td>22.0-1.00</td>
<td>35.0-7.70</td>
</tr>
<tr>
<td>15.</td>
<td>32.0-3.60</td>
<td>29.0-4.00</td>
<td>44.0-9.90</td>
<td>15.</td>
<td>35.0-10.48</td>
<td>29.0-8.00</td>
<td>35.0-7.70</td>
</tr>
<tr>
<td>16.</td>
<td>33.0-4.60</td>
<td>30.0-5.50</td>
<td>44.0-9.90</td>
<td>16.</td>
<td>41.0-16.48</td>
<td>34.0-13.00</td>
<td>36.0-8.70</td>
</tr>
<tr>
<td>17.</td>
<td>43.0-14.60</td>
<td>33.0-8.00</td>
<td>46.0-11.90</td>
<td>17.</td>
<td>47.0-22.48</td>
<td>36.0-15.00</td>
<td>47.0-19.70</td>
</tr>
<tr>
<td>18.</td>
<td>50.0-21.60</td>
<td>42.0-17.00</td>
<td>48.0-13.90</td>
<td>18.</td>
<td>50.0-25.48</td>
<td>39.0-18.00</td>
<td>50.0-22.70</td>
</tr>
<tr>
<td>19.</td>
<td>61.0-32.60</td>
<td>42.0-17.00</td>
<td>61.0-26.90</td>
<td>19.</td>
<td>58.0-33.48</td>
<td>42.0-21.00</td>
<td>53.0-25.70</td>
</tr>
<tr>
<td>20.</td>
<td>67.0-38.60</td>
<td>56.0-20.60</td>
<td>69.0-34.90</td>
<td>20.</td>
<td>64.0-39.48</td>
<td>46.0-25.00</td>
<td>62.0-34.70</td>
</tr>
</tbody>
</table>

RAW SCORES, MEANS AND STANDARD DEVIATIONS OF AMPLITUDE OF JAW MOVEMENT AT VARIOUS SPEEDS FOR EXPERIMENTAL AND CONTROL GROUP
### TABLE II

<table>
<thead>
<tr>
<th>Comparison</th>
<th>t-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, X (slow speed, normal speakers and controls)</td>
<td>0.74</td>
</tr>
<tr>
<td>B, Y (medium speed, &quot;&quot;&quot;&quot;&quot;&quot;&quot;&quot; )</td>
<td>1.11</td>
</tr>
<tr>
<td>C, Z (fast speed, &quot;&quot;&quot;&quot;&quot;&quot;&quot;&quot; )</td>
<td>1.36</td>
</tr>
<tr>
<td>A, B (articulation cases, slow versus medium speed)</td>
<td>0.85</td>
</tr>
<tr>
<td>A, C (&quot;&quot;&quot;&quot;&quot;&quot;&quot;&quot; , slow versus fast speed)</td>
<td>1.22</td>
</tr>
<tr>
<td>B, C (&quot;&quot;&quot;&quot;&quot;&quot;&quot;&quot; , medium versus fast speed)</td>
<td>2.10</td>
</tr>
<tr>
<td>X, Y (normal speakers, slow versus medium speed)</td>
<td>0.70</td>
</tr>
<tr>
<td>X, Z (&quot;&quot;&quot;&quot;&quot;&quot;&quot;&quot; , slow versus fast speed)</td>
<td>0.50</td>
</tr>
<tr>
<td>Y, Z (&quot;&quot;&quot;&quot;&quot;&quot;&quot;&quot; , medium versus fast speed)</td>
<td>1.40</td>
</tr>
</tbody>
</table>

ANALYSES OF VARIANCE SHOWING SIGNIFICANCE OF THE DIFFERENCES IN MEAN SCORES EXPRESSED IN T-VALUES

The first three inter-comparisons in Table II reflect the significance of the means differences in amplitude of concomitant jaw movement between the articulation cases and their controls under conditions of speed. Expressed in confidence levels, according to Table IV in Hoel (18) those t values with 19 degrees of freedom should exceed 2.861 to be significant at the one per cent confidence level, and 2.093 at the five per cent confidence level. It is evident that none of these differences can be said to be statistically significant. We cannot accept with any
confidence the hypothesis that articulation cases have more concomitant jaw movements than do normal speakers, even though the mean differences tend to suggest such a belief.

The second three comparisons in Table II reflect the significance of the mean differences in amplitude of concomitant jaw movement used by the articulation cases at different speeds of utterance. These values, also, should exceed 2.861 to be statistically significant at the one per cent confidence level and 2.093 at the five per cent confidence level. Only one of these, the difference between the medium and fast speeds is statistically significant at the five percent confidence level.

The final three comparisons reflect the significance of comparable differences in the amplitude of jaw movement under the three conditions of speed for the normal speaking controls. None of these approached statistical significance at the five per cent confidence level. In all of these comparisons of the amplitude under differing speeds, the subjects seemed to have less amplitude at medium speeds than they did at either low or high speeds, but in only one instance, in the articulation cases can we feel certain that such a trend does exist.

Qualitative observations of children during test. From qualitative observations of the children's performance in the diadochokinetic tongue movements used during this test it appeared that the difficulty of synchronizing the
speech attempt with the required beat increased proportionately to the speed of the beat. It appeared that both groups of children had the greatest difficulty in achieving this synchronization at the fast speed, four \( [\text{la}'] \)s per second, and the least difficulty at the slowest speed, two \( [\text{la}'] \)s per second.

It appeared to the experimenter that the articulatory cases had greater difficulty at fast speed than their controls. They showed greater signs of incoordination, which were manifested in concomitant jaw movements of irregular amplitude, and a lack of rhythm in their pronunciation of the required nonsense syllable. These symptoms appeared to decrease proportionately at the medium and slow speeds of three and two \( [\text{la}'] \)s per second respectively. At these speeds both groups appeared to have little difficulty in synchronizing their speech attempts with the required beat.

However, it is interesting to note that these qualitative observations of the children during testing were not entirely borne out by the results. From these it appeared that both groups found it easiest to achieve diadochokinetic tongue movements without concomitant jaw movements at the medium speed of three \( [\text{la}'] \)s per second. Both had the greatest difficulty at the fast speed of four \( [\text{la}'] \)s per second, and at this speed the articulation cases had greater concomitant jaw movements than their controls. But, contrary to expectation, both groups had greater concomitant jaw movements at the slow speed of two
This finding actually concurs with research undertaken by Hunsley (19) who in a series of diadochokinetic tests of tongue and jaw movement discovered that both stutterers and non-stutterers found it easier to follow a rhythmic pattern of clicks at a medium speed than they did at a slow speed. This may be explained by the fact that the medium speed used in both tests approximated the speed of normal speech more closely than did either the fast or slow speeds. In the present study the fast speed of four \( [\text{la}] \)'s per second, although slower than the 4.6 norm for nine year olds established by Blomquist (5) in the repetition of the syllable \([\text{tuh}]\) was evidently sufficiently fast to produce some tension in both groups with a resulting increase of concomitant jaw movements. The slow speed of two \( [\text{la}] \)'s per second was evidently so un-related to the speed of normal speech that it called for a different pattern of speech. The effort to produce this different pattern of speech, and to synchronize it with the required two \( [\text{la}] \)'s per second again produced sufficient tension in both groups to result in an increase of concomitant jaw movements.
CHAPTER V

Implications for Therapy

The results of this study do not indicate that children with articulatory defects differ markedly from normal speakers in their ability to move the tongue independently of the jaw. Both groups seemed to use such concomitant movements in the utterance of the syllable [lə]. This finding tends to throw some doubt on the fairly common practice in speech therapy with these cases to administer tongue exercises routinely or to fix the jaw during tongue lifting by means of a tongue depressor or by resting the chin upon a table. It also throws some doubt upon the theories of emergent specificity as espoused by Muyskens and Meader (30) and Bobath (6). These individuals seemed to be able to utter a tongue lifting syllable along with the lifting of the mandible without any distortion of the [l] sound.

Many texts in speech correction stress the importance of improving the speed of the independent activity of the tongue, feeling that the slower diadochokinesis of the jaw may in turn slow down the tongue movement which it accompanies. The findings of the present study do not indicate that this is necessarily true, at least for the subjects studied. The speeds used were within the norms for rate of diadochokinetic movements as given by Lundeen (27) and Jenkins (22), and even when amplitude of movement was
large, the fast speeds could be attained. The articulation cases, however, did seem to have more jaw movements when using fast speeds than did the normal speakers and perhaps we should concentrate our efforts on the differentiation of the jaw movement from the tongue lifting only at these speeds.

It should be noted here that the articulatory cases used as subjects were not dysarthric; they were normal in coordination ability; they had relatively few errors as compared with the more severely articulatory cases with whom the speech therapist especially feels the need for training in differential diadochokinesis. The mere fact that all of these cases had been able to manage the correct articulation of the /l/ sound may indicate that the process of differentiation of the tongue tip lifting from the basal jaw movement had already occurred. None of these children were lallers. It might well be that the same experiment performed with lalling and dysarthric cases would reveal marked and statistically significant differences. However, the routine use of tongue training involving the differential diadochokinesis with the majority of cases in the public school population does not seem to be justified.

There is another factor which should be considered in evaluating the results. It is that the width of the mouth opening was not measured. An attempt was made to do this by means of a small wedge inserted between
the upper and lower front teeth, but it was found that
the children reacted unfavourably and as a result produced
such a-typical and abnormal jaw movements that the attempt
was abandoned. However, it was obvious that some of the
children used smaller tongue liftings in producing the
syllable [la] than did others. This may have contributed
to the statistical uncertainty with which we must regard
the results.
CHAPTER VI

SUMMARY

The problem. The specific questions asked in this study were (1) Did children with mild articulatory defects use more jaw movements concomitantly with their tongue movement than their matched normal speaking controls in the utterance of the nonsense syllable [la] at speeds of two [la]'s per second: three [la]'s per second: and four [la]'s per second? (2) Did the amplitude of the concomitant jaw movement increase proportionately with the speed of the tongue movement?

The procedure. The subjects used in the study were forty nine-year-old elementary children from the public schools of Greater Victoria, British Columbia, Canada. The experimental group consisted of twenty children with articulatory errors of one or more consonant sounds, and the control group consisted of twenty children with normal speech, matched in terms of sex, age, and intelligence with the experimental group.

The apparatus used was a cardo-pneumo polygraph: a tambour with a piece of rubber stretched tightly across the top: a piece of heavy rubber tubing attaching the tambour to the polygraph: an adjustable iron stand to hold the tambour firmly in position: a timing device consisting of an R. C. A. phonograph playback, with metal
discs attached to the central spindle in such a way as to give a decisive beat of two, three and four clicks per second. This set the rate of utterance of the syllable spoken by the subject.

Each subject was required to rest his chin on the center of the rubber stretched across the top of the tambour, and to say the series [la la la la] twice at each of three different speeds.

The results. The articulation cases as a group had mean amplitudes of concomitant jaw movements which were larger than the mean amplitudes of the control group at slow, medium and fast speeds. However, as the standard deviations were too large in comparison with these means, an analysis of variance was performed to evaluate the significance of these mean differences. As a result of this analysis it was found that none of the mean differences were statistically significant. Thus, it is impossible to accept the hypothesis that cases with articulatory errors have more concomitant jaw movements than do normal speakers, even though the means differences tend to suggest such a belief.

As regards the mean differences in amplitude of concomitant jaw movements used by the articulation cases at different speeds of syllabic utterance, it was found that only the difference between the medium and fast speed was statistically significant at the five per cent confidence level. In the normal speaking control group none of
the differences were statistically significant at the five per cent confidence level. The subjects in both groups seemed to have less amplitude of jaw movements at medium speeds than they did at either low or high speeds.

Implications of these findings for speech therapy were presented.

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