ARTICULATORY DYSPRAXIA AND ITS EFFECT ON THE ARTICULATION OF SPEECH SOUNDS IN DEAF CHILDREN

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(Deemed University), Bangalore, India

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July 1999

CERTIFICATE

This is to certify that this thesis entitled 'Articulatory dyspraxia and its Effect on Articulation of Speech Sounds in Deaf children' is the bonafide work of Ms. G. Malar, submitted in fulfilment for the degree of DOCTOR OF PHILOSOPHY to the National Institute of Mental Health and Neurosciences (Deemed University), Bangalore. This thesis has been prepared under my supervision and guidance. I further certify that this thesis or part thereof has not been the basis for the award of any other degree or diploma of this or any other University.

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DECLARATION

This thesis entitled 'Articulatory Dyspraxia and its Effect on Articulation of Speech Sounds in Deaf children' is the result of my own study carried out under the guidance of Dr. M. Jayaram, Additional Professor, Department of Speech Pathology and Audiology, NIMHANS, Bangalore. I further declare that this thesis, or part thereof, has not been submitted earlier to any University for the award of any degree or diploma.

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List of Speech Sounds and their Symbols

(as used in this report)

/p/ as in the word ‘pin’

/b/ as in the word ‘bin’

/t/ as in the word ‘ten’

/d/ as in the word ‘den’

/θ/ as in the word ‘thin’

/ð/ as in the word ‘then’

/k/ as in the word ‘kite’

/g/ as in the word ‘gate’

/kʰ/ - aspirated /k/

/m/ as in the word ‘mine’

/n/ as in the word ‘nine’

/ṇ/ - retroflex /n/

/ŋ/ as in the word `singer'

/ṅ/ as in the word `bundh'

/ñ/ as in the word `ginger'

/r/ as in the word ‘red’

/ṛ/ - retroflex /r/

/l/ as in the word ‘let’

/ḷ/ - retroflex /l/

/ḻ/ - retroflex /l/

/tʃ/ as in the word ‘chunk’

/dʒ/ as in the word ‘junk’

/y/ as in the word ‘yak’

/s/ as in the word ‘sack’

/ʃ/ as in the word ‘shed’

/v/ as in the word ‘van’

/a/ as in the word ‘up’

/a:/ as in the word ‘par’

/i/ as in the word ‘it’

/i:/ as in the word ‘eat’

/u/ as in the word ‘put’

/u:/ as in the word ‘pool’

/e/ as in the word ‘pet’

/e:/ as in the word ‘pay’

/o/ as in the word ‘one’

/o:/ as in the word ‘oat’

/aɪ/ as in the word ‘pie’

/aʊ/ as in the word ‘pouch’

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Chapter 1

INTRODUCTION

The 'act of speaking' is the most usual and the optimal form of language system which, in turn, is a primary channel to the thought process in human beings. Speech in human beings is essential for two functions: one is the 'instrumental' function of satisfaction of personal needs while the other is the 'interactional' function of relating oneself to the larger society (Halliday, 1975). The development of speech in any individual begins with his earliest communicative attempts as a child. But, these attempts are not words at all, but actions **that** bring about or result in consistent responses in the environment (Bruner, 1978). Vocalizations come to accompany these actions (Carter, 1975; Pea, 1980). These vocalizations become increasingly conventionalized and will finally take the form of formal spoken words.

1.1 Production of Speech

The production of speech could be described as the modification of the outgoing breath stream and voice by altering the size **and** shape of the resonators. The resonators are altered by way of constrictions through the articulators. The articulators are the tongue, lips and palate. The lungs are the source of the breath stream, and the vocal cords in the larynx are instrumental in converting the breath stream into voice (phonation). Muscles of the glottis and larynx regulate the airflow (or the modified breath stream) into the oral cavity while the muscles of the velopharyngeal port further regulate airflow through the oral and nasal cavities.

It is said that about a hundred muscles, from the respiratory mechanism to the articulatory system, are involved in the act of speech production. During the act of speaking, hundreds of muscular adjustments are made each second. It is very essential that, for normal speech production, these changes must occur in a proper sequence and are strictly controlled with respect to timing. Contraction of inappropriate muscles or variations in the degree of contraction or variations with respect to timing result in abnormal articulatory patterns.

Efficient and coordinated use of structures of respiration, phonation, resonation and articulation is necessary for the rapid, smooth and fluently articulated speech. The complex task of integrating the many participating muscles in connected speech along with the responsibility of modifying articulatory output centrally in response to externally and internally originated input is coordinated by various cortical and subcortical centres like the motor cortex of the cerebrum (especially, the Broca's area along with the Wernicke's area), the reticular formation, the limbic system, and the cerebellum. Needless to say that a disorder of any of these central or peripheral systems would impede efficient production of speech.

1.2 Disorders Impairing Speech

Several developmental variables significantly influence, either for the better or the worse, the accomplishment of efficient speech skills in human beings (Winitz, 1969). Some of these variables are the chronological age of the individual, intelligence of the individual, cultural variables (like socioeconomic status, sex, sibling status, etc.), motor skills, laterality, kinesthetic sensibility, development of sensory and motor functions, and social behavior, physical health, auditory memory span, auditory discrimination, personality and adjustment, fluency, and verbal educational achievement (spelling and reading).

In addition, there are specific organic disorders that impair human speech. Some of these major disorders include:

i) anomalies of the structures of articulation: congenital or acquired

ii) motor disorders due to central or peripheral nervous system pathology: cerebral palsy, dysphasia, dysarthria, dyspraxia etc.

iii) disorders of hearing.

iv) disorders of phonation - endocrinal, structural, neoplastic and psychological factors affecting the larynx and the glottal mechanism.

v) disorders of rhythm: stuttering and cluttering.

vi) mental retardation.

Secondary speech disorders arising out of the primary problem of hearing disorder (for example, deafness) are said to account for developmental speech problems in a considerable number of children.

The term 'deafness' is used loosely, in lay terms, to refer to any type and level of damage to the sense of hearing that handicaps an individual in his/her day to day functions.

According to the definition adopted by the Conference of Executives of American Schools for the Deaf in 1975 (Silverman and Lane, 1978), hearing impairment is a generic term indicating a hearing disability ranging in severity from mild to profound. It includes the subsets of deaf and hard of hearing. The deaf are those in whom the hearing disability precludes successful processing of auditory-linguistic information, with or without hearing aid. The hard of hearing are those who have residual hearing sufficient to enable them to process linguistic information through hearing, with or without a hearing aid.

The general deaf population is made up of two distinct classes based entirely on the time of the loss of hearing: The 'congenitally impaired' are those who are born deaf or have acquired the impairment soon after birth. The 'adventitiously impaired' are those who were born with normal hearing, but in whom the sense of hearing became nonfunctional later through illness or accident. The term deaf traditionally refers to individuals with profound congenital loss of hearing.

In practice, in most cases, the hearing impairment comes to be noticed around one year, when children are expected to speak but fail to do so. Before this age, lack of response to auditory/oral communication in the environment may not be noticed. Therefore, classifying the hearing impaired based on the time of onset in relation to language acquisition may be more meaningful. Accordingly, the 'prelingually impaired' are those in whom the impairment has set in before the first eighteen months of life, that is, before language development could be observed. The 'postlingually impaired' are those in whom the impairment occurred after the development of oral language.

1.3 Implications for Speech

There are certain specific implications of hearing impairment on the physical qualities of speech. The congenitally deaf usually have a characteristic voice quality, a kind of hollow-sounding hypernasal voice; syntactic & semantic errors in language; impaired articulation; and prosodic deviations. Voiced/voiceless distinctions are difficult for them; voiced consonants tend to be voiceless. Reception of sounds having low visibility is hard. Final consonants are often deleted, and schwa vowels may be added. Fine vowel distinctions are not accurate, and there is a tendency to neutralize vowels toward the schwa position. The mandible is lowered excessively, and the tongue does not move sufficiently. Coarticulation effects are uncontrolled; although phonemes may be produced accurately in isolation or in syllables, but in certain contexts they sound unnatural. Inflection patterns are stereotyped or absent. Variations in stress are not present or are inappropriate. Vocal attack may be abrupt. There is inadequate variation in the duration of vowels. The *hi* and /s/ sounds are particularly difficult (Hanson, 1983).

In summary, deafness not only delays the acquisition of language, but also frequently results in the following articulatory deviations:

a) Impaired discrimination of own speech and speech of others.

b) Difficulties with voiced/unvoiced distinctions.

c) Defective production of high frequency sounds.

d) Poor distinctions between similar vowels.

e) Unnatural coarticulation.

f) Neutralization of vowels (toward the schwa).

g) Consonant cluster reductions.

h) Sound omissions and substitutions.

1.4 Remedy/Rehabilitation

Rehabilitation of the adventitiously or congenitally hearing impaired involves remedial training in using the residual hearing, however little it is, and augmenting it with training in lip reading, among others. Language development is the focus of training, though importance is given for the development of speech, particularly speech sound articulation and speech intelligibility.

In addition to this oralistic approach, rehabilitation of the hearing impaired may also involve use of gestures and signs either independently or with speech. In India, particularly in the last three decades, the emphasis has been on oralism. In practice, even after years of such expert training, oralism has not always yielded the desired resuits. There are many reasons for this. One thing is that, sign language is believed to come naturally to the deaf and hard of hearing children. The other being the attitude and the efficiency of the efforts taken by the parents and teachers of the hearing impaired children in developing oral language.

1.5 Additional Disabilities

Research, in the recent past, has indicated an altogether different factor which may have an influence on speech/language development in deaf children. Although hearing impairment is the primary problem, there is evidence to show that approximately one third of hearing impaired children have secondary learning disabilities that interfere with their ability to profit from instruction (Shildroth, Rawlings, and Allen, 1989). Learning disorders include dyslexia and dysgraphia (a disorder of sensory-motor integration), dyscalculalia (problems in computing), and dyspraxia (problem in controlling or initiating motor movements required for activities like speaking, writing etc.). 'Dyspraxia' is a major learning disability that is directly related to the development of speech and language (van Uden, 1983). Routine psychological testing does not attend to these problems. This is a serious concern calling for immediate attention not only to resolve diagnostic issues but also to help the individual deaf child to benefit from educational treatment based on his specific needs.

1.5.1 Dyspraxia

Dyspraxia is a psychomotor disorder affecting speech. Psycho/ neuromotor disorders are organic disturbances that affect the articulatory processes. These organic disorders may be pathological alterations of the cerebral cortex, cerebellum, and upper motor neurons, or are neuromuscular disorders involving the nuclei or lower motor neurons of the cranial nerves, along with pathological changes of the muscles (van Uden, 1983; Hanson, 1983).

Before proceeding further it is important to take note of the fact that there is a distinct technical difference between 'apraxia' and 'dyspraxia'. Apraxia is defined in medicine as the complete loss of ability to plan and carry out complex motor movements and are more specifically identified with cortical lesions. Dyspraxia, on the other hand, denotes difficulty in planning and carrying out complex movements and is used more in the context of education and learning (Bush and Waugh, 1982). Eupraxia refers to efficient motor programming and coordination. But, most often than not, the terms apraxia and dyspraxia are used interchangeably. The focus of this study is dyspraxia, but sometimes the word apraxia has also been used.

Dyspraxia is an impairment in the ability to produce voluntary muscle movements. Wilson (1908) defined dyspraxia as an inability to perform certain subjectively purposive movements or movement complexes, with conservation of motility, sensation and of coordination.

1.5.2 Nature of Dyspraxia

Dyspraxia is a disorder related to the control of motor movements. It depends on the nature of movements, whether they are voluntary or involuntary. Dyspraxia is more relevant to voluntary movements. Involuntary movements remain unaffected. Therefore, a close review of the difference between voluntary and involuntary movements is required to understand the nature of apraxia. Voluntary movements as opposed to automatic movements originate in an impulse of the will to perform. It involves an idea of the nature of the act to be performed. In the case of automatic activities, where an impulse is allowed to result in an action, cerebral processes which are largely unconscious are utilized. In the case of voluntary and more complex performances, the transformation takes more time depending on sensory awareness.

A voluntary complex motor performance is thus organized in space and time. Each new stage is triggered by the knowledge that the preceding one has been completed. Different forms of sensory awareness are involved depending on the nature of the act. Like in modelling with clay, visual and tactual guidance proprioceptor impulses from eyes and fingers reach consciousness. The extent of these guiding impulses vary from one act to another depending on the extent to which' the act has become automatic through practice and the extent to which we are conditioned to the act/situation.

Among these voluntary, complex motor activities, some activities are more highly organized. For example, perfectly intelligible speech occurs with spontaneous organization of the movement patterns of the tongue, lips and other articulators. Here purposive movements are organized in terms of schemas rather than kinesthetic, motor, visual or other sensory images, in isolation.

The 'schema' is a spatiotemporal disposition which may or may not enter consciousness, which may sometimes be conscious and at other times unconscious (in voluntary and involuntary acts, respectively). Apraxia, is a disorganization of these schemas underlying purposive movement. It ranges from disturbance at the highest level (where schemas are related to the formulation of the idea of the movement) down to the lowest level (at which level schema consists of a motor pattern, which regulates the selection of appropriate muscles). 'Schema' is a spatiotemporal disposition and apraxia is essentially a disorganization of the sequence of events in the nervous system in time.

According to Kent and Rosenbek (1983), the disruption of speech in apraxia is related to disintegration of the above mentioned temporal schema that aid in the control of movement sequences, and spatial targets defined by a space coordinate system of the vocal tract. They suggest that the inaccuracies of place of production described in apraxia of speech might be taken to mean either that the speaker's access to the space coordinate system for target speech sounds is impaired, or that the generalized spatio-temporal schema cannot reliably use spatial information in generating specifications. Errors in apraxic speakers may be a reflection of the general failure of the 'schema' - in the specifications of motor commands for an intended motor response or the maintenance of the position of the articulators,

1.5.3 Types of Dyspraxia

Liepmann (1905) identified three types of apraxia, namely, (i) ideomotor apraxia, (ii) ideational apraxia, (iii) limb-kinetic or innervatory apraxia. Other forms of nonverbal apraxia also exist like, (i) Constructional apraxia , (ii) Apraxia for dressing, (iii) Whole Body Apraxia, and (iv) Facial Apraxia. However, dyspraxia has been broadly classified into verbal and nonverbal dyspraxia in this study.

1.5.3.1 Oral Apraxia

This condition is observed in patients with cerebral damage and has been variedly named and described as, 'oral nonverbal apraxia' by

Eisenson (1954), who views apraxia as defective volitional use of tools, and when these tools are tongue, lips, and velum, oral apraxia is the result; and 'buccofacial apraxia' by de Arjuriaguerra and Tissot (1969), who defined it as a disturbance in carrying out voluntary swallowing movements; of movements of the tongue toward the chin, the nose, the corners of the mouth; of movements in making clicking sounds; movements in making apico-dental tsk-tsk sound; of the voluntary mimicry of laughter, of anger, etc., and of the action of whistling. The condition has also been termed as lingual apraxia (Taylor, 1932), and described in terms of nonprotrusion of tongue in some cases of aphasia (Jackson, 1878).

The above described nonverbal apraxia of the oral mechanism becomes oral verbal apraxia or 'apraxia of speech' when the impaired oral movements may disrupt volitional, oral motor behavior that produce speech and may result in random, bizarre, and irrelevant vocal and/or verbal outflow. The primary disturbance in apraxia of speech is a disruption in the temporal organization and coordination of different articulators (Itoh et al., 1979, 1980).

1.5.3.2 Articulatory Dyspraxia

The condition may more aptly be termed 'articulatory dyspraxia' as the function of speech in its totality comprises a wide range of activities including perception by the auditory and visual senses. This is followed by integration in the Wernicke's area for linguistic representation. This representation of the responses is then transmitted to the motor speech (Broca's) area in the motor cortex which then plans and executes an appropriate verbal response. The condition of apraxia refers specifically to problems in the planning, execution and control of complex (oral) motor movements, and not to other functions of perception or integration; and articulation is that specific aspect of speech concerned just with the phonemic-motor end product (deRenzi, Pieczuro and Vignolo, 1966).

Articulatory dyspraxia is an articulatory disorder resulting from impairment, as a result of brain damage, of the capacity to program the positioning of speech musculature and sequencing of muscle movements for the volitional productions of phonemes (Darley, 1969). There is no significant weakness, slowness, or incoordination of reflex and other automatic acts. Prosodic alterations may be associated with the articulatory problems, perhaps in compensation for it.

All this is not to imply that dyspraxic disorders in the deaf are neurogenic in origin. It is hypothesized that speech sound articulation in deaf children is affected because they have not learnt the spatiotemporal schema for speech sounds. This inability, in turn, may be due to the fact that their sensory perception of speech is faulty. The point being made here is that the existence of dyspraxia and deafness may have resulted in poor articulatory skills.

1.6 Dyspraxia in Deaf Children

As mentioned earlier, cognitive and profound auditory disorders in 20 - 25% of the cases seem to be associated with specific disturbances in cognitive motor behavior (van Uden, 1983).

Dangerous barriers are posed by the coexistence of dyspraxia and profound deafness. These associated disorders prevent even those deaf children with normal intelligence and, who have received excellent oral education and systematic training in speech from acquiring adequate speech skills. Likewise, dyspraxia in isolation may not seriously impede with an individual's speech skills. Strong auditory function with a strong auditory memory may compensate, in many ways, the difficulties arising out of dyspraxia.

These facts call for special programs of basic training in the integration of motor behavior in these children. This calls for a very co-operative environment where skilled special educators need to work in conjunction with a multidisciplinary team, which may include a professional specialized in the management of learning disabilities. One has to start with an analysis of factors that may be interfering with the child's ability to master speech skills and offer education strategies for remediation (Shildroth, Rawlings, and Allen, 1989).

1.7 Lacuna in the Field

Dyspraxia and other learning disabilities in deaf children have caught the attention of researchers only in the last two and a half decades or so. Even then research output in this field is scanty. Instituut voor Doven, Netherlands is a pioneering institute in this area and is responsible for most of the research output in this area.

Studies on the effects of dyspraxia on speech in the profound deaf have generally focused on spontaneous speaking skills and intransitive limb movements. Use of volitional movements of the articulators to study articulatory apraxia has not been taken up at all. Generally, studies in this area provide more information about the effects on speech rather than specifically on speech sound articulation in the deaf.

Further, there have not been any studies on the nature of oral tactual sensation, lateralization, etc., in dyspraxic deaf children, which based on observations in the normal hearing, are suspected to be associated with problems in motor programming. In addition, there are no studies in this area in our country though we have a substantial deaf population

1.8 Need for the Study

India, is a country with a vast hearing disordered population. Generally, oralism as opposed to sign language is emphasized in this country in the education of the deaf children. Deafness, among others, affects the language acquisition as well as the development of articulatory skills in these children. The result is that not only the deaf children are deficient in the usage of language, but whatever they speak may not be intelligible for others. Misarticulation of speech sounds is the major factor which affects speech intelligibility in the speech of deaf children. The articulatory skills can be affected because of a motor programming disorder called dyspraxia. Information on dyspraxia in deaf children is needed in order to develop more effective procedures of teaching articulation of speech sounds. Much of the research output in this area has come from Instituut voor Doven, Netherlands and there is absolutely no information on the prevalence of dyspraxic errors in deaf children, or their nature, or their influence on speech sound articulation in the Indian context.

As said earlier, past studies on dyspraxia in deaf children have concentrated on spontaneous speech and intransitive limb movements. Mobility of the tongue is one aspect emphasized in the past and no cognizance has been taken of lips, jaw and other articulators. Even with regard to tongue, the movement patterns and its deviations have been analysed in general, but not with respect to speech sound production. Thus, we have tests like tongue mobility (Chilla and Kozielski, 1977), test for intransitive hand positions (Berges and Lezine, 1963), finger tipping testing (van Uden, 1967), test for sequential memory of motor movements of hand (Kaufman and Kaufman, 1983), etc. It is very difficult, based on the results of these tests, to infer dyspraxia of articulatory movements and their influence on speech.

Generally, the assumption in previous research is that presence of dyspraxic errors affects speech sound articulation. Alternately, it is possible that an inability to master the required sensory-motor schema for production of sounds because of deafness may have impaired the movement of articulators. Therefore a 'cause and effect' relationship is purely hypothetical. There is a need to study if dyspraxic errors reduce as a result of remedial training for the improvement of speech sound articulation and vice versa. Such an analysis would shed more light on the relationship between articulatory and dyspraxic errors.

As this study is the first study in this area in this country, it is also essential that a relevant test battery for the identification of dyspraxic errors in deaf children, suitable to our context, be developed. One another consideration in developing the test battery should be that such tests deal with the movements of the articulators as related to speech production, as far as possible.

1.9 Statement of the Problem

The present study is an investigation of the presence of articulatory dyspraxia in profound deaf children, and its effect on articulation of speech sounds. Influence of motor and speech therapies in improving speech and motor functions was also investigated.

1.10 Objectives of the Study

The objectives of the study were to

a) construct/assemble a relevant test battery to investigate the nature of dyspraxic errors in deaf children,

b) investigate the prevalence of dyspraxic errors in a population of school going deaf children,

c) investigate the effects of dyspraxic errors on speech articulation,

d) design techniques of therapy for errors of dyspraxia and speech sound misarticulation, and

e) investigate the effects of therapy for dyspraxia on speech sound articulation in deaf children as well as the effect of speech therapy on dyspraxic errors

Chapter 2

REVIEW OF LITERATURE

A deaf individual is one who has sustained a profound (91 dB or greater) primary sensorineural hearing impairment, prelingually and caused by either exogenous or endogenous factors. These individuals may only be aware of loud auditory stimuli and thus may not learn language auditorily or spontaneously (Quigley and Kretschmer, 1982)

2.1 Implications of Hearing Impairment on Speech

A major sequel of deafness may be summarized by the term 'delayed speech automation'. Of the several difficulties faced by children with hearing impairment, researchers have identified 5 factors as typically endangering the development of eupraxia of speech. They are as follows:

* Lack of tempo for motor behavior - Many researchers (Morsh, 1937; Ewing and Stanton, 1943; Ewing, 1957; Myklebust, 1964) have shown that the deaf were slow and tardy compared to the normal hearing children in their motor movements and physical activities. This may be due to the time taken to react to stimuli in the environment The reaction time for visual stimuli (which the deaf mostly rely upon)

is usually longer than that for auditory stimuli which the deaf are deprived of (Woodworth and Schlosberg, 1971).

* Lack of rhythm - Rosenstein (1957) found deaf children to have poorer ability in discriminating rhythm patterns than normal hearing and blind children. Beertema (1980) found congenitally profound deaf children deficient in producing a series of repetitive syllables on a diadochokinetic task. Van Uden (1969) found deaf preschool children to be significantly poorer than normal hearing children in their ability for imitation of rhythmic patterns.

* Lack of breathing control - Normal hearing people control their breathing not only consciously but also unconsciously (Teel et al., 1967). In the deaf, the unconscious breathing seems to be normal. Difficulties appear when they try to use their breathing consciously (like in blowing, blowing nose etc.). Many researches have documented severe disturbances of breathing control in deaf children who are starting to learn to speak (Hudgins, 1937; Mitrinovitch, 1937; Woldring, 1956; Speth, 1958; Brankel etal., 1965). 'Deaf mute-phonasthenia' may be a consequence with the result being a falsetto voice. Apart from these, there are other indirect consequences like difficulty with the rhythm of words and rhythmic grouping of words into phrases (van Uden, 1982).

* Strong and conscious control of speech - A normal hearing child will start his speaking even when the cortical organization of his brain is yet incomplete. He speaks with the help of subcortical centre, including the limbic system (Dimond, 1980). Speech in a normal hearing baby grows from below to above - from unconscious 'steering' towards a conscious control. But, in a prelingual profound deaf child, the way to automation flows from above to below, when at 4 or 5 years of age the therapists start their work in a very conscious way. This deficiency could be rectified. It has been shown that natural babbling of a deaf child can be guided towards speech by means of classical or operant conditioning (Rosa de Werd, 1964; Ewing and Ewing, 1964; Calvert and Silverman, 1975; Ling, 1976).

Lack of frequency of speech usage - No skill can develop without sufficient repetition and training. Speech has to be automated with proper training in deaf children as the innate ability to develop speech is very limited in deaf children in the absence of proper auditory input (Markides, 1976).

Assessment of the speech production skills of the deaf has revealed certain typical characteristics that could be grouped under the following three categories:

a) Phoneme production - Both vowel and consonant errors are present in the speech of the deaf. A higher percentage of vowel errors are seen in their speech than in the speech of the normal hearing children. More visible consonants (like /p, b, m/) are more readily and more correctly produced. Errors of omission are the most common errors on consonants and errors of substitution are often substitutions of voiced for voiceless consonants. Nature of errors on vowels are more likely to be of substitution type than of omission (Huntington etal., 1968).

b) Prosodic feature production - Word and sentence duration in the speech of the deaf is much longer than in the normal hearing (Hardy, 1958; Colton and Cooke, 1968; Nickerson et al., 1974). There are abnormalities of pitch control (McGarr et al., 1976). Errors in timing have been reported consistently. The deaf pause inappropriately between words and in mid-phrase (Hudgins and Numbers, 1942; Hood, 1966; John and Howrath, 1965).

c) Speech intelligibility - Intelligibility of speech of the deaf is poor (less than 20%) as reported by Brannon (1964), John and Howrath (1965), Markides (1970), and Smith (1973).

The congenitally deaf have severe deficits not only in the semantic and the syntactic aspects of language but also in the quality of phonation. The latter deficiency exhibits itself in poor voice quality (generally hypernasal and hollow). Voiced-voiceless confusions, omission of final consonants of words, and a tendency for neutralizing final vowels towards a ^ schwa ' were observed. Vowel distinctions are not accurate and there is a tendency to neutralize vowels toward the schwa (Hanson, 1983).

A more detailed statement on the nature of misarticulation in the prelingually deaf was made by Smith (1972) following an elaborate study of the nature of segmental errors (errors at the level of phonemes) in the speech of prelingual profound deaf. Smith describes these errors in terms of the following categories:

i) Omission: the target phoneme is completely omitted.

ii) Substitution: the target phoneme is replaced by another phoneme.

iii) Distortion: the sound produced is recognizably the right phoneme, but it is not produced normally.

iv) Intrusion: an inappropriate phoneme intrudes into an utterance.

2.1.1 Segmental Errors : Consonants

Smith (1972) classified and analysed consonants, and the nature of articulatory errors on them, as follows:

i) Labials like /f, v, p, b, m, w, r/ and postlabials which includes all other consonants. Here, the major findings were that the omission of postlabial consonants tended to be more prevalent while omission of labial consonants was very rare. Substitutions in the case of labial consonants involved a forward shift (that is, the sound which was produced was articulated farther forward in the mouth than the one which should have been produced). A contrasting pattern of backward shift tends to prevail in the case of postlabial consonants.

ii) The postlabials alone were classified and studied as affricates /tʃ, dj/ and fricatives /ʃ, ʒ, s, z, θ, ð/. Substitutions were mostly effected between these groups like, /j/ for /dʒ/, or from within the group itself like /s/ for /z/. Very rarely were the phonemes of these categories replaced by other phonemes like /l/ for /θ/. In these two categories, the voiceless consonants like /z, r, tʃ/ tended to be more frequently misarticulated than the voiced consonants like /ʒ, dʒ/. Thus, the errors of substitution in this category seemed to be characterized with added voicing as voiceless consonants were replaced by their voiced counterparts. The unvoiced consonants of this group tended to be misarticulated twice as often as their voiced counterparts (Penn, 1955).

iii) Plosives like /p, b, t, d, k, g/ and all other nonplosive consonants. In the prelingually deaf, a typical type of misarticulation called the 'plosive shift' can be observed. This is described as a trend involving substitution of nonplosive targets with plosives like /d/ for *It I.* The nasal consonants /m, n/ were often substituted by their oral counterparts while a nasal sound like /n/ seemed to be very frequently omitted. In general, the plosives were more often omitted than substituted in comparison to the fricatives and affricates.

2.1.2 Segmental Errors : Vowels

Vowel intrusion seems to be a major and a most frequently noted problem (Smith, 1972), especially, intrusion of the centrally produced vowel *Idl.* Next to that vowel omissions were quite common. Again vowel *Isl* was primarily involved.

Vowel distortions are of three types. The most common type of error was the vowel elongation. Longer vowel durations, 2 to 3 times longer than in normal speech have been noted in the speech of deaf children (Reilly, 1979). The second type of vowel distortion, although only occasionally seen, is associated with diphthongs where the first element is prolonged with the second element either omitted or heard as a distinct sound (Markides, 1970) The third type of vowel distortion reported is characterized in terms of abnormal formant patterns (Monsen, 1976; Osbergeret al., 1979).

Vowel substitutions involve certain clusters of vowels.

i) The central axis cluster comprising /i, ɩ, ə, ɔ/. Vowels in this cluster are interchanged with their neighbours in the cluster without any typical pattern of inclination in any one direction.

ii) The low front cluster comprising /ə, ɛ, æ, a/. Vowels in this cluster are mutually interchanged with other members within the cluster.

iii) The high back cluster comprising /u, ʊ, o, ɔ/. There is a pattern of replacement by diphthongs with a downward and central shift.

iv) The low stable cluster comprising /ʌ, a/. These vowels tend to be produced correctly and are the ones employed to replace the less stable vowels.

v) The high front cluster comprising /i, eɩ/. Errors in this cluster are not evident.

There have been recurrent claims in the literature to the effect that the prelingual deaf produce consonants much more clearly than vowels (Nickerson, 1975). An exception to this general finding was that of Smith (1972) who reported that similar proportions of vowels and consonants which were actually produced were produced correctly, though far more consonants than vowels were omitted. However, accurate production of phonemes in isolation or in syllables does not assure their fine coarticulation in the production of larger speech segments.

2.2 Implications of Hearing Impairment on the Various Aspects of Cognitive Development

Traditionally it was believed that the deaf were inferior in intellectual functioning when compared to the normal hearing (Pintner and Patterson, 1916; Pintner, Eisenson and Stanton, 1941). On the contrary, it has been shown that the deaf are quantitatively equal, but qualitatively unequal to the normal hearing persons (Myklebust and Brutton, 1953). The qualitative differences may be accounted for by the difficulties that the deaf will have with verbal test instructions that the tests depend upon and a lack of general life experiences. Thinking processes of the deaf are similar to that of the hearing, and therefore, must be explained without recourse to verbal processes (Furth, 1964).

Although nonverbal intelligence scores are comparable, the academic achievement scores of the deaf have been consistently poor in comparison with those of the normal hearing children (Hine, 1970; diFrancesca, 1972; McClure, 1977; Reich, Hamhleton and Houldin, 1977; Trybus and Karchmer, 1977, Allen, 1986). The deaf are better skilled in arithmetics than in reading skills (Hamp, 1972), Considering their style of cognitive functioning, the deaf are more field-dependent, that is, they are poor in differentiating objects from their background. Their concept formation is based more on symmetry and sameness and they are rather poor in concepts dealing with opposition. They are also poorly equipped in generalizing acquired concepts to new tasks. It is reported that they are able to concentrate on only one salient characteristic of an aspect at a time.

Regarding memory, the deaf present large deficits in the processing of sequentially or temporarily presented stimuli (Odom and Blanton, 1967). However, the deaf are significantly better than their hearing counterparts in memory tasks that involve visual tracking, motor recall, or location in space. In the area of motor development, the deaf show deficits in static equilibrium, balance, locomotor coordination and more complex kinesthetic skills, but show no differences in the area of speed. Visual, tactile and spatial perceptual skills of the deaf parallel those of the hearing (Blank and Bridger, 1966; Schiff and Dytell, 1971). On tasks requiring integration and use of a number of cognitive skills like reasoning and problem solving, the deaf demonstrate poor performance on more difficult tasks.

2.3 Management of Deaf Children

A comprehensive educational program should be the answer to overcome the hurdles caused by hearing impairment. There are two distinct approaches to the field of education of the hearing impaired. One approach allows use of manual form of language. This approach includes methods like cued speech (Cornett, 1967), finger spelling (Quigley, 1969), manual codes of spoken language like manually coded English (Wilbur, 1987), and also sign languages like the American Sign Language which are considered by many to be the natural languages of the deaf people (Johnson, 1988). Needless to say that the use of these manual approaches has several shortcomings. The most important disadvantage is the barrier laid on the interaction between the deaf and the hearing-speaking world surrounding them. Also, an inability to transfer knowledge in their primary/natural language (manual language, in this instance) to written form (as written language is based on oral language) would leave the deaf individuals additionally handicapped in terms of education and vocation in this increasingly literate world.

The other major approach in the education of the deaf is the aural-oral approach which is a predominant method of educating the deaf in India. Aural-oral remedial training focuses, to begin with, on the development and optimal utilization of the residual hearing (that is, whatever sense of hearing that has been retained inspite of the loss). This process is called auditory training. In the case of congenitally and prelingually impaired children, auditory training starts with creation of sound awareness and then proceeds towards identification and discrimination of gross and fine inanimate, animate, human and speech sounds in sequence An essential aspect of auditory training is the amplification of sounds. The deaf are then taught to use their visual sense to augment their perception of speech by following the movements of the lips and other visible articulators (lip reading), facial expressions, body language, etc., of the speaker. The most important component of the training program for the deaf is speech training. Deficit in the deaf in the perception of sounds, especially, speech sounds adversely affects the development of speech skills in the deaf. Training to speak involves enhancement of the voice quality and correction of defective articulation making use of kinesthetic sensations and auditory monitoring and also non-auditory techniques like visual and tactile techniques (Newby and Popelka, 1985). Effective training in the above mentioned skills help in reducing the strain and pressure on the communication efforts of the deaf.

Researchers in the past have shown that prelingual profound deaf children could be educated in the aural-oral way (Conrad, 1979; Thomassen, 1970). Detailed studies on the achievement of aural-oral trained deaf children in an oral environment have been undertaken at the Instituut voor Doven, Netherlands. One study by van Balen (1974) was on the tempo of speech. Measurement of speech tempo in normal hearing adult speakers led to identification of 3 kinds of tempo which are used by the hearing speakers. One was the quick tempo of 7.15 (+0.76) syllables per second (like that of news readers); the other was the moderate tempo of 5.23 (±1.55) syllables per second (like that used in conversations); and then the solemn tempo.of 2.60 (±3.23) syllables per second (like that used by reciters of poetry and preachers). Data was collected from the prelingually profound deaf children of 11 to 12 years of age as evident in their conversations in the classroom. The obtained speech tempo of 3.07 (±2.56) syllables per second was less than the observed conversational tempo in the speech of normal hearing adult speakers. But, this should be taken as near normal considering the fact that they are children. It was also reported in this study that the speech tempo, in itself did not affect the intelligibility of speech. This has also been supported by Pickett and Pickett (1963).

Another study (van Uden, 1977) was on oral fluency. Oral fluency was quantified on a subtest of Wechsler's Intelligence Scale for Children for short-term memory for spoken sentences and on a test for saying as many words as possible within 2 minutes. Profound deaf children averaged 90% and 80% in these two tests, respectively, by 14 years of age. This can be taken to be an indication of near normalcy in their speech behavior.

At the stage of'babbling', which is one of the earliest observed speech activity in children, the congenitally profound deaf children are not qualitatively different from the normal hearing children (Lenneberg et al., 1965; Mavilya, 1969; 1970; van Uden, 1983). But, quantitative differences will be evident. On an average, the profound deaf children babble much less than the normal hearing children (at six to seven months, it does not extend beyond a few minutes of an hours observation time). There is also less selfimitation. Vowels dominate consonants in the babbling of deaf babies (Mavilya, 1969). Intonations in the babbling of normal hearing babies are likely to be replaced by shorter rhythmic iterations in congenital profound deaf babies. The length of breath units (a term of Irwin, 1947 which refers to a single stretch of exhalation) is very low in deaf babies, and on an average, comprises of just three phonemes. After the first six months the babbling deteriorates further, although it never stops altogether.

But, the deteriorating speech activities could be reinforced positively and substantially by a 'constant' from outside. A strong, purposeful and stimulating interaction from a teacher or parent in the environment reflecting to the child orally could be this 'constant'. In the process of educating to speak, care should be taken to observe that the speech loop processes operating in the profound deaf children are more visual and articulatory than auditory in nature when compared to normal hearing children (van Uden, 1983). Van Uden (1959) has identified two more factors which could significantly influence/enhance eupraxia for speech in the congenitally profound deaf children. One is the habit of watching the face of the speaker (face directedness), which may develop into lip reading and the other is the skill of developing/augmenting sound perception through hearing aids.

Skilful and dedicated instruction could help in alleviating the deficiencies in the speech of the deaf children. This fact has been confirmed by many studies which also observed similarities in the eupraxia of speech in deaf and normal hearing children. In a study of the intelligibility of speech of deaf children, Hudgins and Numbers (1942) noted that the order of difficulty of learning phonemes (where some phonemes are easily learned than others) typically correlated with the frequency of such phonemes in colloquial language. The more pronounceable a phoneme is for the deaf children, the more it is used in daily conversation by the normal hearing children also (Miller, 1960). Also, deaf children most frequently babble those consonants which are produced by the normal hearing children early in their development (Lach et al., 1970).

Inspite of these assurances, in practice, several deaf children of average and above average intelligence make insufficient progress even after years of ideal special education. The reason is that, apart from the auditory disorder, there are other factors that play a crucial role in influencing the normal development of speech in deaf children. The attitude of parents, educators and the child himself (Redgate et al., 1972) and the presence of hitherto unidentified disabilities additional to deafness are some of these factors. Several of these disabilities are distinctive enough to warrant further investigations on effective correctional measures. These disabilities may be considered in terms of

a) emotional functioning: hysteric and hysteroid tendencies, pathological weaknesses in concentration, autism, hyperactivity,

b) motor functioning: spasm, athetosis, choreo-athetosis, choreiformity, ataxia, and severe clumsiness, and

c) cognitive functioning: mental deficiency, difficulty with memory, perceptual disturbance (van Uden, 1983).

In addition, there are disturbances which can be grouped under the broad term of'learning disabilities'. These are less striking to the untrained eye, but, which require careful diagnosis and institution of remedial procedures unique to each child.

2.4 Learning Disabilities Additional To Deafness

These are disabilities that interfere with a child's ability to profit from instruction. These often manifest as difficulties in learning to speak, read, write or compute. Senf (1972) describes learning disabilities as disturbances in sensory-motor integration. They are disorders in the processing and integration of information. Ross (1976) describes learning disability as the 'disability to recode and reorganize information'. Vellutino (1977) and Torgesen (1979 as quoted by Wong, 1979), describe learning disability as an 'encoding disorder and verbal deficit'. Wong (1979) describes learning disabled children as 'more impulsive', and 'easily distracted', etc. But, these descriptions are, at best, inadequate and vague

Two disabilities have been found to considerably endanger proper oral speech/language development in deaf children in addition to deafness (van Uden, 1983). One is a motor handicap called apraxia or dyspraxia, and two, an intermodal integration disability like dyslexia. Dyslexia is a problem in the integration of the written and spoken form of words and letters. There are also other learning disabilities like dysgraphia (writing disability) and dyscalculia (computing disability), among others.

2.5 Cognitive Processes in the Learning Disabled Deaf Children

Affolter (1984), in a 10-year term long study compared development of learning disabled deaf and normal hearing children with deaf and normal hearing children who had no learning disability. He concluded that the groups differed in several areas including eye contact, complex motor skills, eye hand coordination, imitation of gestures, problem solving skills, symbolic nonverbal processing, drawing, picture recognition, and recognition of successive patterns in auditory, visual and vibro-tactile presentation conditions. He identified 3 types of impaired cognitive processing in the learning disabled deaf and hearing children.

The deficits were in the areas of

a) processing of simultaneous input from disparate modalities (that is, intermodal processing deficits),

b) integration of tactile-kinesthetic information, and

c) sequencing of events or stimuli.

Affolter (1984) proposed that differed imitation, symbolic nonverbal processing and language acquisition require a certain critical amount of tactile-kinesthetic information processing and modality interconnection while direct imitation and speech-sound development requires a certain critical level of sequential integration.

Social learning curricula/programs emphasizing perceptual-motor skills, concept formation, and social learning skills have resulted in measurable improvement and progress in the educational performance of deaf children with learning disabilities (Naiman, 1974).

2.6 Psychomotor Disturbances Affecting Speech Articulation

As said earlier, learning disabilities encompass disturbances in motor and cognitive behavior. Such disorders are also termed as psychomotor disorders as they arise out of organic disturbances in the central nervous system. Eupraxia or optimal motor functioning can be defined operationally as the quick finding of the members like articulators needed for an action like speech act (van Uden, 1983). Disturbances in the motor functioning can have consequences like improper gait, imbalance, incoordination, speech misarticulation, etc.

Generally motor skills are divided into 'general', 'orofacial' and 'skills involving speech musculature'. Disturbances in these skills have been studied for their influence on speech articulation. Very few studies (Winitz, 1969; Frisch and Handler, 1974), and that too only vaguely, have correlated general motor skills with speech articulation problems. Gallagher and Shriner (1975) examined 3 year old children for oral and facial motor skills and reported that motor difficulties like constraints in motor sequencing affected proper articulation. Dworkin and Culatta (1980) examined relationships between tongue strength and articulatory proficiency and found no significant correlation. Skills involving speech musculature like rate and accuracy of movements of the articulators were studied again by Gallagher and Shriner (1975). Generally weak correlations were found between rapidity of repeated movements and articulatory proficiency. But most children with inaccurate movements had problems with articulation.

Causes of such motor deficiencies are many and varied, including defective development of the pyramidal pathways, the extrapyramidal tracts and the cerebellum in the various forms of congenital diplegia (Brain, 1965).

2.6.1 Dyspraxia in Deaf Children

Dyspraxia is a psychomotor problem and is described as the difficulty in carrying out complex voluntary movements. This is a challenging condition to the speech-language pathologists and special educators engaged in the education of the deaf. Dyspraxia hinders the proper development of oral language in deaf children and defies usual approaches to clinical treatment of articulation problems.

In 1970, van Uden constructed a test for eupraxia. This test measured the speed of recognition of arms, legs and fingers for transitive movements The results of this test highly correlated with those of an earlier test for eurhythmia (van Uden, 1955). In children who scored below the 25th percentile rank in these tests for eupraxia and eurhythmia, typical difficulties in speech were observed (with related difficulties in speech-reading and auditory training). This disturbance was described as 'dyspraxia of speech'.

2.6.2 Prevalence of Dyspraxia

Almost all aspects of nature show a so called normal distribution, that is, about 16% of the subordinates fall under the high category, 68% in the moderate category and 16% in the low category on any given function. In the same way, the function of motor programming may also be taken to be normally distributed in the normal hearing population. But, the incidence of dyspraxia among the profound deaf seem to be significantly higher than expected. About 20-25% of the prelingually profound deaf children seem to exhibit dyspraxia (van Uden, 1971).

Van Uden (1974) substantiated his earlier finding (1971) with results from a population of 95 prelingually profound deaf children with normal intelligence and aged 2 years 6 months to 6 years. The results, in brief, were

Children with only dyspraxia	-	15%
Children with only sensory-motor integration disturbance	-	8%
Children with both dyspraxia and integration disturbance	-	22%
Children with no serious learning disability	-	55%
Total	-	100%

Information on the incidence and prevalence of deafness is scanty. But, it is generally accepted that there is a vast population of deaf and hearing impaired in this country. Joshi and Rege (1954) in a study based on hospital situations reported that 4.8% of the patients attending their hospital had congenital deafness. Mishra, Bhatia andBhatia (1961) reported that 13.6% and 2.9% of the 1,390 school going children in the age group of 3 to 12 years had mild and moderate deafness, respectively. They also observed that the incidence was higher in the lower socioeconomic strata of the society

Similar studies were conducted by Gupta (1967), Nikam (1970) and Shah (1971) Gupta in his survey of 3,504 school going children found that

35.4% of these children had mild deafness while 4.3% had moderate deafness. Nikam studied 2,086 school children in the age range of 2 to 14 years and reported 3.9% hearing loss in them. Shah reported that 1,113 of the 7,100 school going children of 5 to 8 years of age screened had hearing problems. Of them, 75.68% had mild hearing loss, 8.4% had moderate hearing loss, and 1.8% had profound loss. These studies also reported higher prevalence of hearing loss in the lower socioeconomic groups. Kameshwaran (1967) reported that 6% of the general population and 3.5% of the school going children in Tamil Nadu had hearing loss. Mukherjee and Roy (1967) covered 206 school going children belonging to the age group of 5 to 10 years and reported that almost 21.8% of these children had mild hearing loss and 58% had moderate hearing loss. The 1981 census made an estimate of the incidence in the age group of 5 years and above for every 1,00,000 population. In rural areas it was 19 and in urban areas the incidence was 15. Thus, it is evident that we have a substantial population of deaf children in this country. Therefore, there is a need for optimal utilization of the meagre resources at our disposal in the management of these children.

In the Indian context, information on the prevalence of dyspraxic disorders in deaf children is not available. As mentioned earlier, oralism is the preferred approach in the education and communication management of deaf children in this country. However, oralism has not always produced the desired results. Perhaps, dyspraxia is one factor which has a bearing on the speech-language development of deaf children. Therefore, revitalization of this approach requires knowledge about the prevalence of learning disabilities like dyspraxia in deaf children and on ways of effective management of these problems.

2.6.3 Dyspraxia in Deaf as a Result of Inadequate Neurological Interconnections

Eupraxia, a term first used by Cobb (1948), refers to an easy development and maintenance of a motor program. It also encompasses the motor control of body movements The centre for these activities of building up and monitoring of motor programs is the motor brain. A most conspicuous component of this centre is the motor pyramid cell (Zemlin, 1988). The motor pyramid cells and other motor neurons (that supply the muscles and joints from the motor brain) grow fibrils among themselves through repeated positive stimulation. This intermodal interaction between cells of the same type can be described as gestalt formations as they are formed selectively, profiledly and stochasticly in such a way that the whole is more than the sum of the parts. Development and presence of more and more interconnections results in a rich brain field. Fewer and weaker connections are characteristic of a poor brain field. A poor brain field may be the result of illness, infections (like rubella), atrophies, shock, haemorrhage, enlarged ventricles, among others. On the other hand, a rich brain field is built up by continuous feedback from the muscles, joints and also from the environment (outside the individual) though a motor neuron is less dependent on stimuli from outside than a sensory neuron. These motor neurons will atrophy and die when they are unable to actualize their innervating activities by not receiving feedback from the muscles and joints.

A rich motor brain field would ensure programming of skilled movements for the innervation of the right group of muscles, coordination of movements in space and time (including sequences of movements, rhythm and planning behavior), and motor memory for skills (van Uden, 1983). In profound deaf children, there is a natural tendency for deterioration of the speech motor brain field as a result of lack of auditory feedback coupled with deficient rhythm, breath control etc., make speech acquisition a laborious process. This may be the reason for the high prevalence of speech dyspraxia among the congenitally profound deaf. The present study on the influence of dyspraxic errors on speech articulation in deaf children was carried out with this presumption.

As mentioned earlier in Chapter 1, one of the major objectives of this study was to investigate the prevalence of dyspraxia in deaf children. This necessitated development of a psychodiagnostic test battery to identify dyspraxic errors in deaf children. The process of setting up of the battery requires an understanding of the characteristic features and consequent implications of dyspraxia in speech. More important of these implications are discussed below.

2.6.4 Profile of the Learning Aptitudes in Deaf Children with Dyspraxia

Van Uden (1971) administered 'the Nebraska nonverbal test of learning aptitude' (Hiskey, 1966) to 2 groups of 16 deaf children aged between 4 years 6 months and 9 years 6 months. One group consisted of dyspraxics and the other of eupraxics. These groups were matched for age, degree of deafness and nonverbal intelligence (performance IQ).

The Hiskey-Nebraska test (1966) for these ages comprises of 8 sub-tests, namely,

a) Imitation and memory of bead patterns
b) Memory for colours
c) Picture identification
d) Picture association
e) Paper folding
f) Visual attention span
g) Block patterns
h) Completion of drawings

The eupraxics scored significantly higher in tests for paper folding and picture association which require skills in sequential visual and motor memory and abstract thinking for invisible relations. On the other hand, the dyspraxic deaf were deficient in these areas. The dyspraxics scored significantly higher on the subtest for bead patterns and visual attention span which implied that the deaf dyspraxics have strong simultaneous visual memory.

2.6.5 Speech Learning in Dyspraxic Deaf Children

The presence of dyspraxia was found to adversely affect the speech learning process in the prelingual profound deaf. This was confirmed by van Uden (1977) in a study of 95 prelingually profound deaf children. In this study, he compared the progress made by children in learning speech with their performance on an inventory for eupraxia. Of the 95 children, 22 were ranked above the 75th percentile while 18 were ranked below the 26th percentile. The rest were placed in between these extremes. Of the 18 who were identified to have poor eupraxia, a majority (15) of them made retarded progress in speech, 2 made moderate progress, and only one child made good progress. This finding is sufficient evidence for a definite link between dyspraxia and problems in speech articulation. On the contrary, of the 22 who were identified to have eupraxia, 14 made good progress in speech, 7 made moderate progress, and only 1 made retarded progress This is reassuring in the sense that it means that absence of additional learning disabilities makes instruction through the aural-oral mode more useful and successful.

This study (van Uden, 1977) is, in general, about the progress made in oral fluency. A more detailed study encompassing aspects of rate and rhythm, among others, in speech will yield additional information useful for developing speech skills in the deaf dyspraxics.

The discussion in this section pertained to the symptoms of dyspraxia. The syndrome of dyspraxia, in addition, implies an interdependency of motor and cognitive aspects of behavior. Some of these interrelations are discussed in the succeeding sections.

2.6.6 Memory in Dyspraxic Deaf

Van Uden (1983) in a study of 83 children over a course of 8 years concluded that a majority of them (54/83) suffered from severe dyspraxia. This combined with poor auditory memory resulted in weak speech memory and consequent dysgrammaticism.

Auditory memory is not strong in deaf dyspraxics. This results in poor memory for speech and dysgrammaticism. However, in the normal hearing dyspraxic child, auditory memory is stronger than in the deaf. Therefore, these children can compensate for their deficit in speech motor coordination and programming and thus, dyspraxia, even when present, does not appear to be severe enough (van Uden, 1983).

However, a positive factor noted in children suffering from these conditions (dyspraxia and deafness) is that they have a strong memory for simultaneously presented visual data, including the graphic form of words (van Uden, 1983). This ability could be used to support speech and verbal development. Broesterhuizen (1997) reported that the visual memory skills of deaf children, aged 4 to 6 years, are predictive of their later passive written vocabulary and reading comprehension skills.

Generally, the dyspraxic and motor dysphasic deaf children show a better memory for colours, pictures, bead patterns, that is, for simultaneously presented visual data. But, when they had to memorize and imitate successively presented visual data such as pictures in succession, paper-folding patterns, block tapping patterns, etc., they generally scored less in comparison with the eupraxic deaf (van Uden, 1983). Broesterhuizen (1997) reported that speech and speech reading skills in preschool deaf children 3.5 to 6 years depended strongly on fine motor skill of hand and mouth, successive memory, and memory for rhythm. These three interdependent skills can be taken as three aspects of eupraxia. Further, he reported that eupraxia is an even stronger predictor of speech and speech reading skills than hearing loss.

Though a poor memory has negative consequences for speech development, the importance of recognizing the inadequate memory functions is often not emphasized adequately or is often neglected by psychologists and special educators. A precise identification of the variability of memory functions and their variable profile in different children is fundamental to a well planned education program. This is especially important in the case of dyspraxic deaf children whose memory profile is particularly sensitive to identifying distinct patterns of stimulus presentation like simultaneous over sequential presentation (van Uden, 1983). Performances of deaf children on simultaneous versus sequential memory tasks may be an objective indicator to the presence of dyspraxia in them.

2.6.7 **Rhythm in the Dyspraxic Deaf**

Van Uden (1955) found the congenitally profound deaf children in the age group of 3 years 6 months and 6 years 5 months perform significantly less on eurhythmia. These children exhibited problems in executing spontaneous rhythmic movements of the trunk and the arms during the task. The results of this study highly correlated with one of his later tests for eupraxia (1971). Detailed investigation of dyspraxia in deaf children, aged 7 to 10 years, showed a significant positive correlation between scores on test for oral repetition of rhythmically spoken syllables and eupraxia for fingers (van Uden, 1983).

A factor analysis of the data revealed that development of eupraxia of fingers, development of rhythm (eurhythmia), fluent speech, speech reading and speech-hearing were a single factor, that is, there was a high positive correlation between them indicating mutual influence and interdependency between them (van Uden, 1970; 1971). Dyspraxia of the fingers and dysrhythmia involve dyspraxia of speech including difficulty in speech reading and speech-hearing development. Correlations between speech, lip reading, and speech-hearing development on the one hand, and scores of eupraxia tests, including eurhythmia tests, on the other hand, were consistently observed.

Breuer and Weuffen (1975; 1977) have shown an interdependency or interaction between disorders of development of rhythm, memory for speech and dysgrammaticism in normal hearing dyspraxic children of 3 to 8 years. Elstner and Karlstad (1978) and Lotzman (1979) also supported these findings. Hence, testing for eurhythmia should be an integral part of testing for dyspraxia. Consideration of speech rhythm while studying the effects of dyspraxic errors on speech would help acquire more relevant data.

2.6.8 Intransitive Movements in Dyspraxic Deaf

Some children who perform skilfully in gymnastics and sports are at times clumsy with their speech motor movements (van Uden, 1967). The reason for this is the difference between the transitive and intransitive movements. Transitive movements are those which use some material towards an objective. For example, dressing oneself, building with blocks, etc. Subjects control these movements because the materials evoke them. An intelligent child, even being clumsy, may execute these movements skilfully by compensating for his clumsiness. Intransitive movements do not use materials (Kaplan, 1972). For example, dancing, speaking etc . It is difficult to detect dyspraxic speakers by means of tests for transitive movements. But, they are easier to detect using tests for intransitive movements such as test for eurhythmia, movements of the fingers, and speech (Berges and Lezine, 1963;Zazzo, 1964).

By means of the tests for intransitive movements, the control of the body movements - the 'body relation-gnosis' in the words of Prick and Calon (1950) - can be easily detected. Dyspraxia is actually a disturbance of this control. It follows from this that dyspraxia should be investigated more clearly and deeply using tests for intransitive movements. A study on speech/articulatory dyspraxia should essentially include tests for voluntary, intransitive movements of the articulators.

2.6.9 Tempo/rate of Speech in Dyspraxic Deaf

Past research has suggested that tempo and rhythm of movements are positively and significantly correlated (van der Veldt, 1928; Montpellier, 1935). They observed that rhythmic movements enhance automation, and automation, in turn, by speeding up and repeating a movement, enhances rhythmicity Van Galen (1974) made similar observations in the speech.' of normal hearing people in a speech reaction-time experiment From • , these findings we could understand that the tempo for speech in the deaf dyspraxics may not be as good as in the normal hearing population. Van Balen (1974) investigated for the tempo of speech in samples of conversational speech. He identified an average tempo of 6.4 (±1.3) syllables per second, a quick tempo of 7.8 or more syllables per second as well as a slow tempo of 5.0 or less syllables per second in the speech of normal hearing population. In comparison, the speech tempo of the prelingually profound deaf children aged 9, 11 and 12 years was very poor and ranged from 2.54 (±2.00) to 3.07 (±2.56) syllables per second. Since, development of rhythm was found to be deficient in dyspraxic deaf, it can be assumed that their tempo was also deficient. As a reiteration to this, Van Uden's investigation of 83 profound deaf children in the age group of 7 to 10 years (1983), carried out between 1966 and 1972, revealed a positive correlation between results on oral fluency (speaking as many words as possible in 2 minutes) and findings on eupraxia of limbs. The correlations were significant in the younger age groups.

There are also studies on the rapid repetitions of syllables or the diadochokinetic rate, and movements of the articulators on a nonspeech task in the normal hearing children. However, no such studies seem to have been carried out with the deaf or dyspraxics. Since such movements are less spontaneous and more volitional than conversational speech, studies of this nature may reveal important information about dyspraxia. With this as a basis, the present study measured the rapid repetitive movements of the articulators which did not necessarily require that the intended speech sound be produced. Fairbanks and Spriestersbach (1950) reported on the rate at which the alveolar ridge could be touched with tongue tip on a nonspeech task in normal adults. This movement is similar to the movement involved in producing the sound /ta/. They came out with the following scale for judging the rate of these movements in normal adults: below average -less than 3.5 contacts per second; average - from 3.5 to 6.0 contacts per second; and above average - more than 6.0 contacts per second.

Sprague (1961) reported on the rate of such movements in normal children and came out with the following scale: below average - less than 3 per second; average - from 3.0 to 5.5 per second; and above average - more than 5.5 per second. Similar information is also available on the rate at which the back of the tongue can be elevated to touch the palate as in the production of the sound /ka/ in normal adults and children. Blomquist (1950), Irwin and Becklund (1953), and Fletcher (1972) indicated that normal children can be expected to repeat this syllable 3 to 5 times per second. Normal adults produced 5 to 6 repetitions of/ka/ in a second according to Lundeen (1950), Ewanowski, (1964), Kreul (1972) and Sigurd (1973).

Motility of the lips has been assessed through tasks which required rapid opening-closing movements, as in the repetition of/pa/. Data reported indicated that normal children produced between 3 to 6 sound/Sec (Blomquist, 1950; Sprague, 1961), while adult normals produced 6-7 sounds per second (Snyder, 1955). The number of jaw closings/second on a diadochokinetic task (Jenkins, 1940) are summarized in Table 2.1.

Age	Number of Jaw movements/sec Male	Female
7 years	3.5 - 3.8	3.7 - 4.0
8 Years	3.6 - 3.9	3.8 - 4.0
9 years	4.0 - 4.4	4.0 - 4.3
10 years	4.1 - 4.3	4.2 - 4.3
14 years	4.9 - 5.1	5.0 - 5.2
15 years	5.1 - 5.3	5.2 - 5.4
Adults	5.2 - 5.4	5.4 - 5.6

Table 2.1 : Mean number of closures of jaw on a diadochokinetic task in normal children of different ages and adults

Another task which yields useful information about a speaker's motor control of the articulators is the rapid repetition of a trisyllabic sequence /pa-ta-ka/. This activity requires the sequential production of labial closing-opening, tongue tip-alveolar contact, and back of tongue-palatal contact, a demanding programming task. Leshin (1948), and Yoss and Darley (1974) have shown that normal children can produce the task 3-4 times /second.

Blomquist (1950) found that normal children of 9 years could produce such a sequence 4.5 times per second. He also reported that these children averaged 4.6 jaw movements per second for the syllable /ta/, 4.6 movements per second for the syllable /pa/, and 4.0 movements per second for the syllable /ka/. At 11 years, the corresponding figures were /pa/: 5.3, /ta/ : 5.2, and /ka/: 4.7 movements per second respectively. Data from Snyder (1955) indicated that normal adults produced these sounds, on an average, 7 times per second. Lundeen (1950) tested diadochokinesis for ten monosyllables and rank ordered them in the order of decreasing order of rate of repetition (from fast to slow) like this : /ta, da, pa, ba, fa and va/. The slowest of all the sounds were /sa, ga and za/.

2.6.10 Oral Tactual Sensation in Dyspraxic Deaf

Dyspraxia is a disorder of motor planning resulting from poor sensory integrative processes (Ayers, 1975). According to her tactile and vestibular systems may also be involved. Putnam and Ringel (1972) suggested that motor involvement coexisted with loss of sensation.

Investigations of oral sensation and perception in apraxic patients suggest that the disorder may be sensory-motor and not solely motor. Guilford and Hawk (1968) observed that aphasic patients with oral apraxia performed worse on tests of oral sensation than aphasic patients without oral apraxia or normal subjects. Similarly, Larimore (1970) found oral sensory-perceptual deficit in 5 apraxic patients when he compared their performance on a variety of tests with that of normal subjects.

Rosenbek, Wertz and Darley (1973) have also endorsed the view that oral sensory-perceptual integrity may be compromised in apraxia of speech causing complications. They compared performance of apraxic patients, aphasic patients and normal subjects on three measures of oral sensation and perception, namely, oral form identification, two-point discrimination, and mandibular kinesthesia. Their apraxic group performed significantly poorer than the other 2 groups in all the three oral-sensory perceptual tests. However, there are several investigations (Deutsch, 1981; Square and Weinder, 1976) which have not confirmed the findings of Rosenbek et al (1973). Such deficits even when present appear to be unilateral than bilateral, and result in tactile-kinesthetic cues for movement that are muted or distorted, but not completely absent (West, 1947).

Similar information is not available with regard to the dyspraxic deaf population. Information of this nature may help in the identification and management of these problems in deaf children.

2.6.11 Lateralization in Dyspraxic Deaf

Children suffering from developmental verbal apraxia are often ambidextrous (Brain, 1965). In a study of lateraiization in relation to proficiency in speech articulation, Johnson and House (1937) found a significantly greater number of children with articulatory problems to be ambidextrous than were a control group of children with normal speech. However, Everhart (1953) found no significant difference in handedness between the two groups of control and experimental children (with articulatory problems). Ambidexterity may indicate that the process of lateralization is incomplete. Incomplete lateralization and speech programming deficits together may shed more light on the nature of speech dyspraxia in the deaf.

2.6.12 Speech Articulation in Dyspraxic Deaf

Articulatory dyspraxia reveals itself notably through features like omission (for example, fower for flower), perseveration (for example, flowler for flower), substitution (for example, slower for flower) and inversion (for example, lowf for flow) of phonemes. An important feature of articulatory dyspraxia is that the child may be able to correctly speak a word, but if he is asked to repeat the word from memory without graphic support, he may make increasing number of inversion errors losing phonemes in the process (for example, flower - fowl - lowl - low etc.). This is probably because the word is not quickly programmed in the brain (van Uden, 1981).

Several researchers (Shankweiler and Harris, 1966; Johns and Darley, 1970; Trost and Canter, 1974; Dunlop and Marquardt, 1977) have rank ordered the sounds based on the difficulty that individuals with speech apraxia manifest. A brief summary of their findings is given in Table 2.2. The sounds are ordered in the decreasing order of difficulty/easiness.

These researchers have not discussed the hierarchy of difficulty of vowels or of consonant clusters, but have only made a general observation that errors on consonants are more than on vowels. A similar study of difficulty of vowels and consonants in the dyspraxic deaf will provide helpful cues to the management of speech in this population.

2.7 **Testing for Dyspraxia in the Profound Deaf**

A comprehensive battery for systematized testing for speech apraxia should encompass the following domains:

a) Language measures: Tools to provide quantitative measures of language (like Porch Index of Communicative Ability - Porch, 1967) and description of expressive speech (like Boston Diagnostic Aphasia Examination - Goodglass and Kaplan, 1972).

b) Functional communication profiles: This would include profiles of communicative abilities of children in their day-to-day life.

Order	Shankweiler and Harris 1966	Johns and Darley 1970	Trost and Canter 1974	Dunlop and Marquardt 1977
Difficult Phonemes	θ	θ	j	v
	z	v	θ	z
	v	l	d	ʃ
	tʃ	dʒ	ŋ	tʃ
	dʒ	z	ʃ	dʒ
		ʃ	v	θ
			d	
			g	
			w	
			b	
Easy Phonemes	Not Reported	n	m	t
		m	n	d
		k	p	b
		b	1	k
		w	r	p
		d	k	n
		h	h	

Table 2.2 : Order of difficulty of sounds that patients with dyspraxia of speech manifest

c) Speech measures: Darley et al (1975), and Wertz and Rosenbek (1971) have suggested inclusion of rapid alternating tasks, repetition of monosyllabic and multisyllabic words, repetition of sentences, conversation, picture description, and oral reading tasks to get a representative sample of subjects' speech. Commercially available tests like Apraxia Battery for Adults (Dabul, 1979) with its six subtests (for diadochokinetic rate, increasing word length, limb and oral apraxia, latency and utterance time of polysyllabic words, repeated trials test, and inventory of articulation characteristics of apraxia) give a rough estimate of the severity of the condition. In addition, specific tests for testing articulation should be included.

d) Oral nonverbal movements: This would include peripheral examination of the articulators, tests for isolated oral movements (testing for specific nonspeech movements involving the articulators like sticking out the tongue, puckering the lips etc.) and tests of oral motor sequencing. The last one tests the coordinated movement of more than one articulator at a time like touching upper lip with the tongue, and raising and lowering the jaw (LaPointe and Wertz, 1974).

Apart from these primary tests, the battery should also consist of supplementary tests for intelligence, auditory comprehension and reading (Wertz, LaPointe and Rosenbek, 1984).

The ultimate goal is to test the child's ability of motor speech programming. Between the years 1966 to 1972, van Uden (1983) examined nearly 15 tests, listed below, for their effectiveness in detecting dyspraxia on 83 profound deaf children aged 7 to 10 years.

a) Memory for simultaneously presented colour rods (Hiskey, 1966 - test for memory for colours).

b) Imitation of successive folding movements (Hiskey, 1966 - test for paper foldings).

c) Memory for simultaneously presented pictures (Hiskey, 1966 - test for visual attention span).

d) Memory for successively presented pictures (van Uden, 1970).

e) Repetition of spoken series of digits (Wechsler, 1949 - test of digit span).

f) Simultaneous digit or symbol association (Wechsler, 1967 - test of coding).

g) Copying simultaneously presented geometrical figures from memory (Benton, 1953).

h) Identifying simultaneously presented geometrical figures from memory (Benton, 1953).

i) Tapping successively four cubes in the shown order (Knox's Cube test, 1914, standardization in Snijders-Oomen, 1970).

j) Placing the fingers in a certain position following demonstration (Berges and Lezine's, 1963 - test for imitation of gestures).

k) Imitating shown finger-movements from memory (van Uden, 1967).

1) Repetition of rhythmically spoken syllables (van Uden, 1970).

m) Speaking as many words as possible within 2 minutes (van Uden, 1970 - test for oral fluency).

n) Lip reading with sound-perception and repetition (van Uden, 1970 - part I of test for lip reading-hearing-imitating).

o) Speaking correctly repeated words again from memory (van Uden, 1970 - part II of test for lip reading-hearing-imitating).

Van Uden (1983) divided these tests into four categories, namely,

i) tests for supple use of mouth when speaking (tests e, m, n and o),

ii) tests for fluent, fine motor function (tests j, k, and 1),

iii) tests of memory for successively presented visual data (b, d, & i), and

iv) tests for memory of simultaneously presented visual data (test a, c, f, g and h).

A positive correlation between group (i) and group (iii) was observed in all the age groups. Also, eupraxia for finger movements correlated with eupraxia for speech movements. There was a negative correlation between group (ii) and group (iv) tests with subjects less fluent in their motor function doing better in tests for simultaneous memory.

Van Uden (1983) also subjected his data to factor analysis in order to identify the factors that determined the results on these tests and to find out if there were any differences between the four age-groups with regard to these factors. The results of the factor analysis indicated that

a) the more eupraxic and fluent in fine motor function the child was, the lower was his/her memory for simultaneously presented visual data. Dyspraxic children appeared to have stronger simultaneous memory that made them to appear more intelligent than their eupraxic counterparts were,

b) children who had low scores in fine motor functions also scored significantly lower in tests on auditory perception,

c) an analysis of the speech errors of the subjects revealed that, apart from the regular articulatory errors (substitutions, omissions, perseverations and additions), they also had some characteristic error patterns as shown below:

- a disordered differentiation of the mouth-position like an /a/ instead of an /o/
- impeded control of the order of phonemes
- voice and articulatory movements which were not coordinated
- unpredictable speech errors
- correctly produced speech pattern was quickly forgotten
- difficulty in imitating longer words,

d) children who exhibited dyspraxic speech errors were found to have impeded lip reading and auditory perception,

e) in tests of integration between spoken words and their written form , deaf dyspraxic did better than eupraxic children, and

f) the more dyspraxic the children were, poorer was their ability to remember successively presented visual data. The performance of the subjects on the test for memory for simultaneously presented pictures and on the test for memory for successively presented pictures were analysed. A pattern of high successive score as opposed to simultaneous score was found to positively correlate with the results on test for oral eurhythmia.

Commenting on the tests used, van Uden (1983) stated that the tests for intransitive movements like Berges and Lezine's etc. were more reflective of speech difficulties than tests for transitive movements. The tests for intransitive movements are actually tests for investigating the programming of the motor brain, control of the body scheme and 'gnosis' (recognition of position of limbs). As far as eurhythmia was concerned, results on the test for oral rhythm (van Uden, 1983) correlated with previous research findings on tests for manual rhythm (Seashore, 1938; Wing, 1968; Stambak, 1965; Birch and Belmont, 1965; and Kahn and Birch, 1968) and also with the test for eupraxia for speech from the same battery.

The validity of the tests for intransitive movements and rhythm were examined (van Uden, 1980) with the help of inventories for eupraxia and significant correlation at the 0.05 level was observed. The performance of children on the test for oral fluency (speaking as many syllables as possible in 2 minutes) significantly correlated with their verbal IQ and reading ability at the 0.01 and the 0.05 level, respectively. Van Uden (1983) concluded that the performance on the oral fluency test could be considered a measure of verbal development of deaf children in that it concerns the content of the words, and not of the speech technique. The results on the lip reading-hearing-imitating test correlated significantly at the 0.01 level (at all age levels, namely, 7, 8, 9, and 10) with the opinion of the subjects' speech trainer. Hence, it was considered to be a valid measure of lip reading-sound perception-speech, taken as one whole.

Following these findings, van Uden (1983) summarized a test battery covering dyspraxia and speech for examining the dyspraxic deaf children.

2.7.1 **Tools for Dyspraxia**

a) For children younger than 3 years of age, an inventory for determining the motor developmental age of the child (for example, those of Cardinaux 1975) is very important. However, this may be suitable in identifying only the at-risk cases.

b) For children of 3 years or more, the following tests are important:

   i) the Hiskey Nebraska Learning Ability Test, especially the subtests for memory,

ii) the sub test for eupraxia for fingers in the Berges-Lezine' s test (1963),

iii) the subtest for imitation patterns, as in the Knox Cube Test, of Schroots, Leidse Diagnostische Test (Swets, Lisse, 1976), and

iv) test for eurhythmia of deaf preschool children (van Uden, 1970).

From the review of literature and subsequent discussion on the nature of dyspraxia and its examination, it is evident that a thorough testing for speech/articulatory dyspraxia should also include testing for voluntary, in-transitive movements of the articulators, diadochokinesis, conversational rhythm, oral-tactile sensation, and lateralization, among others. The test battery employed in this study was designed to include the aforementioned aspects.

2.7.2 Testing for Speech in Dyspraxic Deaf

Van Uden (1983) suggests that examination of the speech of the deaf dyspraxic child should look for five typical errors of speech sound articulation, namely, omission, perseveration, substitution and inversion. Of these, inversion and loss of phonemes in the repetition of a correctly spoken word from memory (for example, bottle - lott - lo etc.) is a critical indicator of speech dyspraxia.

One of the objectives of the present study was to investigate if dyspraxia has any influence on speech sound articulation in deaf children. Therefore, a picture-word articulation test in Tamil was developed. Analysis of the test results included not only the extent of misarticulation, but also evaluation of the type of misarticulation, and the nature of the sounds that were misarticulated.

2.8 Treatment for Dyspraxia

Generally speaking, treatment for articulatory apraxia should not be restricted to mere training in articulation, but should encompass comprehensive speech-language therapy. The treatment should aim at systematic and efficient rebuilding of as much of speech as permitted by the individual's disability. The training should also aim to prepare him to accept the residual disability and augment the residual abilities with other modes of communication (Wertz, LaPointe and Rosenbek, 1984).

2.8.1 Educational Therapy for Dyspraxic Deaf

As mentioned earlier, therapy for dyspraxia should actually be speech-language therapy. It is best to provide therapy using conversational techniques at school. This should also be continued at home.

In the training/education of the dyspraxic deaf, strong memory that these children have for simultaneously presented visual data should be taken advantage of. This ability could be used to provide a strong basis for speech and verbal development. So, it is better to 'deposit' the spoken language used, into the deaf children's diaries, with the use of speech balloons (van Uden, 1978). The more severe the child's dyspraxia is, the more important these 'deposits' are to the child. It may even be that we have to use 'graphic conversation' with some of the more severe dyspraxic children. Strong memory of the written form of the words becomes a strong basis for speech. Many of these children are not able to coordinate the speech articulation movements without graphic support particularly when the speech task becomes more complex.

In relatively older children of around 4 or 5 years of age, training should be provided to them to develop a strong integration of the written and the spoken form of the words as soon as they become ready for written language. This should be done in a way that encourages the child rather than burdening him. For example, this could be in the form of guided play or allowing children above 5 years of age to playfully use the typewriter. This would help in imprinting the written form of the words. This graphic conversation and learning to typewrite may lead to usage of 'group-graphic-aid' in the later years.

Several researchers (White, 1972; Caccamise et. al, 1976; Stuckless et al., 1976) have demonstrated that graphic information is the best and the most reliable mode of training, for all categories of deaf persons, provided they have learnt to understand the written word This is suitable for children and adults, for prelingual and postlingual deaf persons, for persons with multiple or a single handicap, and for those who are being trained in the oral or manual approach.

Special 'reactive methods' will be necessary for the development of speech in deaf dyspraxics (van Uden, 1974, 1980). For example, Kern's method of 'tactually felt structure' (Tast-Fuhl-Struktur, 1958) and the strong analytical method of Vatter (McGinnis, 1963).

An important suggestion in teaching speech to deaf dyspraxics is that training should emphasize more on transitive aspects of speech movements if the deaf children have greater difficulty in motor control. This is for the simple reason that transitive movements can be monitored more easily than intransitive movements.

Another important mode of developing speech in the deaf is to train them to lip read their own speech. This can be accomplished by making the child to speak words and sentences into the camera of a video recorder and getting the child later to lip read from his own speech on the video monitor. Van Uden (1970; 1974) found that this method resulted in significant gains in speech and lip reading for the deaf children.

DeFelippo, Sims and Gottermeier (1995) reported that a group of 12 young-adult deaf who were given video feedback of their own speech production indicated significantly increased accuracy in identifying items on which they had been trained and they also demonstrated better generalization to test items on which they had not been trained. On the other hand, those who viewed the trainer's speech did not achieve significant gains on the task. These findings substantiate the beneficial effects of multisensory feedback by practising lip reading of one's own speech production.

Therefore, a deaf child who has mild dyspraxia will have a greater need to use mirror and/or video-recording in order to observe his own speech. This is in addition to strong training in sound perception and rhythm feeling which are necessary for all prelingual profound deaf children.

On the other hand, a deaf child with moderate dyspraxia will have a greater need for elements of the Kern-method, according to the degree of his 'speech clumsiness', in addition to strong visual and auditory feedback.

A deaf child with apraxia of speech needs even more stronger subjective and transitive impressions of speech like elements of the analytic method, perhaps the analytic method in its entirety, in addition to strong visual and auditory feedback and the elements of che Kern-method (van Uden, 1980).

2.8.2 Motor Therapy for the Dyspraxia

Views have been expressed to the effect that supportive 'kinetic therapy' may also aid the development of speech skills in the dyspraxic deaf (van Uden, 1981). This therapy may be in the form of training of eurhythmia, music, dance, expressive movements and play skills.

There are other researchers like Wertz, Lapointe and Rosenbek (1984) who also opine that praxis makes perfect. Brain (1965) has specifically stated that training in diadochokinesis is extremely valuable in enhancing articulation skills. But, in practice motor therapy has been scarcely used with the dyspraxic deaf. A module of psychomotor exercises to be used with the deaf was developed at the Instituut voor Doven, Netherlands (van den Hoven and Speth, 1982). This included exercises for relaxation, orientation of body parts, gross movements, balance, fine motor movements, coordination, gestures, prewriting skills, among others. With regard to speech, exercises for relaxation of facial muscles, breathing, and movements of the articulators were employed. This module served **as** a basis in designing motor therapy for dyspraxic deaf in this study.

2.8.2.1 Influence/Effects of Motor Therapy

Effects of motor therapy in alleviating difficulties in the learning process have been researched into in the past. Faustman (1968) and Ekwall

(1973) have reported on the significant benefits of the perceptual-motor training methods on routine learning process which may be assumed to include speech skills also. White (1979) found positive relationship between early training in perceptual-motor skills and progress in academic skills. However, there are also researchers like Hallahan and Kauffman (1978) who found that perceptual-motor training did not automatically lead to academic gains.

Wallace and McLoughlin (1979) reported that specific training in motor skills definitely reinforced the learning process with regard to that specific skill. There are others like Husak and McGill (1979) who reported on the substantial influence that the motor domain has over the cognitive domain.

Research findings reported in the previous paragraph pertain to the learning disabled-normal hearing population. Studies concerning specific benefits of motor therapy on speech sound articulation skills, particularly in the dyspraxic deaf population are warranted to meet the existing needs in the field of education of the deaf. Such studies should not only specify appropriate motor therapy techniques for the dyspraxic deaf, but should also observe the influence of motor therapy on speech articulation skills. This necessity led to the final objective of this study, that is, to design motor therapy for dyspraxic errors, and to analyse its effects on dyspraxic errors as well as articulation errors.

2.8.3 Articulation Therapy for Misarticulation

There are two major approaches to the training of articulation skills. One is the sensory approach and the other is the motor approach.

2.8.3.1 Sensory Approach

This primarily involves enhancement of sensory skills to finetune sound production skills. The various sensory avenues utilized for the purpose are the auditory, visual, kinesthetic and tactile senses.

In managing misarticulation, primary attention is given to enhancing hearing skills (Van Riper, 1978). Auditory training begins with creating awareness for sounds. Further training is provided in discrimination and localization of sounds, especially of speech, and awareness of the individual's own speech (Powers, 1971). Training through the visual sense is of utmost importance to the deaf children (Pflaster, 1979).

Training begins with providing models of correct articulatory movements for the child to imitate. These models may include the therapist as a live mode', and also hands, fingers, drawings and other appropriate objects/materials are used to explain the movements of the articulators, Providing visual feedback of the child's own production of speech through mirrors and video recordings, and then helping him to monitor his own speech may also be useful. Sensory training also includes tactile and kinesthetic training to help the child to perceive the movements of the articulators. This involves training to correctly sense the position of articulators, tension and movement (Berry and Eisenson, 1956). Emphasis is on a multisensory approach with a combination of senses as the needs of the individual would indicate (Powers, 1971).

2.8.3.2 Motor Approach

This is a production oriented approach with emphasis on teaching the individual to produce a sound correctly, and then to discriminate his own correct and error productions. One of the chief motor approaches to teaching articulation is the 'phonetic placement method'. In this approach, training begins with general exercises for relaxation and breathing, proceeding through oral exercises for awareness of the articulators and their movements, and finally focuses on the specific placement of articulators for correct production of a given sound (Scripture and Jackson, 1972). This method is based on the assumption that there is a specific place and manner for each sound to be produced. Initially, models are provided for the production of the sound in isolation, and then through phonetic drills, the correct production is strengthened, and then the production skills are assimilated to longer and longer speech strings.

2.8.3.3 Articulation Therapy for the Deaf

As with the normal hearing children in their speech acquisition, training the deaf also starts with preparation for speech, that is, training in hearing, comprehending and responding to speech (Lowell and Pollack, 1974). The preparation also includes preverbal use of articulators. Direct speech training involves a combined sensory-motor approach. In addition, careful attention is given to the suprasegmental aspects of speech, and to developing improved coarticulation (McDonald, 1964). Therapy in the deaf should not merely stop at producing the correct sound, but should proceed further to expanding vocabulary and developing general language as deficient auditory input has a negative influence on their language development (Lowell and Pollack, 1974).

2.8.3.4 Articulation Therapy to the Dyspraxics

In the training of dyspraxics on articulation skills, Darley et al (1975) recommend a multisensory stimulation. They also suggest that the dyspraxics should be allowed several trials in producing a sound, and to arrange stimulus phonemes in a hierarchy of difficulty. They specify that drill work should begin at the phoneme level and progress through simple words to utterances of longer length. Furthermore, a combination of phonetic placement and derivation techniques is advised for better results (Wertz, LaPointe and Rosenbek, 1984)

Reinforcing the recommendation for motor therapy made earlier in this chapter, Darley and his associates (1975) also emphasize the need for exercising the muscles of mastication and expression and use of rhythm as part of the remedial training procedures. The need for motor drill and practice of rhythm are also advocated by Wertz, LaPointe and Rosenbek (1984). Besides these, they also propose reading aloud from written material as a remedy for speech/articulatory dyspraxia. Darley et al (1975) reiterate the need for visual feedback and development of self-monitoring skills.

2.8.3.5 Influence/Effects of Articulation Therapy

It has been reported by Mohr (1980) that speech performance in the dyspraxics improves with practice even without specific treatment being offered. However, dyspraxia of speech can be improved with treatment (Sands et al., 1978). The degree of success depends on the individuals' ability to learn, their ability to generalize and retain learnt tasks, and their willingness to practice (Wertz, LaPointe and Rosenbek, 1984). Wertz et al (1984) also state that functional improvement is poor without treatment, fair with treatment in case of severe dyspraxia, and good with treatment in case of mild and moderate dyspraxia In the administration of articulation therapy for dyspraxia, they highlight the use of multisensory modality, imitation drills, combining sounds with prosodic features and with gestures, reading, arid proper ordering of stimuli as the key to success.

As mentioned earlier in this chapter, this study was carried out with the presumption that the speech of deaf children tends to become dyspraxic in nature when compared to their hearing peers because of insufficient practice rather than innate problems of neurogenic nature. If that was the condition, then appropriate training for speech articulation in the dyspraxics should result not only in improved articulation, but also a decrease in dyspraxic errors. This assumption led us to design motor and speech therapy for the dyspraxic deaf, and to investigate the effects of each kind of therapy on motor and speech articulation problems.

In summary, syndrome of dyspraxia in deaf children implies that the children will also have dysrhythmia or arhythmia and that their memory, though essentially normal, is better for simultaneously presented visual data, and relatively weaker for successively presented visual data. A strong auditory function, with a strong auditory memory, may compensate for dyspraxic errors in normal hearing children. But, in the deaf, the auditory deficit complicates the condition.

Though the problems faced by the deaf dyspraxic children in their speech-language and educational development are many, these are no reasons for pessimism. The obstacles faced by the deaf children in their education can be overcome with appropriate remedial measures like the aforementioned therapies carried out at the proper time Early diagnosis of the problem, delineation of its nature, and establishing the severity of the problem should be followed by special education programs. Special education programs should include, among others, basic training in eurhythmia, eupraxia, serial memory, integration of motor behavior (including speech) and of movement associated with symbols (including verbalizations) as suggested by van Uden (1983). Beyond these therapies, a few extremely difficult cases of apraxia known as 'deaf dactyl children' (van Uden, 1983) perhaps need training in finger spelling to augment their speech along with strong graphic support.

Chapter 3

METHOD

Dyspraxia of speech primarily affects the rhythm and fluency of speech causing inconsistent speech patterns and poor memory for speech movements. All these ultimately result in a deficit in the ability for motor speech programming. Thus dyspraxia becomes an additional causative factor leading to speech impairments in the deaf children. The purpose of this research was to study the prevalence and nature of dyspraxic errors in deaf children and the influence, if any, of these errors on speech sound articulation in the speech of the deaf children. The presence of dyspraxic errors would indicate the need for supportive techniques to correct them in the course of regular speech therapy. The effect of speech and motor therapy on these dyspraxic errors has also been investigated. Detailed investigation in this direction would help the special educators to develop effective supportive measures for management of speech in deaf children. It would also help in deciding appropriate educational placement for severe dyspraxic deaf children.

3.1 Objectives of the Study

The objectives of the study were to

a) construct/assemble a relevant test battery to investigate the nature of dyspraxic errors in deaf children,

b) investigate the prevalence of dyspraxic errors in a population of school going deaf children,

c) investigate the effects of dyspraxic errors on speech articulation,

d) design techniques of therapy for errors of dyspraxia and speech sound misarticulation, and

e) investigate the effects of therapy for dyspraxia on speech sound articulation in deaf children as well as the effect of speech therapy on dyspraxic errors.

3.2 Subjects

Profound deaf children were considered for the study. The subjects were selected based on the results of a pure tone audiometric test. Only those children who had hearing loss of 90dB or more in both ears and in the speech frequencies of 250Hz to 4kHz were selected for the study. A tympanometric test was also carried out to find out if there was any additional, middle ear pathology. Hearing impaired children studying in special schools with Tamil as the medium of instruction were considered for the study.

3.2.1 Inclusion Criteria

a) The subjects should have prelingual profound loss of hearing.

b) The subjects should be in the age group of 4 - 9 years.

c) Subjects should be of average or above average intelligence. This was ensured by administering the Raven's progressive matrices.

d) Subjects should be native speakers of Tamil.

3.2.2 Exclusion Criteria

a) Children having any other physical or mental or neurological problems.

b) Children who had received, or were receiving training in the usage of manual or sign language communication.

c) children who had received, or were receiving any kind of speech therapy for their speech articulation problem.

Based on the above criteria, 113 deaf children were identified for the study. All the children came from upper or lower middle socioeconomic class of the society. Table 3.1 gives details of the number of subjects selected for the study following the inclusion and exclusion criteria.

Age	Males	Females	Total
4 years	10	8	18
5 years	10	8	18
6 years	10	8	18
7 years	12	9	21
8 years	11	8	19
9 years	11	8	19
Total	64	49	113

Table 3.1 : Details of hearing impaired subjects included in the study

For normative data, a control group of 60 normal hearing subjects consisting of 30 boys and 30 girls was included in the study. The selection criteria employed for the hearing impaired subjects, except the one relating to the hearing loss, applied for the control group also. Normal hearing children were also in the age group of 4 to 9 years. Like the deaf children, the normal children were also undergoing education in Tamil medium. All were native speakers of Tamil and came from upper and lower middle socioeconomic class of the society. Details of the control group are given in Table 3.2.

Age	Males	Females	Total
4 years	5	5	10
5 years	5	5	10
6 years	5	5	10
7 years	5	5	10
8 years	5	5	10
9 years	5	5	10
Total	30	30	60

Table 3.2 : Details of the control group included in the study

3.3 Materials

The materials used/developed in this study can be grouped under two categories, namely,

a) Material for testing dyspraxia and articulation.

b) Material for dyspraxia and articulation therapy.

3.3.1 Test Material

3.3.1.1 Testing for Dyspraxia

Testing for dyspraxia was done using a battery of tests. Review of literature had indicated that the major consequences of oral/articulatory dyspraxia were the deficient oral motor movements, poor development of speech rhythm, poor rate of speech, deficient intransitive movements, poor memory for sequentially presented data, deficient tactile sensation in the affected structures etc. Based on this information, the test battery assembled included tests for oral motor control, oral rhythm, diadochokinetic rate, intransitive movements, memory for sequentially presented motor movements, tactile agnosia in the tongue, and aiso a test of thumb turning to see whether lateralization was related in any way to development of motor control The component tools are discussed in detail below.

A : Rhythm Tests

The purpose of these tests was to test for the development of rhythm in speech. Poor perception and reproduction of rhythm patterns is an indication that the child is at-risk for learning speech and speech-reading. Testing was done using sequences of syllables that varied in the number of syllables, pauses, stress and intonation. Different syllables were used to represent different points of articulation. Labial (ba), dental (va), alveolar (9a), palatal (na) and velar (ka) syllables were employed in testing.

i) **Test** 1

This test, developed specifically for this study, included four sequences that varied in both the number of syllables and the pattern of pauses between them (meter). The subjects were asked to repeat the sequences of syllables after the tester. Oral production of the sequences by the tester was accompanied by manual tapping with a peg on a flat surface. The sequence patterns were as follows:

a) * - * - * - *

b) * * - * - *

c) * - - * * *   * = syllables; - = gap between syllables

d) * - * * - *

The responses of the subjects were scored as follows:

0 = Responses were absent or incorrect in terms of both the number of syllables and pattern of pauses,

1 = Responses had correct number of syllables, but incorrect pausing pattern, and

2 = Responses had the correct number of syllables and correct pause pattern.

ii) Test 2

This was an adaptation of the test developed by van Uden (1970). This test included ten sequences that varied in the number of syllables, pauses between them and stress laid on selected syllables. Test 1 and Test 2 were similar except for the additional factor of stress placed on selected syllables in Test 2. The subjects were asked to repeat the sequences of syllables after the tester. The sequences were as follows:

a) * _ * *'

b) * *' _ * _ *

c) * *' _ * _ * *'

d) * * *' _ *

e) *' * * *'

f) * *' _ * * *' _ *

g) *’* *’* *’

h) * * * *’ _ * *’

i) * _ * * * *’ _ * *’

j) * _ * *’ _ * * *’ _ *

* = syllables; - = gap between the syllables; ' = stress

The responses of the subjects were scored as follows:

0 = Responses were absent or were incorrect in terms of number of syllables, pause pattern and stress pattern,

1 = Responses had the correct number of syllables and pause pattern, but the stress pattern was incorrect, and

2 = Responses had correct number of syllables with the correct pause and stress patterns.

iii) Test for Speech Rhythm

This test, developed specifically for the study under the guidance of a linguist, consisted of sequences of syllables styled on ten common conversational, simple sentences in Tamil The sentences included declaratives, imperatives, questions and negations. The subjects were required to repeat the sequences of syllables and not the whole sentences. The sequences employed were as follows:

a) *:'* - *:'* /va:ŋa va:ŋa/

b) * *:'* * /utka:ruŋa/

c) * *' - * * *:'* /epadi iruki:ŋa/

d) * *: - * * *: /nalla: irukke:n/

e) *: *:'* *: /sapti:ŋḷa:/

f) *:'* - *: * * * /kondʒam sa:piduŋa/

g) *'* - * *: * * /romba kuḷu:ruðu/

h) * *: - * *:'* /maḷai vara:ðu/

i) * *' - * * * *' /appa kiḷambuŋa/

j) * *' - * *: * /romba sanðoʃam/

* = syllables; - = gap between syllables; ' = stress;

: = long vowel

The responses of the subjects were scored as follows:

0 = Responses were absent or incorrect in terms of number of syllables, pause pattern, stress pattern, and syllable duration,

1 = Responses had correct number of syllables and pause pattern, but stress pattern, or syllable duration were wrong, and

2 ~ Responses had correct number of syllables with the correct pause and stress patterns, and duration of syllables.

Administration : The subjects were made to sit facing the tester, and were asked to repeat sequences of syllables with correct intonation, speech tempo and stress following the tester. Actual recording was done following one or two trials to make sure that the subjects had understood what is required of them. The responses were audio recorded.

B : Tests **for Oral Dyspraxia**

The purpose of these tests was to test if the children have developed the fine control of the motoric system and control for voluntary movements of the articulators, namely, the tongue, the lips and the mandible.

i) Test for Tongue Mobility

This is an adaptation of the test developed by Chilla and Kozielski (1977). The subjects were asked to imitate ten fine motor movements of the tongue after the tester:

a) to put out tongue straight
b) to move tongue upwards at an oblique angle
c) to move tongue downwards at an oblique angle
d) to push the tongue against the left cheek
e) to push the tongue against the right cheek

f) to move the tongue to and fro - horizontally

g) to trace the boundaries of the lips with the tongue

h) to make the tongue broad and narrow

i) to move tongue up and down behind the teeth

j) grooving of the tongue

The responses of the subjects were scored as follows:

0 = Movements were absent or incorrect,

1 = Movements were more or less correct but can improve, and

2 = Movements were completely correct and independent.

ii) Test for Mobility of Lips

The test, developed specifically for this study, included four motor movements of the lips. The subjects were made to imitate the following movements demonstrated by the tester.

a) round and protrude lips to achieve a tube shape, then unround and retract them

b) protrude the lower lip and curl it outwards

c) screw the lips and move them from side to side

d) lightly press the lips against each other and blow between them to induce vibration of the lips

The responses of the subjects were scored as follows:

0 = Movements were absent or incorrect,
1 = Movements were more or less correct but can improve, and
2 = Movements were completely correct and independent.

iii) Test for Mobility of Jaw

This test, specifically developed for the study, included four motor movements of the jaws. The subjects were made to imitate the following movements as demonstrated by the tester.

a) drop jaw under its own weight and then raise it to close the mouth
b) drop jaw and swing it forwards and backwards
c) drop jaw and swing it from side to side
d) drop jaw and gently rotate it

The responses of the subjects were scored as follows:

0 = Movements were absent or incorrect,
1 = Movements were more or less correct but can improve, and
2 = Movements were completely correct and independent.

Administration : The subjects were seated in front of the tester who demonstrated each item. The subjects were required to imitate these movements. The responses of the subjects were video recorded.

C : Tests for Diadochokinetic Rate

The purpose of these tests was to test for the diadochokinetic rates of the articulators, namely, the tongue, lips and the mandible, as an indicator of the control/flexibility the subjects have for repetitive movements.

i) Test for Diadochokinetic Rate of the Tongue

This test, specifically developed for the study, included rapid repetition of the monosyllable /9a/. The tester demonstrated the movements of the tongue to produce the syllable /9a/. Subjects were asked to imitate these movements as rapidly as possible for five seconds. The total number of repetitions and the rate (repetitions/second) were counted from the video recordings. Subjects were not required to produce the sounds, but most of the children did produce the sound.

ii) Test for the Diadochokinetic Rate of the Lips

This test, specifically developed for the study, included rapid repetition of the monosyllable /pa/. The tester demonstrated movements of the lips to produce the syllable /pa/. Subjects were asked to imitate these movements as rapidly as possible for five seconds. The number of repetitions and the rate were counted from the video recordings.

iii) Test for the Diadochokinetic Rate of the Jaw

This test, specifically developed for this study, included rapid repetition of the monosyllable /ja/. The tester demonstrated the movements of the jaw to produce the syllable /ja/. Subjects were asked to imitate these movements as rapidly as possible for five seconds. The total number of repetitions and the rate were counted from the video recordings.

Administration : The tester demonstrated the movements of the tongue, the lips and the jaw to produce the required syllables namely, /0a/, /pa/ and /ja/. The subjects were asked to imitate these movements as rapidly as possible for five seconds. The test was stopped at the end of five seconds or when the subject felt fatigued whichever was earlier. The responses were audio and video recorded.

D : Tests for Intransitive Movements

The purpose was to test eupraxia with lateralization and differentiation of finger movements.

i) Berges-Lezine's Test for Intransitive Hand Positions

This test, developed by Berges and Lezine (1963), made use of sixteen intransitive hand positions for the purpose. The experimenter formed these hand positions, one by one and out of the subject's sight and later displayed the complete form to the subjects. The subjects were required to imitate the hand positions shown to them. The following were the hand positions employed.

a) 2 2: Both the thumbs up.

b) 1 1 : Both the index fingers up.

c) V L : Victory sign put up in the left hand with the index and middle fingers while the thumb held the other two fingers against the centre of the palm.

d) V R : Victory sign put up in the right hand with the index and middle fingers while the thumb held the other two fingers against the centre of the palm.

e) U L • The little finger and the index finger held up while the other fingers were placed against the centre of the palm by the thumb in the left hand.

f) UK : The little finger and the index finger held up while the other fingers were placed against the centre of the palm by the thumb in the right hand.

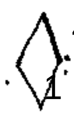
I L

g) O R : Left hand index finger was pointing downward atop the vertically clenched fist of the right hand without any physical contact between the two hands.

I R

h) O L : Right hand index finger was pointing downward atop the vertically clenched fist of the left hand without any physical contact between the two hands.

i)  2 : Tips of the two stretched out thumbs and index fingers brought together with the thumbs pointing upward and the index fingers downward, while the other fingers were placed against the centre of the palm. This form was presented with the back of the hand facing the subjects.

j)  4 1 : Tips of the four pairs of fingers were held pointing upward while tips of the two thumbs were held pointing downwards. This form was achieved with the the palm facing the subjects.

k)  : The thumbs of the two hands were brought together pointing upward, while the other four fingers in each hand were held together in such a way that the fingers of the left hand overlap the right. The back of the hand faced the subjects.

l) X : This form is the same as the previous one except that the little finger of the right hand was placed over that of the left hand.

m) R [ ] L : The index and the little finger of the left hand were held out horizontally to make contact with the corresponding fingers of the right hand held out similarly, while the middle and ring fingers of the two hands were held against the centre of the respective palms with the thumbs. This form was held with the back of the hand facing the subjects.

n) R [ ]: L : This was a modification of the form (m). The change from form (m) was that the left hand was turned upside down so that the projecting index finger met the little finger of the right hand and vice versa. The inside of the palm of the left hand faced the subjects while the back of the right hand faced the subjects.

o) ⚭ The index finger and thumb of each hand were interlinked with each other to form rings, as in a chain.

p) . S : The two thumbs were made to cross each other while the other four fingers in each hand were held out as wings with their tips facing upward. The back of the form faced the subjects.)

The responses of the subjects were scored as follows:

0 = Movements were absent or incorrect,

1 = Correct movements following trials, and

2 = Movements were completely correct, spontaneous and fluent.

ii) Finger Tipping Test

The test, developed by van Uden (1967), included differentiated movements of the fingers. The subjects were asked to establish contact repetitively and at a given tempo, between the tip of the thumb and the tip of the other four fingers. The movements to be executed by the subjects included:

a) Movement of fingers of both the hands synchronously. Repetitive contact is made thrice between

* tip of the index finger with tip of the thumb
* tip of the middle finger with tip of the thumb
* tip of the ring finger with tip of the thumb
* tip of the little finger with tip of the thumb

b) Tip of index, middle, ring and little fingers make contact successively with the tip of the thumb

* R hand tempo: 1 finger per second
* L hand tempo: 1 finger per second
* R hand tempo: 1 finger per 1/2 second
* L hand tempo: 1 finger per 1/2 second
* R hand tempo: 1 finger per 1/4 second
* L hand tempo: 1 finger per 1/4 second

c) Right and left hand synchronously

* tempo: 1 finger per second
* tempo: 1 finger per 1/2 second
* tempo: 1 finger per 1/4 second

The responses of the subjects were scored as follows:

0 = Movements with contact between wrong fingers,

1 = Movements with contact between correct fingers, but not exactly at the tip or without right tempo, and

2 = Movements with contact between correct fingers, at the tip with correct tempo.

Administration : The subjects were asked to imitate precisely the hand positions or movements which the tester demonstrated. The actual test responses were video recorded, after one or two trials.

E : Test **for Sequential Memory**

The purpose of this test was to study the sequential memory for motor movements.

i) Test **for Memory for Motor Movements of Hand**

This test, developed by Kaufman and Kaufman (1983) was adapted for this study. Motor movements of hand were used for the purpose. The movements consisted of placing the hand (below the wrist) in a combination of two or more configurations. The subjects were required to successively place the hand with the palm (P) down, or palm placed vertically facing side (S) or only form and place the fist (F). The sequences of movements were organized to test progressively difficult sequences as indicated below:

a) S F S = Side F = Fist P = Palm

b) F F

c) P S

d) S F S

e) S P F

f) S FF S

g) P S F P

h) S P F S P

i) P S S P F F

j) P S P F S

The responses of the subjects were scored as follows:

0 = Wrong recall and imitation, and

1 = Correct recall and imitation.

Administration : The subjects were made to imitate combinations of the three hand positions, namely, the palm (P), the side (S), and the fist (F), in various sequences as demonstrated by the tester. The responses were video recorded after a few trials. The order of presentation of the tasks, mentioned above, was the same for all subjects because the sequences followed a hierarchy of complexity.

F : Test for Tactile Agnosia of the Tongue

This test was specifically developed for the study. The purpose was to test for tactile sensitivity in the tongue. The test involved touching six specific points on the outstretched tongue of the subjects who remained with their eyes closed. The subjects were required to identify following points touched with their finger tips:

i) tongue tip
ii) left blade
iii) right blade
iv) dorsum/front
v) back of tongue
vi) base of tongue

The responses of the subjects were scored as follows:

0 = Wrong identification, and
1 = Correct identification.

Administration : The tester touched various parts of the outstretched tongue of the subject with the fine tip of a tooth pick. The subjects who remained with eyes closed had to identify the parts touched. The responses were video recorded after one or two trials.

G : **Thumb Turning Test**

The purpose of this test, specifically developed for this study, was to test for control over lateralization of movements. This test involved twisting either of the thumbs independently and then both together in the manner indicated below:

i) twisting the left thumb,

ii) twisting the right thumb, and

iii) twisting both the thumbs together.

Observations were made to check that there were no accompanying movements in other body parts like lips, tongue, arms, etc. The responses of the subjects were scored as follows:

0 = Twisting with accompanying movements of other body structures, and

1 = Independent twisting with no accompanying movements of other body structures.

Administration : The subjects were instructed to twist either of the thumbs independently and then both the thumbs together. The responses were video recorded after a few trials.

3.3.1.2 Testing for Articulation

The purpose was to test for age appropriate development of articulation of speech sounds in Tamil and to understand the nature of misarticulations when present.

A : Picture-Word Articulation Test in Tamil

The test material consisted of sixty six stimulus words selected to test thirty five phonemes in Tamil in the word-initial, word-medial and word-final positions. The test words were all simple common words which could be unambiguously presented in the form of a picture (see Appendix 1 for details of picture word articulation test). The picture-word articulation test was actually a modified adaptation of a similar test developed and tested on normal children by Usha (1986). The responses on the articulation test were analysed in terms of correct responses, incorrect responses (substitution, omission, addition and distortion of sounds), and no responses. Identification of misarticulations was done as a function of age.

Administration : Appropriate pictures of the test words pasted on a 6" x 3" card were presented to the subjects in a random order. The subjects were encouraged to name each picture. If the children were unable to name any picture, then the correct word was given and the subjects were encouraged to repeat the same. If the subjects still failed to come out with the word, then it was counted as a no response'. The responses were audio-recorded after one or two trials.

3.4 Method of the Research

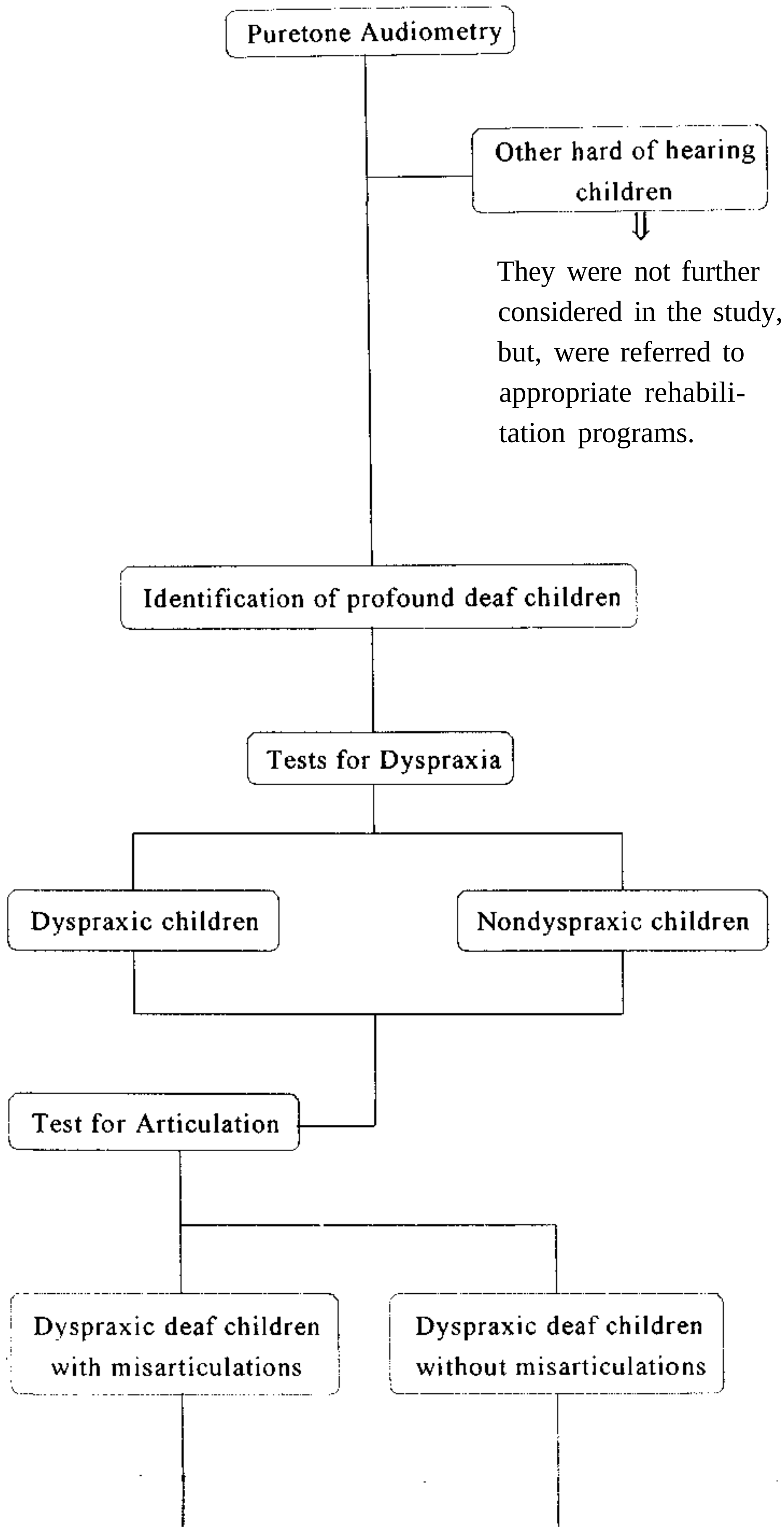
The schematic diagram of the method of the study is given in Figure 3.1. The study consisted of

Step 1: Selection of sample group: Assessment of hearing level and selection of profound deaf children in the age group of 4 to 9 years.

Step 2 : Screening for dyspraxia: Assessment for dyspraxia was done using a battery of tools designed to test motor control. Based on the results of the tests on dyspraxia, the deaf children were to be categorized into two groups of dyspraxic deaf children and nondyspraxic deaf children. But, it so happened that, on tests of dyspraxia, all deaf children happened to be dyspraxic-deaf children.

Step 3: Assessment of speech articulation: This was done for all children in the sample group on a picture-word articulation test in Tamil.

Step 4: The idea in the beginning was to classify the children in the sample group into four subgroups, namely,


Puretone Audiometry
Other hard of hearing children
They were not further considered in the study, but, were referred to appropriate rehabilitation programs.
Identification of profound deaf children
Tests for Dyspraxia
Dyspraxic children
Nondyspraxic children
Test for Articulation
Dyspraxic deaf children with misarticulations
Dyspraxic deaf children without misarticulations

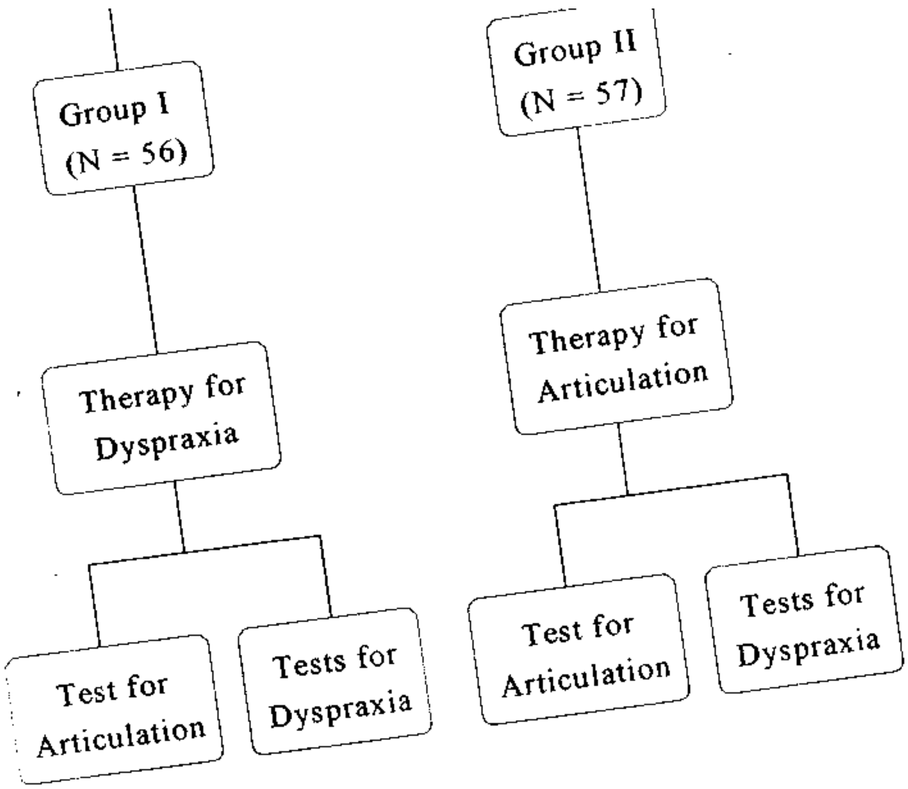


Figure 3.1 : Scheme of the study

Group 1 - Profound deaf children without any associated problems

Group 2 - Profound deaf children with dyspraxia and no misarticulation

Group 3 - Profound deaf children with misarticulation and no dyspraxia

Group 4 - Profound deaf children with dyspraxia and misarticulation

But it so happened, as mentioned earlier, that all deaf children had both dyspraxic and articulation problems leaving us with only one group of deaf children. These children were randomly assigned to two groups with one group receiving motor therapy (motor therapy group) and the other receiving speech therapy for articulation (speech therapy group).

Step 5 : Designing appropriate training methods for planning and execution of motor movements for dyspraxia, and b) speech therapy for articulatory defects.

Step 6 : The group of profound deaf children with both dyspraxia and articulatory defects were again divided into two groups which were subjected to different therapies, namely,

Group A : Motor therapy for dyspraxia

Group B : Speech therapy for articulation

Step 7 : At the completion of therapy, both the groups were subjected to dyspraxia and articulation testing.

3.5 Procedure

3.5.1 Pilot Studies

After setting up the battery of tests, a pilot study was conducted to test the procedure of administration of the tests and recording of responses on them from the subjects of the study. The test materials were mainly designed to be imitative exercises to be suitable for deaf children.

A second pilot study was conducted to test the appropriateness of stimulus words and the pictures selected in the picture-word articulation test, in particular, with reference to the age of the children. The results of this pilot study indicated ambiguity of pictures with respect to three items. Necessary changes were made in the test material to and articulatory defects were again divided into two groups which were subjected to different therapies, namely,

Group A : Motor therapy for dyspraxia

Group B : Speech therapy for articulation

Step 7 : At the completion of therapy, both the groups were subjected to dyspraxia and articulation testing.

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The first two pilot studies also suggested that administering the test and scoring the responses in real time would be difficult besides being unreliable. Hence, it was decided to audio- and video record the performances of the subjects on all the tests. A third pilot study was carried out to decide on the tests whose results were to be audio- or video recorded, and if video recording was to be carried out, then to decide on the right view/angle for placement of the camera.

The results of the pilot studies indicated that just audio recording of responses on tests for rhythm and articulation was sufficient. The subjects' performances on all other tests were to be video recorded. In order to ensure clear and precise recording of the movement of the articulators, fingers, hands etc., camera placement/angle, as shown in Figures 3.2 and 3.3, was decided.

Seating of the subjects and the tester, and the placement of the camera was as shown in Figure 3.2 for tests on oral/articulatory dyspraxia, diadochokinetic rate, and tactile agnosia.

Seating of the subjects and the tester, and the placement of the camera was as shown in Figure 3.3 for tests on intransitive hand movements, sequential memory for motor movements, and thumb turning.

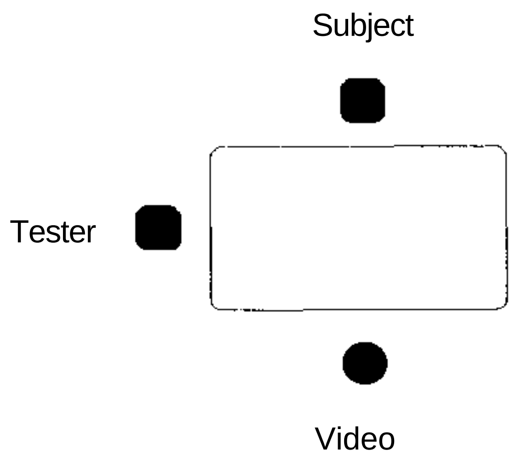

Figure 3.2 : Seating arrangement for the tester and the subjects and the placement of the camera.

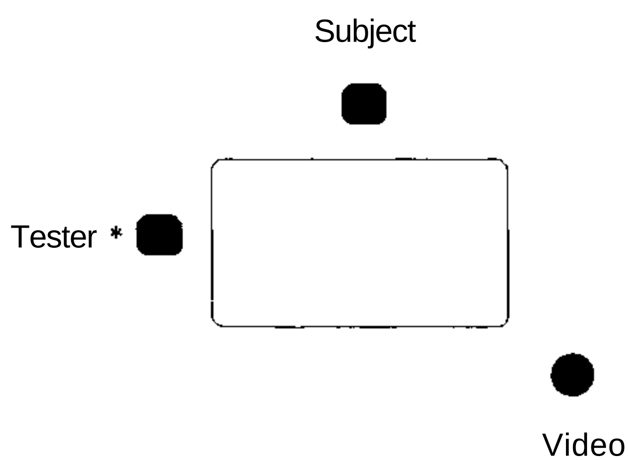

Figure 3.3 : Seating arrangement for the tester and the subjects and the placement of the camera.

Tests for rhythm, and articulation were the two tests, responses on which were to be only audio recorded. Subjects who were included in the pilot study were not considered for the main study.

3.5.2 Testing

Subjects fulfilling the selection criteria were tested for dyspraxia. Testing for dyspraxia was done using the preset battery of tests, with the subjects required to imitate various motor movements demonstrated by the tester. The responses of the subjects were video recorded from appropriate angles ensuring clear and precise recording of movements of articulators and other structures, and/or were audio recorded. This was followed by assessment of speech articulation. The responses on the test for articulation were audio recorded. The testing was carried out in a quiet room in the premises of the school where the children were studying. The rooms had adequate lighting and ventilation and care was taken to minimize the external disturbances. The video and audio recorded performances were later analysed and scored by the tester as well as an another judge.

3.5.3 Analysis of Performance

The performances of the subjects on the tests for dyspraxia were analysed together by the tester and an another judge who was a special educator working with the hearing impaired. The examiner and the second judge were both equipped with details about the purpose, items and scoring patterns for each test in the battery. Each response of the subjects was classified as normal or deviant only after a thorough discussion and total agreement between the two judges (including the tester). No responses on which the two judges differed in their scoring were included for further analysis. In fact, there were no responses on which the examiners differed.

The subjects' performance on the picture-word articulation test was analysed by the tester and a speech pathologist. Misarticulations in terms of omission, distortion, substitution and addition were written down. Errors were recognized and classified in the same manner as was done for dyspraxic responses. That is, a response was classified as a misarticulation only when both the judges agreed on that. Again, there was no item, for any child, on which the judges differed. Also, while deciding on the articulatory errors, the age of the child was considered. For example, a four year old child misarticulating *Ixl* was not taken as an instance of misarticulation because even a normal four year old child has still time to acquire this particular sound.

Since the test results revealed that all subjects in the sample group displayed speech misarticulation and dyspraxic errors, the entire sample was divided into two groups by random sampling. Group A with 56 subjects was provided motor therapy for dyspraxia while Group B consisting of 57 subjects underwent speech therapy for misarticulation.

3.5.4 Techniques of Therapy

3.5.4.1 Motor Therapy for Dyspraxia

The subjects in Group A (motor therapy) were given intensive training on the following tasks (see Appendix 2 for details on techniques of motor therapy). Therapy for dyspraxia involved,

a) Oral Exercises

i) Exercises for relaxation of oral cavity/facial muscles.
ii) Exercises for mandible/lower jaw.
iii) Exercises for soft palate.
iv) Exercises for tongue.
v) Exercises for lips.
vi) Exercises for cheeks.
vii) Exercises for coordinated control of articulators.

b) Fine Motor Exercises

i) Finger and hand exercises.
ii) Exercises with both hands involving eye-hand coordination.

3.5.4.2 Speech therapy for Misarticulation

The techniques of speech therapy for correction of misarticulation of speech sounds included

a) Multisensory Stimulation Techniques

i) Auditory training including training in sound awareness followed by training in auditory discrimination, and localization. The therapy process then moved towards training the child's awareness of his own speech.

ii) Visual training began with the therapist as a model. The child was encouraged to imitate the visible movements of the articulators in the process of production of speech sounds. Mirror was used to provide visual feed back to the children of the movements of their own articulators. Also hands, fingers, drawings and other appropriate objects were used to demonstrate movements and placing of tongue, lips and jaws, particularly, the tongue.

The subjects were demonstrated and given training on one dominant feature of sounds. For example, in the production of/pa/, the children were made aware of the puff of explosive air coming out of the mouth by keeping the hands in front of the mouth.

b) Phonetic Placement Method

The children were made aware of the position of articulators for the different sounds and if necessary, the articulators were even physically manipulated to achieve the required configuration with visual feedback to the children. Demonstration by normal children was also arranged. The teachers and parents of these children were encouraged to try out some of these techniques with their children at home. When the intended sound appeared, even if it was in a distorted form, then phonetic drilling was emphasized. The target sound was practiced, hundreds of time in phonetic sequences of increasing length and complexity (in isolation, in a bisyllable, in a word, in a phrase, and so on). Generalization of the learnt responses was emphasized by encouraging the children to try to use these sounds, even if they are not perfect, in all situations and try to rehearse them at a slow rate for good results. Appropriate reinforcement paradigm was inbuilt into the program.

3.5.4.3 Administration of Therapy

Motor therapy for dyspraxia was provided for subjects in Group A for 15 sessions, each session lasting for 60 minutes or more and on alternate days. Group therapy approach was followed, but, in any group, there were not more than four children. The subjects were made to imitate exercises for facial muscles and oral articulators.

Both gross and fine motor movements were demonstrated and the children were encouraged to imitate them. In case the children were unable to imitate these movements properly, they were helped by the instructor to achieve proper movements. Later, they were also made to rehearse these exercises from memory.

Speech therapy for articulation involved a one to one process where the instructor used multisensory techniques to elicit proper articulation of speech sounds which were previously misarticulated by the subjects.

Motor and speech therapy was carried out under the same setup conditions as was available during testing. Care was taken to make sure that therapy was administered in a quiet room by minimizing the external disturbances to maximum extent possible.

3.6 Posttherapeutic Evaluation

Following therapy for dyspraxia and misarticulation, posttherapeutic evaluation for dyspraxia and speech sound articulation was carried out. The same tests, materials and techniques as in pretherapeutic testing were employed in the posttherapeutic examination. The testing conditions, in general, were the same as in pretherapeutic evaluation, and again all the responses were audio- and/or video-recorded. The responses of the children in the posttherapeutic evaluation were analysed in the same way and by the same judges as in the pretherapy analysis, but the second judge did not know from which recording a particular response was being analysed. There was a gap ranging from thirty nine to forty one days between the pre- and posttherapeutic assessments for different children.

3.7 Analyses

The following analysis were done.

a) Identification of the dyspraxic group in comparison with the normals.

b) Analysis of the nature of dyspraxic and articulatory errors in deaf subjects.

c) Age-wise prevalence of dyspraxic errors and degree of the problem in deaf children

d) Correlational analysis of dyspraxic errors and different types of articulatory errors.

e) Analysis of articulatory errors following intervention for Correcting dyspraxic errors.

f) Analysis of the change in the nature of dyspraxic errors consequent to speech therapy.

Chapter 4

RESULTS

The present study was undertaken to investigate the effects of dyspraxia on the speech articulation of deaf children. Articulatory dyspraxia, as described earlier, is a difficulty in the programming and control of motor movements of articulators required for speech articulation. This study employed a test battery of 14 tests for testing dyspraxia and a picture-word articulation test (PWAT) in Tamil for testing speech articulation. The scheme of the study also provided for administration of motor therapy for dyspraxia and speech therapy for misarticulation and observing for their respective effects on dyspraxic and speech errors as well as their reciprocal effects on speech and dyspraxia.

4.1 Objectives of the Study

The objectives of the study were to

a) construct/assemble a relevant test battery to investigate the nature of dyspraxic errors in deaf children,

b) investigate the prevalence of dyspraxic errors in a population of school going deaf children,

c) investigate the effects of dyspraxic errors on speech articulation,

d) design techniques of therapy for errors of dyspraxia and speech sound misarticulation, and

e) investigate the effects of therapy for dyspraxia on speech articulation as well as the effect of speech therapy on dyspraxic errors.

4.2 Subjects

Based on the results of puretone audiometric test, 113 prelingually profound deaf children were selected for the study. Only those children with hearing loss of 90dB or more in both ears, and in the speech frequencies of 250 Hz to 4 kHz were selected. All the children were in the age group of 4 to 9 years. The children were of average intelligence and without any additional physical, mental or neurological problems. The children were all native speakers of Tamil and were studying in special schools with Tamil as the medium of instruction. Children who had received, or were receiving training in the usage of manual or sign language for communication, or any kind of therapy for their speech articulation problems were not considered for the study. All deaf children were using some kind of gestures, but had received no formal training in sign language. In general, all children came from upper or lower middle socioeconomic strata of the society

Four of the deaf children were left handed, all in the age group of 4 or 5 years. All other children were right handed. Only 4 of these 113 deaf children were day scholars, and all others were residential inmates of the school. Thirteen of these deaf children had history of deafness in the family (siblings or parents). None of these deaf children suffered from any significant illness either at the time of birth or after. In terms of academic performance, 23 deaf children were considered to be better than average, 74 children average and 16 children poorer than average, by the teachers. All deaf children were considered average on the Raven's Progressive Matrices for cognitive abilities at their respective age levels. But, this test had been administered by the teachers at the time of admission to the school. The study also included a control group of 60 normal hearing children in the age group of 4 to 9 years of age. Normal children included in the study fulfilled all the criteria as the deaf children except for the one relating to hearing loss.

An effort was made to get equal number of male and female children in each group. In the final analysis, there were 64 boys and 49 girls in the deaf group with the difference in the number of male and female children not exceeding 3 in any age group.

4.3 Assessment of Children

Two of the main objectives of this study were to (a) identify dyspraxic deaf, and (b) evaluate the effects of speech and motor therapy on dyspraxia and speech articulation. Therefore, all children (113 deaf and 60 normal hearing) were administered tests for dyspraxia and a picture-word articulation test pretherapeutically. Results of the pretherapeutic evaluation also served as a basis for comparing the results of the therapeutic procedures. After the identification of dyspraxic errors in deaf children, the deaf group was divided into two groups - Group A consisting of 56 children, and Group - B consisting of 57 children. Children in these two groups were administered motor therapy and speech therapy for articulation errors, respectively. Post therapeutically, children in both the groups were evaluated on tests for dyspraxia and speech articulation. In the final analysis, two assessments were done - once pretherapeutically and for a second time, following therapy.

4.4 Statistical Procedures

Generally, all data have been analysed statistically using Student's t-test for independent samples or paired samples. The difference in the performance on different tests by children of different age groups has been tested with one-way analysis of variance (ANOVA). Only the mean effects have been tested in this instance. Appropriate posthoc test (Student-Newman-Keuls, in this instance) has been performed to isolate the source of significance for any variable with ANOVA's that had 'p' values less than 0.01. Linear discriminant function analysis (Fisher, 1936) was employed to classify the subjects into the two groups under question - dyspraxic and normals. Canonical correlation analysis (Thompson, 1984) was used to find the relationship between two sets of variables. This correlational analysis allowed for intervariable correlation within each set. This analysis yielded information on the extent to which each single variable in the set could predict the outcome of other variables of the set, or the extent to which it relates to other variables in the set. The canonical correlation analysis also enabled similar predictions in terms of each variable on the outcome of variables in the other set.

4.5 Performance of Normal Hearing and Deaf Children - Pretherapy

Comparison between the performance of the normal hearing and the deaf, at all age levels, was made using t-test for independent samples with Levene's test for equality of variance. The means and standard deviations of the performance of the children on the different tests, and the significance of difference of means between the deaf and normal hearing subjects for age 4, 5, 6, 7, 8, and 9 years are presented in Tables 4.1 through 4.6. respectively. The upper half of all these tables has the results from tests for dyspraxia. The bottom half pertains to results on the PWAT. Results on the articulation test have been presented in two ways: first, the results have been analysed in terms of correct, incorrect and no responses. Below this, the incorrect responses have been further subdivided and presented in the form of type of incorrect (misarticulation) response, namely, distortion, addition, substitution and omission.

	Deaf		Normal				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythml	0.61	0.50	3.50	1.08	-9.72	26	0.01
Rhythm2	0.00	0.00	4.50	0.71	-27.43	26	0.01
Sp. Rhythm	0.22	0.43	5.60	0.84	-22.54	26	0.01
Tong. Mobility	6.39	2.62	12.00	1.94	-5.92	26	0.01
LipMobility	2.39	0.78	3.90	1.60	-3.39	26	0.01
Jaw Mobility	2.50	0.51	4.40	1.43	-5.13	26	0.01
DDK-Tongue	0.93	0.30	1.97	0.18	-10.11	26	0.01
DDK-Lip	1.31	0.36	2.55	0.37	-8.65	26	0.01
DDK-Jaw	1.78	0.44	2.51	0.40	-4.32	26	0.01
Berges-Lezine's	9.31	2.30	6.85	1.08	3.17	26	0.01
Finger Tipping	7.00	5.18	7.10	2.33	-0.06	26	NS
MotorMemory	1.78	1.11	3.70	0.95	-4.59	26	0.01
Tong Agnosia	4.11	2.27	4.50	0.85	-0.52	26	NS
Thumb Turning	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

.Test for Articulation

Correct	7.49	7.30	76.36	10.21	-20.74	26	0.01
Incorrect	47.31	25.93	23.64	10.21	2.75	26	0.01
No Response	45.20	30.76	0.00	0.00	4.61	26	0.01
Distortion	0.59	0.92	7.12	2.26	-10.84	26	0 01
Addition	1.10	1.93	4.70	2.42	-4.33	26	0.01
Substitution	12.12	9.75	6.82	3.29	1.66	26	NS
Omission	33.50	17.27	5.00	3.20	5.13	26	0.01

Table 4.1: Mean scores and standard deviation (SD) of deaf and normal hearing subjects of 4 years of age on tests for dyspraxia and speech articulation, and the result oft-test for the significance of difference of means at the 0.01 (p) level, 'df stands for degrees of freedom.

	Deaf		Normal				
Tests for Dyspraxia							
Rhythm 1	0.83	0.51	4.00	1.05	-10.75	26	0.01
Rhythm 2	5.56	0.24	5.10	0.99	-20.79	26	0.01

Sp. Rhythm	0.22	0.43	6.00	1.25	-18.06	26	0.01
Tong. Mobility	8.28	1.81	13.00	2.21	-6.12	26	0.01
LipMobility	2.22	0.73	4.00	1.10	-5.26	26	0.01
JawMobility	2.44	1.04	4.70	1.16	-5.28	26	0.01
DDK-Tongue	1.01	0.29	2.54	0.42	-11.43	26	0.01
DDK-Lip	1.44	0.33	3.06	0.47	-10.73	26	0.01
DDK-Jaw	1.99	0.57	2.77	0.54	-3.53	26	0.01
Berges-Lezine's	10.25	2.43	7.25	1.93	3.35	26	0.01
Finger Tipping	8.22	5.09	7.70	3.02	0.30	26	NS
Motor Memory	2.39	0.70	4.50	0.71	-7.64	26	0.01
Tong. Agnosia	3.94	2.26	5.50	0.85	-2.08	26	NS
Thumb Turning	0.39	0.61	0.10	0.32	1.39	26	NS
Test for Articulation							
Correct	10.94	8.63	84.54	6.73	-23.27	26	0.01
Incorrect	48.48	26.69	15.46	6.73	3.82	26	0.01
No Response	40.57	31.54	0.00	0.00	4.03	26	0.01
Distortion	0.42	0.42	5.60	2.15	-9.48	26	0.01
Addition	3.37	4.69	3.34	1.20	0.02	26	NS
Substitution	15.15	8.51	4.09	2.58	3.98	26	0.01
Omission	29.54	22.44	2.42	1.46	3.79	26	0.01

Table 4.2 : Mean scores and standard deviation (SD) of deaf and normal hearing subjects of 5 years of age on tests for dyspraxia and speech articulation, and the result oft-test for the significance of difference of means at the 0.01 (p) level, 'df stands for degrees of freedom.

	Deaf		Normal				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	1.39	1.28	4.50	1.43	-5.88	26	0.01
Rhythm2	0.22	0.73	5.60	1.43	-13.26	26	0.01
Sp.Rhythm	0.00	0.00	6.50	1.58	-17.72	26	0.01
Tong. Mobility	9.28	1.02	14.00	2.40	-7.32	26	0.01
LipMobility	2.83	0.71	4.90	0.88	-6.81	26	0.01
JawMobility	2.78	0.88	5.00	1.05	-5.98	26	0.01
DDK-Tongue	1.17	0.27	2.76	0.70	-8.70	26	0.01
DDK-Lip	1.53	0.42	3.28	0.71	-8.19	26	0.01
DDK-Jaw	2.16	0.50	2.98	0.73	-3.53	26	0.01
Berges-Lezine's	9.28	2.10	8.25	1.80	1.31	26	NS
Finger Tipping	7.67	3.82	14.30	3.50	-4.53	26	0.01
Motor Memory	1.50	1.10	5.40	1.43	-8.08	26	0.01
Tong. Agnosia	5.28	1.27	5.60	0.70	-0.74	26	NS
Thumb Turning	0.83	0.79	0.90	0.74	-0.22	26	NS
Test for Articulation							
Correct	35.94	15.76	90.91	7.32	-10.36	26	0.01
Incorrect	63.30	15.22	9.09	7.32	10 54	26	0.01
No Response	0.76	1.96	0.00	0 00	1.21	26	NS

Distortion	3.62	3.86	3.79	2.79	-0.12	26	NS
Addition	3.37	4.14	1.52	1.43	1.36	26	NS
Substitution	23.74	8.28	2.73	2.24	7.81	26	0.01
Omission	32.57	14 81	1.06	1.25	6.67	26	0.01

Table 4.3 : Mean scores and standard deviation (SD) of deaf and normal hearing subjects of 6 years of age on tests for dyspraxia and speech articulation, and the result oft-test for the significance of difference of means at the 0.01 (p) level, 'df stands for degrees of freedom.

	Deaf		Normal				
	Mean	SD	Mean	SD	t	df	
Tests for Dyspraxia							
Rhythm 1	1.33	0.91	4.80	0.92	-9.86	29	0.01
Rhythm2	0.24	0.54	6.00	0.82	-23.50	29	0.01
Sp. Rhythm	0.29	0.46	7.50	0.97	-28.28	29	0.01
Tong. Mobility	9.86	1.24	14.60	1.78	-8.66	29	0 01
Lip Mobility	3.10	0.70	5.40	1.51	-5 88	29	0.01
Jaw Mobility	2.62	1.07	5.10	0.74	-6.59	29	0.01
DDK-Tongue	1.14	0.27	2.96	0.43	-14.34	29	0.01

DDK-Lip	1.57	0.33	3.52	0.33	-15.42	29	0.01
DDK-Jaw	1.88	0.55	3.25	0.34	-7.28	29	0.01
Berges-Lezine's	10.95	2.40	9.65	2.35	1.42	29	NS
Finger Tipping	11.90	4.21	17.70	4.30	-3.56	29	0.01
MotorMemory	1.71	1.10	5.60	0.52	-10.54	29	0.01
Tong. Agnosia	5.24	1.14	5.80	0.42	-1.50	29	NS
ThumbTurning	1.19	0.93	1.70	0.67	-1.55	29	NS
Test for Articulation							
Correct	34.70	13.59	95.15	5.04	-13.53	29	0.01
Incorrect	43.29	17.92	4.85	5.04	6.60	29	0.01
No Response	22.01	23.42	0.00	0.00	2.95	29	0.01
Distortion	0.29	0.78	2.12	1.92	-3.83	29	0.01
Addition	1.59	1.89	1.06	1.25	0.80	29	NS
Substitution	16.52	13.79	1.21	1.39	3.47	29	0.01
Omission	24.89	16.06	0.46	1.02	4.76	29	0.01

Table 4.4 : Mean scores and standard deviation (SD) of deaf and normal hearing subjects of 7 years of age on tests for dyspraxia and speech articulation, and the result oft-test for the significance of difference of means at the 0.01 (p) level 'df stands for degrees of freedom.

	Deaf		Normal				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	1.47	1.39	5.50	0.71	-8.55	27	0.01
Rhythm2	0.58	0.61	7.20	1.03	-21.86	27	0.01
Sp. Rhythm	0.26	0.56	10.10	1.52	-25.38	27	0.01
Tong. Mobility	10.21	2.18	15.90	2.99	-5.87	27	0.01
Lip Mobility	2.74	1.05	5.70	1.16	-6.99	27	0.01
Jaw Mobility	3.16	0.83	5.30	1.06	-5.99	27	0.01
DDK-Tongue	1.09	0.32	3.53	0.55	-15.05	27	0.01
DDK-Lip	1.45	0.38	3.87	0.61	-13.23	27	0.01
DDK-Jaw	2.07	0.64	3.55	0.56	-6.12	27	0.01
Berges-Lezine's	12.03	2.50	11.95	1.59	0.09	27	NS
Finger Tipping	13.05	5.26	19.50	2.83	-3.59	27	0.01
MotorMemory	2.00	1.20	6.10	0.88	-9.51	27	0.01
Tong. Agnosia	5.05	1.43	5.80	0.42	-1.60	27	NS
Thumb Turning	1.37	1.01	2.00	0.82	-1.70	27	NS
Test for Articulation							
Correct	38.44	15.65	97.12	2.08	-11.71	27	0.01
Incorrect	36.20	14.90	2.88	2 08	6.98	27	0.01
No Response	25.36	24.32	0.00	0.00	3 27	27	0.01

Distortion	0.80	1.06	0.91	0.78	-0.29	27	NS
Addition	0.72	1.78	0.61	0.78	0.19	27	NS
Substitution	11.48	8.39	1.06	1.02	3 88	27	0.01
Omission	23.20	11.55	0.30	0.64	6.21	27	0.01

Table 4.5 : Mean scores and standard deviation (SD) of deaf and normal hearing subjects of 8 years of age on tests for dyspraxia and speech articulation, and the result of t-test for the significance of difference of means at the 0.01 (p) level, 'df' stands for degrees of freedom.

	Deaf		Normal				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	1.53	1.12	6.10	0.88	-11.17	27	0.01
Rhythm 2	0.53	0.77	8.40	1.08	-22.78	27	0.01
Sp. Rhythm	0.63	0.68	11.10	1.66	-24.12	27	0.01
Tong. Mobility	10.58	1.92	16.00	1.49	-7.75	27	0.01
LipMobility	3.42	0.84	6.30	1.60	-8.03	27	0.01
JawMobility	3.53	0.90	5.70	1.25	-5.38	27	0.01
DDK-Tongue	1.18	0.46	3.76	0.49	-13.88	27	0.01

DDK-Lip	1.59	0.54	4.02	0.35	-12.89	27	0.01
DDK-Jaw	1.80	0.75	3.82	0.43	-7.79	27	0.01
Berges-Lezine's	12.18	1.57	12.70	1.64	-0.83	27	NS
Finger Tipping	12.79	5.30	20.50	3.98	-4.03	27	0.01
Motor Memory	2.26	1.05	6.40	0.52	-11.71	27	0.01
Tong. Agnosia	4.68	2.38	5.70	0.48	-1.32	27	NS
ThumbTurning	2.42	0.84	2.50	0.53	-1.69	27	NS
Test for Articulation							
Correct	37.96	10.77	99.09	1.28	-17.74	27	0.01
Incorrect	51.60	13.10	0.91	1.28	12.10	27	0.01
No Response	10.45	16.34	0.00	0.00	2.00	27	0.01
Distortion	0.88	0.92	0.61	0.79	0.79	27	NS
Addition	0.96	1.36	0.00	0.00	2.21	27	NS
Substitution	15.07	6.30	0.30	0.64	7.34	27	0.01
Omission	34.69	11.18	0.00	0.00	9.72	27	0.01

Table 4.6 : Mean scores and standard deviation (SD) of deaf and normal hearing subjects of 9 years of age on tests for dyspraxia and speech articulation, and the result of t-test for the significance of difference of means at the 0.01 (p) level, 'df stands for degrees of freedom.

The results tabulated in Tables 4.1 to 4.6 showed that

a) on a majority of the dyspraxic tests, the deaf and the normal children's performance was significantly different in all the age groups,

b) on the Berges and Lezine' s test, a test for intransitive hand positions, the deaf children in the age groups of 4 to 8 years, performed better than normal children, but the difference in mean scores was not statistically significant at the 0.01 level for children aged 6, 7 or 8 years while the difference was significant for children aged 4 and 5 years. Normal children, aged 9 years, had a slightly higher score than the deaf on this test, but the difference was again not statistically significant,

c) on the finger tipping test, the normal children of 6, 7, 8 and 9 years performed better than the deaf children in these age categories ($p < 0.01$). However, deaf children of 4 and 5 years performed better than normal children on this test, but the difference was not statistically significant at the 0.01 level,

d) the mean scores of deaf and normal children were not significantly different on tests for tongue agnosia and thumb turning in any age group,

e) on the picture-word articulation test, the mean percentage of correct and incorrect articulation and the mean percentage of " no responses' was significantly different ($p < 0.01$) between the deaf and the normal hearing children in all age groups. Obviously, the normal children, in all age groups, had a significantly higher percentage of correct articulation, and 'no responses' than the deaf children. In the case of deaf children, the percentage of correct articulation rose sharply from around 10% (4 and 5 years) to around 35% by age 6 which then did not show much change from this level in the older age groups (age 7, 8 and 9 years). However, there was not much difference in the mean percentage of incorrect articulation across the age groups (47.31% at 4 years and 51.6% at 9 years). But, the mean percentage of 'no responses' sharply declined from 5 to 6 years before increasing again at 7 years,

f) regarding the type of articulatory errors, the deaf children were more likely to omit or substitute a sound. This was a consistent trend observed among deaf children in all the age groups. However, whether there was a difference in the mean percentage of different types of articulatory errors has not been statistically tested. Normal children, however, were more likely to come out with a distorted production of the sound rather than omit, add, or substitute a sound, but this again is outside statistical significance, and

g) there was a large variability in the data, in all age groups, with respect to the results of the articulation test as reflected in the high standard deviations.

Step	Entered	Wilks' Lambda Statistic	dfl	df2	df3	Exact F Statistic	dfl	df2	Sig.
1	Rhythm2	0.13	1	1	171	1153.55	1	171	0.01
2	Thumb Turning	0.10	2	1	171	743.38	2	170	0.01
3	Berges-Lezine's	0.09	3	1	171	540.63	3	169	0.01
4	Sp. Rhythm	0.08	4	1	171	437.13	4	168	0.01
5	DDK-Jaw	0.08	5	1	171	379.65	5	167	0.01
6	Tong. Mobility	0.07	6	1	171	353.54	6	166	0.01
7	Jaw Mobility	0.07	7	1	171	311.34	7	165	0.01

Table 4.7 : Stepwise statistics : variables entered in Fisher's linear discriminant functions analysis.

	Standardized
Rhythm 2	0.784
Sp. Rhythm	0.592
Tong. Mobility	0.353
Jaw Mobility	0.197
DDK-Jaw	-0.448
Berges-Lezine's	-0.481
Thumb Turning	-0.537

Table 4.8 : Linear discriminant function coefficients of the tests.

		Predicted Group Membership		Total
Original	Group	Dyspraxic	Nondyspraxic	
173	Dyspraxic	113	0	113

Table 4.9 : Classification of children into dyspraxic and non-dyspraxic category based on the results of linear discriminant function analysis.

4.6 Prevalence of Dyspraxia in Deaf Subjects

One of the main objectives of this study was to investigate the prevalence of dyspraxia in deaf children. An experimental group of 113 deaf children and a control group of 60 normal children were selected to investigate this. Both the experimental and the control groups were selected making sure that the members of the group did not have any significant disabling motor conditions. Following collection of data from the deaf children on tests for dyspraxia, the total score of each deaf child, in each test, was compared with the mean score of normal hearing children of the same age. The subject was considered to be deficient in motor functioning, if he had achieved below his age level in more than one of the tests for dyspraxia which included tests for rhythm, oral movements, diadochokinetic rate, intransitive hand movements and sequential motor memory. As a result of this procedure, all deaf children included in the study came to be classified as dyspraxics.

Before proceeding further, it was necessary to make sure that our classification of normal and deviant groups in this study had been done correctly. This was done using discriminant analysis. The basic idea of discriminant analysis was to find the combination of tests that maximizes the separation between the groups. This study investigated a single characteristic - dyspraxic movements and consequent classification of subjects into two groups - the dyspraxics and the nondyspraxics. Therefore, Fisher's Linear Discriminant Analysis (Fisher, 1936) was employed. Some of the tests in the battery of tools for dyspraxia were constructed specifically for the study by the researcher. It was necessary, therefore, to find out if the component tools could be put to use in future as diagnostic aids to distinguish and identify individuals with dyspraxia. Also, it was essential to choose a subset of the tests most effective in identifying the characteristic of dyspraxia, and thereby differentiating dyspraxics from nondyspraxics.

4.6.1 Summary of Fisher's Linear Discriminant Functions

The discriminant analysis, through a stepwise procedure, identified seven tests from the battery as more efficient in detecting dyspraxia. These seven tests, put together, effectively differentiated dyspraxics from nondyspraxics. The tests so classified along with the results of discriminant function analysis are given in Table 4.7.

Accordingly, tests for (a) rhythm-2, (b) thumb turning, (c) Berges and Lezine's test for intransitive hand positions, (d) speech rhythm, (e) diadochokinetic rate of jaw, (f) tongue mobility, and (g) jaw mobility were identified as more effective tools of the battery in differentiating dyspraxics from nondyspraxics. The relative efficiency of the individual tests in identifying the presence or absence of dyspraxia is determined by the rank achieved by them in the stepwise selection. The top ranked (test for rhythm-2) should be considered the most effective while the least ranked test for jaw mobility is comparatively less efficient. In Table 4.7 the tests, which were found to be effective in discriminating dyspraxics from nondyspraxics, are arranged in the decreasing order of their efficiency. Thus, each test, in the list, is more effective than the succeeding one.

The standardized coefficient of the seven tests identified by the linear discriminant analysis as most efficient are given in Table 4.8. Using these coefficients in the equation for discrimination, it can be determined whether a given subject should be sorted as dyspraxic or nondyspraxic as per any given test.

Table 4.9 gives the results of classification of subjects as dyspraxic or nondyspraxic as per the results of the linear discriminant function analysis. As shown in the table, one hundred percent of the selected children were correctly classified. That is, all the 113 children in the deaf group were found to be dyspraxic, while the 60 normal hearing children of the normative group were put in the nondyspraxic category.

4.7 Agewise Comparison of the Normal and Deaf Children

One-way ANOVA was carried out to see if there was any difference in the performance of children of different age groups within the normal hearing and the deaf group. The agewise means on different tests and the results of ANOVA analysis together with the results of posthoc comparison are given in Tables 4.10 and 4.11 for the normal hearing children and in Tables 4.12 and 4.13 for the deaf children. Generally, more number of age differences in the normal hearing population than in the deaf were apparent. A notable observation was that on test of diadochokinesis of articulators (tongue, lips, jaw-tests 8, 9, 10 - Tables 4.13), the performance of deaf children in the different age groups was not significantly different. In other words, the performance of a 4-year old deaf child was almost the same as the performance of a 9-year old deaf child.

		1	2	3	4	5	6	7
Age (years)								
4.00	M	3.50	4.50	5.60	12.00	3.90	4.40	4.50
	SD	1.08	0.71	0.84	1.94	1.60	1.43	0.85
5.00	M	4.00	5.10	6.00	13.00	4.00	4.70	5.50
	SD	1.05	0.99	1.25	2.21	1.10	1.16	0.85
6.00	M	4.50	5.60	6.50	14.00	4.90	5.00	5.60
	SD	1.43	1.43	1.58	2.40	0,88	1.05	0.70
7.00	M	4.80	6.00	7.50	14.60	5.40	5.10	5.80
	SD	0.92	0.82	0.97	1.78	1.51	0.74	0.42

8.00	M	5.50	7.20	10.10	15.90	5.70	5.30	5.80
	SD	0.71	1.03	1.52	2.99	1.16	1.06	0.42
9.00	M	6.10	8.40	11.10	16.00	6.30	5.70	5.70
	SD	0.88	1.08	1.66	1.49	1.60	1.25	0.48
df		5,59	5,59	5,59	5,59	5,59	5,59	5,59
F Ratio		8.52	19.27	28.93	5.25	5.97	1.60	5.84
FProb.		0.01	0.01	0.01	0.01	0.01	NS	0.01
Posthoc		7&4	7&4	7&4	7&4	7&4	--	5&4
		8&4	8&4	7&5	8&4	7&5		6&4
		8&5	8&5	8&4	8&5	8&4		7&4
		9&4	8&6	8&5	9&4	8&5		8&4
		9&5	8&7	8&6	9&5	9&4		9&4
		9&6	9&4	8&7		9&5		
		9&7	9&5	9&4				
			9&6	9&5				
			9&7	9&6				
			9&8	9&7				

Table 4.10 : Means (M) and standard deviations (SD) of the performance of normal children on different tests of dyspraxia and the results of analysis of variance for the significance of difference of means between the age groups. Tests considered

were rhythm-1 (1), rhythm-2 (2), speech rhythm (3), tongue mobility (4), lip mobility (5), jaw mobility (5), and tongue agnosia (7). 'df denotes degrees of freedom.

		8	9	10	11	12	13	14
Age (years)								
4.00	M	1.97	2.55	2.51	6.85	7.10	3.70	0.00
	SD	0.18	0.37	0.40	1.08	2.33	0.95	0.00
5.00	M	2.54	3.06	2.77	7.25	7.70	4.50	0.10
	SD	0.42	0.47	0.54	1.93	3.02	0.71	0.32
6.00	M	2.76	3.28	2.98	8.25	14.30	5.40	0.90
	SD	0.70	0.71	0.73	1.80	3.50	1.43	0.74
7.00	M	2.96	3.52	3.25	9.65	17.70	5.60	1.70
	SD	0.43	0.33	0.34	2.35	4.30	0.52	0.67
8.00	M	3.53	3.87	3.55	11.95	19.50	6.10	2.00
	SD	0.55	0.61	0.56	1.59	2.83	0.88	0.82
9.00	M	3.76	4.02	3.82	12.70	20.50	6.40	2.50
	SD	0.49	0.35	0.43	1.64	3.98	0.52	0.53
df		5,59	5,59	5,59	5,59	5,59	5,59	5,59

F Ratio	18.05	12.07	9.07	19.03	29.90	13.02	31.23
FProb.	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Posthoc	5&4	5&4	7&4	7&4	6&4	5&4	6&4
	6&4	6&4	8&4	7&5	6&5	6&4	6&5
	7&4	7&4	8&5	8&4	7&4	6&5	7&4
	8&4	8&4	8&6	8&5	7&5	7&4	7&5
	8&5	8&5	9&4	8&6	7&6	7&5	7&6
	8&6	8&6	9&5	8&7	8&4	8&4	8&4
	8&7	9&4	9&6	9&4	8&5	8&5	8&5
	9&4	9&5	9&7	9&5	8&6	9&4	8&6
	9&5	9&6		9&6	9&4	9&5	9&4
	9&6			9&7	9&5		9&5
	9&7				9&6		9&6
							9&7

Table 4.11 : Means (M) and standard deviations (SD) of the performance of normal hearing children on different tests of dyspraxia and the results of analysis of variance for the significance of difference of means between the age groups. Tests considered were diadochokinetic rate of tongue (8), diadochokinetic rate of lips (9), diadochokinetic rate of jaw (10), Berges and Lezine's test for intransitive hand positions (11), finger tipping (12), sequential motor memory (13), and thumb turning (14). ' df' denotes degrees of freedom.

		1	2	3	4	5	6	7
Age (years)								
4.00	M	0.61	0.00	0.22	6.39	2.39	2.50	4.11
	SD	0.50	0.00	0.43	2.62	0.78	1.04	2.27
5.00	M	0.83	0.06	0.22	8.28	2.22	2.44	3.94
	SD	0.51	0.24	0.43	1.81	0.73	1.04	2.26
6.00	M	1.39	0.22	0.00	9.28	2.83	2.78	5.28
	SD	1.29	0.73	0.00	1.02	0.71	0.88	1.27
7.00	M	1.33	0.23	0.28	9.86	3.10	2.62	5.24
	SD	0.91	0.54	0.46	1.24	0.70	1.07	1.14
8:00	M	1.47	0.58	0.26	10.21	2.74	3.16	5.05
	SD	1.39	0.61	0.56	1.92	1.05	0.83	1.43
9.00	M	1.53	0.53	0.63	10.58	3.42	,3.53	4.68
	SD	1.12	0.77	0.68	1.92	0.84	0.90	2.38
df		5,112	5,112	5,112	5,112	5,112	5,112	5,112
FRatio		2.53	3.39	3.38	12.77	5.59	4.18	1.80
FProb.		NS	0.01	0.01	0.01	0.01	0.01	NS

Posthoc					
	4&8	6&9	4&5	4&7	4&9
	5&8	7&9	4&7	4&9	5&9
	5&9		4&8	5&7	6&9
			4&9	5&9	7&9
			5&6		
			5&7		
			5&8		
			5&9		

Table 4.12 : Means (M) and standard deviations (SD) of the performance of deaf children on different tests of dyspraxia and the results of analysis of variance for the significance of difference of means between the age groups. Tests considered were rhythm-1 (1), rhythm-2 (2), speech rhythm (3), tongue mobility (4), lip mobility (5), (6) jaw mobility, and tongue agnosia (7). 'df denotes degrees of freedom.

		8	9	10	11	12	13	14
Age (years)								
4.00	M	1.01	1.31	1.78	9.31	7.00	1.78	0.17
	SD	0.29	0.36	0 44	2.30	5.18	1.12	0.38
5.00	M	1.17	1.44	1.99	10.25	8.22	2.39	0.39
	SD	0.27	0.33	0 57	2 43	5.09	0.70	0 61

6.00	M	1.14	1.53	2.16	9.28	7.67	1.50	0.83
	SD	0.27	0.42	0.50	2.10	3.82	1.10	0.79
7.00	M	1.09	1.57	1.88	10.95	11.90	1.71	1.19
	SD	0.32	0.33	0.55	2.40	4.21	1.10	0.93
8.00	M	1.18	1.44	2.07	12.03	13.05	2.00	1.37
	SD	0.46	0.38	0.65	2.50	5.26	1.20	1.01
9.00	M	1.80	1.59	1.80	12.18	12.79	2.26	1.41
	SD	0.75	0.54	0.75	1.57	5.30	1.05	0.84
df		5,112	5,112	5,112	5,112	5,112	5,112	5,112
F Ratio		1.74	1.31	1.26	6.04	6.10	1.91	8.09
FProb.		NS	NS	NS	0.01	0.01	NS	0.01
Posthoc					4&8 4&9 5&8 5&9 6&8 6&9	4&7 4&8 4&9 5&7 5&8 5&9 6&7 6&8 6&9		4&6 4&7 4&8 4&9 5&7 5&8 5&9

Table 4.13 : Means (M) and standard deviation (SD) of the performance of deaf children on different tests of dyspraxia and the results of analysis of variance for the significance of different of means between the age groups. Tests considered were diadochokinetic rate of tongue (8), diadochokinetic rate of lips (9), diadochokinetic rate of jaw (10), Berges and Lezine's intransitive hand positions (11), finger tipping (12), sequential motor memory (13), and thumb turning (14). 'df denotes degrees of freedom.

Results in Tables 4.10 to 4.13 indicated that

a) the performance of the normal children on dyspraxia tests increased with increase in age from 4 to 9 years. However, the difference in the mean scores was statistically significant only between certain age groups. In general, the 7-year olds, 8-year olds, and 9-year olds appeared to have performed significantly better than the 4-year, 5-year and 6-year old children, although the exact relationship seemed to be slightly different for different tests (Table 4.10 and 4.11),

b) as an exception to the above, the mean scores on the test for tongue mobility (Test 6 - Table 4.10) were not statistically different between the different age groups,

c) in the case of deaf children, again older deaf children performed better on dyspraxic tests than th-: younger children. However, the difference in mean scores was statistically significant only between certain age groups. In general, children of 8 and 9 years performed significantly better than children aged 4 or 5 years,

d) two exceptions to the results reported in (c) above were that the performance of deaf children on tests of rhythm-1 (1), tongue agnosia (7), DDK - tongue (8), DDK - lips (9), and DDK - j aw (10) was not statistically significant between the different age groups, and

e) all differences in mean scores which were statistically significant between age groups were significant at the 0.01 level.

4.8 Performance of Male and Female Children: Normal Hearing and Deaf Groups

An analysis was also undertaken to compare the performance of male and female children in each of the two groups - normal hearing and the deaf - on the tests for dyspraxia and speech articulation. The results are tabulated in Tables 4.14 to 4.19 for normal children. The results in these tables are arranged in the same way as in the Tables 4.1 to 4.6. The upper half of these tables has the results from tests for dyspraxia while the bottom half gives the results on the PWAT.

	Male		Female				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	3.40	1.14	3.60	1.14	-0.28	8	NS
Rhythm 2	4.60	0.89	4.40	0.55	0.43	8	NS
Sp. Rhythm	5.60	0.89	5.60	0.89	0.00	8	NS
Tong. Mobility	11.20	1.30	12.80	2.28	-1.36	8	NS
LipMobility	4.00	2.34	3.80	0.84	0.19	8	NS
Jaw Mobility	4.20	1.64	4.60	1.34	-0.42	8	NS
DDK-Tongue	1.90	0.22	2.04	0.09	-1.30	8	NS
DDK-Lip	2.48	0.40	2.62	0.36	-0.58	8	NS
DDK-Jaw	2.48	0.46	2.54	0.39	-0.22	8	NS
Berges-Lezine's	6.70	0.98	7.00	1.28	-0.42	8	NS
Finger Tipping	7.40	2.88	6.80	1.92	0.39	8	NS
Motor Memory	4.20	1.10	3.20	0.45	1.89	8	NS
Tong. Agnosia	4.60	0.89	4.40	0.89	0.35	8	NS
Thumb Turning	0.00	0.00	0.00	0.00	--	--	--
Test for Articulation							
Correct	77.27	11.34	75.45	10.19	0.27	8	NS
Incorrect	22.73	11.34	24.55	10.19	-0.27	8	NS
No Response	0.00	0.00	0.00	0.00	--	--	--

Distortion	6.97	2.75	7.27	1.98	-0.20	8	NS
Addition	5.15	2.30	4.25	2.71	0.57	8	NS
Substitution	6.67	3.80	6.97	3.14	-0.14	8	NS
Omission	3.94	3.14	6.06	3.21	-1.06	8	NS

Table 4.14 : Mean and standard deviation (SD) of normal hearing male and female subjects of 4 years of age on tests for dyspraxia and speech articulation, and the result oft-test for the significance of difference in means between the two sexes at the 0.01 (p) level, 'df stands for degrees of freedom.

	Male		Female				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	4.00	1.23	4.00	1.00	0.00	8	NS
Rhythm2	5.00	1.23	5.20	0.84	-0.30	8	NS
Sp. Rhythm	6.00	1.00	6.00	1.58	0.00	8	NS
Tong. Mobility	12.20	1.79	13.80	2.49	-1.17	8	NS
LipMobility	4.20	1.30	3.80	0.84	0.58	8	NS
Jaw Mobility	4.80	1.48	4.60	0.89	0.26	8	NS
DDK-Tongue	2.38	0.50	2.70	0.27	-1.25	8	NS

DDK-Lip	3.04	0.53	3.08	0.46	-0.13	8	NS
DDK-Jaw	2.74	0.62	2.80	0.52	-0.17	8	NS
Berges-Lezine's	6.80	2.08	7.70	1.89	-0.72	8	NS
Finger Tipping	8.40	4.22	7.00	1.23	0.71	8	NS
Motor Memory	4.80	0.84	4.20	0.45	1.41	8	NS
Tong. Agnosia	5.20	1.10	5.80	0.45	-1.13	8	NS
Thumb Turning	0.20	0.45	0.00	0.00	1.00	8	NS
Test for Articulation							
Correct	85.75	7.62	83.33	6.34	0.55	8	NS
Incorrect	14.24	7.62	16.67	6.34	-0.55	8	NS
No Response	0.00	0.00	0.00	0.00	--	--	--
Distortion	5.15	2.54	6.06	1.86	-0.65	8	NS
Addition	3.34	1.27	3.34	1.27	0.00	8	NS
Substitution	3.94	3.14	4.24	2.25	-0.17	8	NS
Omission	1.82	1.27	3.03	1.51	-1.37	8	NS

Table 4.15 : Mean and standard deviation (SD) of normal hearing male and female subjects of 5 years of age on tests for dyspraxia and speech articulation, and the result oft-test for the significance of difference in means between the two sexes at the 0.01 (p) level, 'df stands for degrees of freedom.

	Male		Female				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	4.40	1.14	4.60	1.82	-0.21	8	NS
Rhythm2	5.60	1.52	5.60	1.52	0.00	8	NS
Sp. Rhythm	6.80	1.30	6.20	1.92	0.58	8	NS
Tong. Mobility	13.60	2.70	14.40	2.30	-0.50	8	NS
LipMobility	4.20	0.45	5.60	0.55	-4.43	8	0.01
JawMobility	4.80	0.84	5.20	1.30	-0.58	8	NS
DDK-Tongue	2.72	0.67	2.80	0.80	-0.17	8	NS
DDK-Lip	3.30	0.52	3.26	0.94	0.08	8	NS
DDK-Jaw	3.00	0.58	2.96	0.92	0.08	8	NS
Berges-Lezine's	8.40	1.85	8.10	1.95	0.25	8	NS
Finger Tipping	13.80	4.03	14.80	3.27	-0.43	8	NS
MotorMemory	5.00	1.00	5.80	1.79	-0.87	8	NS
Tong. Agnosia	5.60	0.89	5.60	0.55	0.00	8	NS
Thumb Turning	0.80	0.45	1.00	1.00	-0.41	8	NS
Test for Articulation							
Correct	89.08	6.98	92.73	7 97	-0.77	8	NS
Incorrect	10.91	6.98	7.27	7.97	0.77	8	NS
No response	0.00	0.00	0.00	0 00	--	--	--

Distortion	4.85	2.92	2.73	2.49	1.24	8	NS
Addition	1.82	1.27	1.21	166	0.65	8	NS
Substitution	3.03	1.86	2.42	2.75	0.41	8	NS
Omission	1.21	1.27	0.91	1.36	0.36	8	NS

Table 4.16 : Mean and standard deviation (SD) of normal hearing male and female subjects of 6 years of age on tests for dyspraxia and speech articulation, and the result oft-test for the significance of difference in means between the two sexes at the 0.01 (p) level, 'df stands for degrees of freedom.

	Male		Female				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	4.60	0.89	5.00	1.00	-0.67	8	NS
Rhythm2	5.80	0.84	6.20	0.84	-0.76	8	NS
Sp. Rhythm	7.40	0.89	7.60	1.14	-0.31	8	NS
Tong. Mobility	14.60	2.07	14.60	167	0.00	8	NS
Lip Mobility	5.20	1.64	5.60	1.52	-0 40	8	NS
JawMobility	5.40	0.55	4.80	0.84	1.34	8	NS
DDK-Tongue	2.98	0 34	2 94	0.55	0 14	8	NS

DDK-Lip	3.60	0.35	3.44	0.34	0.74	8	NS
DDK-Jaw	3.30	0.26	3.20	0.43	0.45	8	NS
Berges-Lezine's	9.60	2.16	9.70	2.77	-0.06	8	NS
Finger Tipping	15.40	5.13	20.00	1.41	-1.93	8	NS
MotorMemory	5.40	0.55	5.80	0.45	-1.26	8	NS
Tong. Agnosia	5.80	0.45	5.80	0.45	0.00	8	NS
ThumbTurning	1.60	0.55	1.80	0.84	-0.45	8	NS
Test for Articulation							
Correct	93.63	5.18	96.67	4.95	-0.95	8	NS
Incorrect	6.34	5.18	3.34	4.95	0.95	8	NS
No response	0.00	0.00	0.00	0.00	--	--	--
Distortion	3.03	1.51	1.21	1.97	1.64	8	NS
Addition	1.21	1.27	0.91	1.36	0.37	8	NS
Substitution	1.51	1.51	0.91	1.36	0.66	8	NS
Omission	0.61	1.36	0.30	0.68	0.45	8	NS

Table 4.17 : Mean and standard deviation (SD) of normal hearing male and female subjects of 7 years of age on tests for dyspraxia and speech articulation, and the result oft-test for the significance of difference in means between the two sexes at the 0.01 (p) level. 'df stands for degrees of freedom.

	Male		Female				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	5.40	0.55	5.60	0.89	-0.43	8	NS
Rhythm2	6.80	0.84	7 60	1.14	-1.26	8	NS
Sp. Rhythm	10.00	1.58	10.20	1.64	-0.20	8	NS
Tong. Mobility	16.00	1.87	15 80	4.09	0.10	8	NS
LipMobility	6.00	1.41	5.40	0.89	0.80	8	NS
JawMobility	5.40	1.52	5.20	0.45	0.28	8	NS
DDK-Tongue	3.38	0.41	3.68	0.68	-0.84	8	NS
DDK-Lip	3.62	0.39	4.12	0.72	-1.37	8	NS
DDK-Jaw	3.28	0.41	3.82	0.59	-1.68	8	NS
Berges-Lezine's	11.10	1.75	12.80	0.91	-1.93	8	NS
Finger Tipping	20.60	2.30	18.40	3.13	1.27	8	NS
MotorMemory	6.20	1.10	6.00	0.71	0.34	8	NS
Tong. Agnosia	5.80	0.45	5.80	0.45	0.00	8	NS
Thumb Turning	2.20	0.84	1.80	0.84	0.76	8	NS
Test for Articulation							
Correct	97.27	2.25	96.97	2.14	0.22	8	NS
Incorrect	2.73	2.25	3 03	2.14	-0.22	8	NS
No response	0.00	0.00	0 00	0.00	--	--	--

Distortion	0.91	0.83	0.91	0.83	0.00	8	NS
Addition	0.61	0.83	0.61	0.83	0.00	8	NS
Substitution	0.91	0.83	1.21	1.27	-0.45	8	NS
Omission	0.30	0.67	0.30	0.68	0.00	8	NS

Table 4.18 : Mean and standard deviation (SD) of normal hearing male and female subjects of 8 years of age on tests for dyspraxia and speech articulation, and the result oft-test for the significance of difference in means between the two sexes at the 0.01 (p) level, 'df stands for degrees of freedom.

	Male		Female				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	6.20	0.84	6.00	1.00	0.34	8	NS
Rhythm2	8.60	0.55	8.20	1.48	0.57	8	NS
Sp. Rhythm	11.00	1.87	11.20	1.64	-0.18	8	NS
Tong. Mobility	16.00	1.58	16 00	1.58	0.00	8	NS
Lip Mobility	6.40	1.14	6.20	1.10	0.28	8	NS
Jaw Mobility	6.00	1.58	5.40	0 89	0 74	8	NS
DDK-Tongue	3.74	0.55	3 78	0.50	-0.12	8	NS

DDK-Lip	4.06	0.34	3.98	0.34	0.34	8	NS
DDK-Jaw	3.84	0.40	3.80	0.51	0.14	8	NS
Berges-Lezine's	12.60	1.85	12.80	1.61	-0.18	8	NS
Finger Tipping	23.00	3.32	18.00	3.00	2.50	8	NS
Motor Memory	6.40	0.55	6.40	0.55	0.00	8	NS
Tong. Agnosia	5.80	0.45	5.60	0.55	0.63	8	NS
ThumbTurning	2.40	0.55	2.60	0.55	-0.58	8	NS
Test for Articulation							
Correct	98.48	1.52	99.70	0.68	-1.63	8	NS
Incorrect	1.52	1.52	0.30	0.68	1.63	8	NS
No Response	0.00	0.00	0.00	0.00	--	--	--
Distortion	0.91	0.83	0.30	0.68	1.26	8	NS
Addition	0.00	0.00	0.00	0.00	--	--	--
Substitution	0.60	0.83	0.00	0.00	1.63	8	NS
Omission	0.00	0.00	0.00	0.00	--	--	--

Table 4.19 : Mean and standard deviation (SD) of normal hearing male and female subjects of 9 years of age on tests for dyspraxia and speech articulation, and the result oft-test for the significance of difference in means between the two sexes at the 0.01 (p) level, 'df stands for degrees of freedom.

	Male		Female				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	0.60	0.52	0.63	0.52	-0.10	16	NS
Rhythm 2	0.00	0.00	0.00	0.00	--	--	--
Sp. Rhythm	0.10	0.32	0.38	0.52	-1.39	16	NS
Tong. Mobility	6.00	2.91	6.88	2.30	-0.69	16	NS
Lip Mobility	2.50	0.85	2.25	0.71	0.67	16	NS
Jaw Mobility	2.30	0.48	2.75	0.46	-2.00	16	NS
DDK-Tongue	0.92	0.18	0.94	0.42	-0.12	16	NS
DDK-Lip	1.18	0.30	1.46	0.39	-1.73	16	NS
DDK-Jaw	1.61	0.36	2.00	0.45	-2.04	16	NS
Berges-Lezine's	8.45	2.57	10.38	1.41	-1.90	16	NS
Finger Tipping	6.90	5.04	7.13	5.69	-0.90	16	NS
Motor Memory	2.20	0.79	1.25	1.28	1.94	16	NS
Tong. Agnosia	3.80	2.35	4.50	2.27	-0.64	16	NS
Thumb Turning	0.10	0.32	0.25	0.46	-0.82	16	NS
Test for Articulation							
Correct	7.12	7.82	7.95	7.09	-0.23	16	NS
Incorrect	48.03	27.89	46.40	25.12	0 13	16	NS
No Response	44.85	33.50	45.64	29.22	-0.05	16	NS

Distortion	0.61	1.06	0.57	0.79	0.08	16	NS
Addition	1.37	2.42	0.76	1.15	0.65	16	NS
Substitution	11.67	9.37	12.69	10.83	-0.21	16	NS
Omission	34.39	18.76	32.38	16.40	0.24	16	NS

Table 4.20 : Mean and standard deviation (SD) of deaf male and female subjects of 4 years of age on tests for dyspraxia and speech articulation, and the result of t-test for the significance of difference in means between the two sexes at the 0.01 (p) level, 'df stands for degrees of freedom.

	Male		Female				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	0.70	0.48	1.00	0.54	-1.25	16	NS
Rhythm2	0.00	0.00	0.13	0.35	-1.13	16	NS
Sp. Rhythm	0.30	0.48	0.13	0.35	0.86	16	NS
Tong. Mobility	8.10	197	8.50	1.69	-0.46	16	NS
LipMobility	2.10	0.74	2.38	0 74	-0.78	16	NS
Jaw Mobility	2.50	108	2.38	1.06	0.25	16	NS
DDK-Tongue	1.01	0.33	1.00	0.27	0.07	16	NS

DDK-Lip	1.35	0.32	1.56	0.32	-1.41	16	NS
DDK-Jaw	1.99	0.70	1.99	0.41	0.01	16	NS
Berges-Lezine's	9.35	2.19	11.38	2.37	-1.88	16	NS
Finger Tipping	6.40	3.67	10.50	5.93	-1.81	16	NS
MotorMemory	2.20	0.79	2.63	0.52	-1.31	16	NS
Tong. Agnosia	3.30	2.21	4.75	2.19	-1.39	16	NS
Thumb Turning	0.50	0.71	0.25	0.46	0.86	16	NS
Test for Articulation							
Correct	10.76	8.64	11.18	9.20	-0.10	16	NS
Incorrect	46.51	30.67	50.95	22.53	-0.34	16	NS
No Response	42.73	37.10	37.88	25.14	0.32	16	NS
Distortion	0.61	0.79	0.19	0.54	1.28	16	NS
Addition	1.67	1.67	5.50	6.37	-1.83	16	NS
Substitution	13.03	9.45	17.80	6.81	-1.20	16	NS
Omission	31.21	22.17	27.46	24.13	0.34	16	NS

Table 4.21 : Mean and standard deviation (SD) of deaf male and female subjects of 5 years of age on tests for dyspraxia and speech articulation, and the result of t-test for the significance of difference in means between the two sexes at the 0.01 (p) level, 'df stands for degrees of freedom.

	Male		Female				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	1.50	1.35	1.25	1.28	0.40	16	NS
Rhythm2	0.00	0.00	0.50	1.07	-1.49	16	NS
Sp. Rhythm	0.00	0.00	0.00	0.00	--		
Tong. Mobility	9.40	0.84	9.13	1.25	0.56	16	NS
LipMobility	2.80	0.79	2.88	0.64	-0.22	16	NS
JawMobility	2.70	1.06	2.88	0.64	-0.41	16	NS
DDK-Tongue	1.32	0.27	0.98	0.07	3.55	16	0.01
DDK-Lip	1.64	0.48	1.40	0.32	1.22	16	NS
DDK-Jaw	2.08	0.43	2.26	0.59	-0.76	16	NS
Berges-Lezine's	9.35	2.51	9.19	1.60	0.16	16	NS
Finger Tipping	8.50	4.25	6.63	3.16	1.04	16	NS
MotorMemory	1.70	1.16	1.25	1.04	0.86	16	NS
Tong. Agnosia	5.70	0.48	4.75	1.75	1.65	16	NS
Thumb Turning	1.10	0.74	0.50	0.76	1.70	16	NS
Test for Articulation							
Correct	32.88	9.77	39.77	21.22	-0.92	16	NS
Incorrect	67.12	9.77	58 52	19.82	1.23	16	NS
No Response	0.00	0.00	1.71	2.74	-1.98	16	NS

Distortion	2.58	4.46	4.93	2.66	-1.31	16	NS
Addition	3.94	5.21	2.65	2.40	-0.64	16	NS
Substitution	26.52	8.18	20.26	7.46	1.67	16	NS
Omission	34.09	12.52	30.68	17.99	0.47	16	NS

Table 4.22 : Mean and standard deviation (SD) of deaf male and female subjects of 6 years of age on tests for dyspraxia and speech articulation, and the result of t-test for the significance of difference in means between the two sexes at the 0.01 (p) level, 'df stands for degrees of freedom.

	Male		Female				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	1.33	1.07	1.33	0.71	0.00	19	NS
Rhythm2	0.33	0.65	0.11	0.33	0.93	19	NS
Sp. Rhythm	0.25	0.45	0.33	0.50	-0.40	19	NS
Tong. Mobility	10.17	1.12	9.44	1.33	1.35	19	NS
Lip Mobility	3.08	0.67	3.11	0.78	-0.09	19	NS
JawMobility	2.58	0.90	2.67	1.32	-0.17	19	NS
DDK-Tongue	1.04	0.26	1.27	0.26	-1.99	19	NS

DDK-Lip	1.46	0.26	1.72	0.36	-195	19	NS
DDK-Jaw	1.73	0.44	2.07	0.64	-142	19	NS
Berges-Lezine's	9.92	2.68	12.33	0.90	-2.58	19	0.01
Finger Tipping	12.25	4.92	11.44	3.25	0.43	19	NS
MotorMemory	1.83	0.94	1.56	1.33	0.56	19	NS
Tong. Agnosia	5.50	0.80	4.89	1.45	1.24	19	NS
ThumbTurning	1.08	1.08	1.33	0.71	-0.60	19	NS
Test for Articulation							
Correct	35.48	13.66	33.67	14.25	0.30	19	NS
Incorrect	49.62	16.19	34.85	17.39	2.01	19	NS
No Response	14.90	17.33	31.48	27.94	-1.68	19	NS
Distortion	0.38	0.94	0.17	0.50	0.61	19	NS
Addition	1.90	2.34	1.18	1.01	0.85	19	NS
Substitution	20.83	15.96	10.77	7.74	1.74	19	NS
Omission	26.52	18.70	22.73	12.45	0.53	19	NS

Table 4.23 : Mean and standard deviation (SD) of deaf male and female subjects of 7 years of age on tests for dyspraxia and speech articulation, and the result oft-test for the significance of difference in means between the two sexes at the 0.01 (p) level, 'df stands for degrees of freedom.

	Male		Female				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	1.36	1.43	1.63	1.41	-0.40	17	NS
Rhythm 2	0.64	0.67	0.50	0.54	0.47	17	NS
Sp. Rhythm	0.18	0.60	0.38	0.52	-0.73	17	NS
Tong. Mobility	10.36	2.25	10.00	2.20	0.35	17	NS
LipMobility	3.09	1.04	2.25	0.89	1.84	17	NS
JawMobility	3.09	0.94	3.25	0.71	-0.40	17	NS
DDK-Tongue	1.09	0.38	1.10	0.26	-0.06	17	NS
DDK-Lip	1.36	0.39	1.56	0.36	-1.13	17	NS
DDK-Jaw	1.87	0.58	2.35	0.67	-1.67	17	NS
Berges-Lezine's	11.95	2.77	12.13	2.26	-0.14	17	NS
Finger Tipping	14.82	3.16	10.63	6 74	1.82	17	NS
MotorMemory	2.09	1.30	1.88	1.13	0.38	17	NS
Tong. Agnosia	4.82	1.78	5.38	0.74	-0.83	17	NS
ThumbTurning							
Test for Articulation							
Correct	37.74	14.41	39.39	18.20	-0.22	17	NS
Incorrect	32.37	15.82	41.48	12.57	-1.35	17	NS
No Response	29.89	27.60	19.13	18.89	0 95	17	NS

Distortion	0.97	1.23	0.57	0.79	0.80	17	NS
Addition	0.41	0.71	1.14	2.65	-0.87	17	NS
Substitution	8.82	7.13	15.15	9.05	-1.71	17	NS
Omission	22.17	13.14	24.62	9.61	-0.45	17	NS

Table 4.24 : Mean and standard deviation (SD) of deaf male and female subjects of 8 years of age on tests for dyspraxia and speech articulation, and the result oft-test for the significance of difference in means between the two sexes at the 0.01 (p) level, 'df stands for degrees of freedom.

	Male		Female				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	2.00	1.10	0.88	0.84	2.43	17	NS
Rhythm2	0.55	0.82	0.50	0.76	0.12	17	NS
Sp. Rhythm	0.73	0.79	0.50	0.54	0.71	17	NS
Tong. Mobility	11.55	1.70	9.25	1.39	3.13	17	0.01
LipMobility	3.45	0.69	3.38	1.06	0.20	17	NS
JawMobility	3.45	0.82	3.63	1.06	-0.40	17	NS
DDK-Tongue	1.11	0.20	129	0.69	-0.82	17	NS

DDK-Lip	1.47	0.37	1.75	0.71	-1.12	17	NS
DDK-Jaw	1.51	0.51	2.20	0.88	-2.17	17	NS
Berges-Lezine's	12.55	1.65	11.69	139	1.19	17	NS
Finger Tipping	14.73	2.41	10.13	7.06	2.02	17	NS
Motor Memory	2.27	0.91	2.25	1.28	0.05	17	NS
Tong. Agnosia	4.82	2.40	4.50	2.51	0.28	17	NS
ThumbTurning	1.82	0.60	0.88	0.84	2.87	17	0.01
Test for Articulation							
Correct	37.46	10.16	38.63	12.23	-0.23	17	NS
Incorrect	51.38	15.10	51.90	10.73	-0.08	17	NS
No Response	11.16	20.30	9.47	9.81	0.22	17	NS
Distortion	0.97	1.02	0.76	0.81	0.47	17	NS
Addition	0.83	1.42	1.14	1.34	-0.48	17	NS
Substitution	14.46	6.55	15.91	6.27	-0.48	17	NS
Omission	35.12	12.38	34.09	10.11	0.19	17	NS

Table 4.25 : Mean and standard deviation (SD) of deaf male and female subjects of 9 years of age on tests for dyspraxia and speech articulation, and the result of t-testfor the significance of difference in means between the two sexes at the 0.01 (p) level, 'df stands for degrees of freedom.

The results in Tables 4.14 to 4.19, in general indicated that the normal children, both boys and girls, improved their performance, on every test with increase in age. These results can be summarized as follows.

a) In the case of normal children, there was no statistically significant difference in the mean scores of male and female children in any test, either for dyspraxia or speech articulation, and at any age (except lip mobility - 6 years).

b) Outside statistical significance,

i) the performance of female children on rhythm tests was slightly better than male children upto 8 years and at 9 years, this pattern seemed to tilt in favour of male children,

ii) the female children of 4 to 6 years seemed to do better on the test for tongue mobility than male children, but, by 7 years, the male children reached the performance level of female children and maintained it in the later years, and

iii) on tests for lip and jaw mobility, the male children seemed to perform slightly better than female children at any given age.

A similar analysis was done with respect to deaf children and the resuits are tabulated in Tables 4.20 to 4.25 for different age groups. These results can be summarized as follows:

a) There was no statistically significant difference between the mean scores of male and female children, in any age group and on any test. However, there were some exceptions (DDK - tongue: 6 years, Berges-Lezine's: 7 years, tongue mobility, and thumb turning: 9 years). When so many t-comparisons are made (252 in this instance), one or two significant differences can probably be taken as instances of Type I error.

b) In general, deaf children (both male and female) performed better with increase in age, but the tendency was not as consistent as it was in the case of normal hearing male and female children (Tables 4.14 to 4.19).

4.9 Effects of Dyspraxic Errors on Speech Articulation of the Deaf

Another major objective of the study was to investigate the effects of dyspraxic errors on the articulation of speech sounds in deaf children. This was done by computing correlations between the subjects' performance on the tests for dyspraxia and the phonemes misarticulated by them. For this purpose, 3 sets of variables were set up. One set consisted of the 14 tests for dyspraxia. The testing for articulation included 35 phonemes in Tamil which according to the manner of articulation were classified into 10 groups, namely, high vowels, mid vowels, low vowels, plosives, nasals, affricates, fricatives, laterals, trills and semivowels. The responses were evaluated in terms of correctly articulated, misarticulated or no responses. Since the aim was to study the effects on misarticulation, two more sets of variables representing the phonemes misarticulated and not responded to were set up for analysis. These two sets, in turn, consisted of the 10 groups of sounds as individual variables. These two sets of variables were studied for the nature and strength of relationship with the first set of 14 variables.

Here, it is important to note that all 3 sets of variables consisted of more than one individual variable. Hence, it was decided to employ the canonical correlation analysis for the investigation of the relationships instead of the usual Product-moment analysis of linear relationship. The canonical analysis has the added advantage of investigating with respect to the following features:

* The extent to which each variable, on a set of 2 or more variables can be predicted or explained by another set of 2 or more variables.

* The contribution made by each single variable to the explanatory power of the set of the variables to which it belongs to

* The extent to which each single variable in one set contributes to predicting or explaining the composite of the variables in the other set

The three sets of variables together with the mean and standard deviations (SD) are given in Tables 4.26 to 4.28.

Tests	Number	Mean	SD
Rhythm 1	XI	1.20	1.05
Rhythm 2	X2	0.27	0.59
Speech Rhythm	X3	0.27	0.50
Tongue Mobility	X4	9.14	2.30
Lip Mobility	X5	2.80	0.89
Jaw Mobility	X6	2.84	0.96
DDK Tongue	X7	1.09	0.33
DDK Lips	X8	1.48	0.40
DDK Jaw	X9	1.95	0.59
Berges Lezine's	X10	10.70	2.48
Finger Tipping	XI1	10.20	5.36
Motor Memory	X12	1.94	1.08
Tongue Agnosia	XI3	4.73	1.89
Thumb Turning	X14	0.91	0.91

Table 4.26 : Set I of 14 tests for dyspraxia with mean and standard deviations (SD)

Sounds	Number	Mean	SD
Misarticulation			
High Vowels	XI5	31.46	27.96
Mid Vowels	X16	20.69	19.75
Low Vowels	X17	26.55	37.84
Nasal	X18	60.57	26.82
Plosive	X19	57.44	25.45
Affricates	X20	65.04	33.33
Fricatives	X21	50.06	28.64
Laterals	X22	53.48	32.33
Trills	X23	54.20	39.51
Semivowels	X24	55.17	38.00

Table 4.27 : Set II of 10 types of misarticulated sounds **with** mean and standard deviations (SD)

Sounds	Number	Mean	SD
No responses			
High Vowels	X25	24.98	37.13
Mid Vowels	X26	22.68	32.84
Low Vowels	X27	16.81	33.81
Nasals	X28	19 87	27.90

Plosives	X29	18.64	28.18
Affricates	X30	22.35	3 5.25
Fricatives	X31	25.16	31.90
Laterals	X32	26.80	31.14
Trills	X33	37.17	40.38
Semivowels	X34	23.60	33.84

Table 4.28 : Set III of 10 types of sounds that received no response with mean and standard deviations (SD).

4.9.1 **Correlations**

The first step of canonical correlation analysis involved the calculation of the intervariable correlation matrix. Intervariable correlations between variables in Set I, Set II and Set III are presented in Tables 4.29 through 4.33.

4.9.1.1 Canonical Correlations within Each Set of Variables

This is analysed by computing the coefficient of determination, 'R-squared', from the multiple correlation coefficient 'R'. This coefficient of determination suggests the percentage of contribution made by each single variable in explaining the entire set of variables. The coefficient of determination for the variables in each set are presented in Tables 4.34 to 4.36.

	XI	X2	X3	X4	X5	X6	X7	X8	X9	X10	XI1	X12	X13	X14
XI	1.00													
X2	0.55	1.00												
X3	0.15	0.14	1.00											
X4	**0.40**	0.36	**0.23**	1.00										
X5	0.14	**0.21**	0.19	**0.37**	1.00									
X6	0.17	**0.22**	**0.31**	**0.47**	**0.28**	1.00								
X7	**0.32**	**0.23**	0.15	**0.32**	**0.21**	0.17	1.00							
X8	0.19	0.19	0.09	**0.23**	0.07	0.02	**0.57**	1.00						
X9	0.17	0.17	0.11	**0.26**	0.05	**0.29**	**0.50**	**0.47**	1.00					
X10	0.14	0.09	**0.20**	**0.38**	**0.34**	**0.31**	0.12	0.02	0.02	1.00				
XII	**0.22**	0.25	0.09	**0.42**	**0.25**	0.25	-0.04	-0.12	-0.23	**0.50**	1.00			
X12	-0.04	0.07	-0.05	0.11	-0.10	0.09	-0.23	-0.06	-0.17	0.06	0.09	1.00		
X13	0.20	0.18	0.02	**0.22**	0.08	0.19	0.25	0.10	0.06	0.17	0.22	-0.03	1.00	
X14	**0.47**	0.36	**0.21**	**0.50**	**0.28**	0.22	**0.33**	0.19	-0.05	**0.33**	0.36	0.06	0.25	1.00

Figures in bold' are significant at the 0.05 level

Table 4.29 : Correlation of variables within Set I

	X15	**X16**	**X17**	**X18**	**X19**	**X20**	**X21**	**X22**	**X23**	**X24**
X15	**1.00**									
X16	0.49	1.00								
X17	0.34	0.33	**1.00**							
X18	**0 34**	0.26	0.39	1.00						

X19	0.49	0.41	0.32	0.55	1.00					
X20	0.45	0.31	0.33	0.58	0.67	1.00				
X21	0.39	0.37	0.28	0.56	0.54	0.55	1.00			
X22	0.42	0.36	0.37	0.61	0.54	0.49	0.67	1.00		
X23	0.30	0.25	0.27	0.48	0.46	0.52	0.55	0.54	1.00	
X24	0.31	0.40	0.25	0.51	0.42	0.39	0.59	0.60	0.51	1.00

All correlations were significant at the 0.05 level

Table 4.30 : Correlation of variables within Set II

	X25	X26	X27	X28	X29	X30	X31	X32	X33	X34
X25	1.00									
X26	0.87	1.00								
X27	0.70	0.71	1.00							
X28	0.60	0.62	0.68	1.00						
X29	0.67	0.67	0.67	0.74	1.00					
X30	0.69	0.62	0.69	0.77	0.81	1.00				
X31	0.64	0.60	0.69	0.80	0.70	0.76	1.00			
X32	0.49	0.51	0.56	0.85	0.61	0.66	0.81	1.00		
X33	0.40	0.44	0.46	0.66	0.46	0.51	0.73	0.71	1.00	
X34	0.47	0.43	0.47	0.62	0.52	0.53	0.72	0.71	0.65	1.00

All correlations were significant at the 0.05 level

Table 4.31 : Correlation of variables within Set III

	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24
XI	-0.03	-0.12	**-0.22**	-0.03	0.09	0.15	-0.02	-0.18	-0.02	**-0.26**
X2	**-0.20**	**-0.22**	**-0.23**	0.09	-0.06	0.10	-0.04	-0.14	0.06	-0.18
X3	-0.06	-0.13	-0.03	0.03	-0.06	0.01	-0.14	-0.17	**-0.20**	-0.14
X4	0.10	-0.07	**-0.21**	0.06	0.08	0.03	0.04	-0.09	-0.00	-0.16
X5	**0.20**	0.08	-0.05	0.13	0.17	0.09	0.14	0.11	-0.12	-0.03
X6	-0.05	-0.11	-0.06	0.10	-0.01	**-0.03**	-0.12	-0.13	-0.07	-0.17
X7	0.04	-0.03	-0.13	-0.04	0.04	0.12	0.05	0.00	-0.08	-0.11
X8	0.11	-0.03	-0.06	-0.11	0.11	0.13	0.00	-0.01	0.04	-0.11
X9	0.18	-0.04	0.15	0.00	0.01	0.11	-0.09	-0.07	-0.04	**-0.21**
X10	-0.02	-0.05	-0.05	0.03	0.04	0.04	-0.03	-0.10	-0.13	-0.16
XII	-0.04	-0.07	**-0.20**	0.03	-0.00	0.08	0.09	-0.15	-0.00	-0.01
X12	0.02	0.05	0.10	0.03	-0.01	0.11	-0.11	-0.13	0.09	0.02
X13	-0.02	-0.19	-0.18	-0.10	-0.05	-0.03	-0.05	-0.12	-0.08	0.01
X14	-0.09	-0.19	**-0.31**	-0.12	-0.07	-0.07	-0.03	-0.18	-0.09	-0.13

Figures in bold are significant at the 0 05 level

Table 4.32 : Correlation of variables in Set I with Variables in Set II.

	X25	X26	X27	X28	X29	X30	X31	X32	X33	X34
XI	-0.26	-0.29	-0.19	-0.20	-0.23	-0.26	-0.20	-0.13	-0.05	0.01
X2	-0.24	-0.23	-0.21	-0.19	-0.16	-0.17	-0.23	-0.16	-0.12	-0.04
X3	-0.08	-0.04	-0.09	0.06	0.04	-0.04	0.09	0.08	0.20	0.04
X4	-0.41	-0.50	-0.36	-0.24	-0.27	-0.22	-0.25	-0.18	-0.11	-0.03
X5	-0.38	-0.37	-0.26	-0.21	-0.22	-0.23	-0.23	-0.23	0.02	-0.10
X6	-0.22	-0.24	-0.19	-0.13	-0.14	-0.15	-0.01	-0.11	0.02	0.10
X7	-0.28	-0.27	-0.13	-0.13	-0.15	-0.13	-0.07	-0.04	0.07	0.12
X8	-0.13	-0.24	-0.17	-0.10	-0.15	-0.12	-0.08	0.01	-0.06	0.07
X9	-0.19	-0.20	-0.14	-0.14	-0.08	-0.14	-0.01	0.01	0.00	0.10
X10	-0.17	-0.23	-0.17	-0.11	-0.12	-0.11	-0.06	-0.12	0.06	0.03
XII	-0.25	-0.29	-0.25	-0.12	-0.17	-0.17	-0.22	-0.14	-0.10	-0.14
X12	-0.02	-0.08	-0.08	0.05	-0.04	-0.06	0.04	0.04	-0.06	-0.04
X13	-0.20	-0.24	-0.08	-0.11	-0.09	-0.05	-0.05	-0.08	0.02	-0.04
X14	-0.27	-0.28	-0.20	-0.04	-0.13	-0.06	-0.10	-0.08	0.06	0.03

Correlations of ±0.20 andf above were all significant at the 0.05 level

Table 4.33 : Correlation of variables in Set I with variables in Set III

Number	Variable	R^2
XI	Rhythm 1	0.41820
X2	Rhythm 2	0 37600
X3	Speech Rhythm	0.14689
X4	Tongue Mobility	0.52602
X5	Lip Mobility	0.25120
X6	Jaw Mobility	0.37108
X7	DDK Tongue	0.52424
X8	DDK Lips	0.41433
X9	DDK Jaw	0.51178
X10	Berges-Lezine's	0.36723
II1	Finger Tipping	0.45499
X12	Motor Memory	0.15501
XI3	Tongue Agnosia	0.14481
X14	Thumb Turning	0.47497

Table 4.34 : Squared multiple correlations of each variable in Set I with all other variables in Set I.

Number	Variable	R^2*
Misarticulations		
X15	High Vowels	0.37834
X16	Mid Vowels	0.34983
XI7	Low Vowels	0.24285
X18	Nasal	0.52247
X19	Plosive	0.55490
X20	Affricates	0.56405
X21	Fricatives	0.57059
X22	Laterals	0.59461
X23	Trills	0.42986
X24	Semivowels	0.48626

* In Tables 4.34 to 4.36, the R2 can be coverted to percentages by multiplying the given figure by 100. The derived percentage indicates the correlation between a given variable with the remaining variables, pu together, in the same set.

Table 4.35 : Squared multiple correlations of each variable in Set II with all other variables in Set II.

Number	Variable	R^2
No Responses		
X25	High Vowels	0.81253
X26	Mid Vowels	0.80662
X27	Low Vowels	0.65079
X28	Nasals	0.82608
X29	Plosives	0.72555
X30	Affricates	0.76645
X31	Fricatives	0.82079
. X32	Laterals	0.80508
X33	Trills	0.61685
X34	Semivowels	0.60027

Table 4.36 : Squared multiple correlations of each variable in Set III with all other variables in Set III.

It is evident from the results on the performances of the deaf dyspraxic subjects that, of the 14 variables in Set I, Variable X4 (tongue mobility) contributed the most - around 53% - to the explanatory power of the entire battery of tools for testing dyspraxia. Expectedly, it correlated positively and significantly with the most number of variables (12/13) in the set. At the 0.01 level, it correlated with 9 variables, namely, XI (rhythm-1), X2 (rhythm-2), X5 (lip mobility), X6 (jaw mobility), X7 (DDK tongue), X9

(DDK jaw), XlO(Berges and Lezine's), X11 (finger tipping), X14 (thumb turning), and at the 0.05 level with 3 variables, namely, X3 (speech rhythm), X8 (DDK lips) and X13 (tongue agnosia). Next came the variable X7 (DDK tongue), contributing around 52% to the explanatory power of the set. This variable correlated significantly at the 0.01 level with 5 variables, namely, XI (rhythm-1), X4 (tongue mobility), X8 (DDK lips), X9 (DDK jaw), X14 (thumb turning), and at the 0.05 level with the 4 variables X2 (rhythm-2), X5 (lip mobility), X12 (motor memory) and X13 (tongue agnosia). Variable X9 (DDK jaw) also contributed above 50%, that is, around 51% towards the predictions. This variable correlated significantly and positively at the 0.01 level with 4 other variables, namely, X4 (tongue mobility), X6 (jaw mobility), X7 (DDK tongue), X8 (DDK lips), and at the 0.05 level with 1 variable X11 (finger tipping).

Variables X14 (thumb turning), X11 (finger tipping), XI (rhythm-1), and X8 (DDK lips) contributed around 47%, 45%, 42%, and 41% respectively. Variables X2 (rhythm-2), X6 (jaw mobility), X10 (Berges and Lezine's), and X5 (lip mobility) contributed 38%, 37%, 37%, and 25% respectively. The other variables X12 (motor memory), X3 (speech rhythm), and X13 (tongue agnosia) contributed around 16%, 15%, and 14%.

Of the 10 groups of sounds misarticulated, variable X22 (misarticulation of laterals) correlated the most with the entire group of misarticulated sounds. They correlated 59% with the outcome of the other variables. It could also be said that 59% of the variance in all other variables together could be explained by the laterals This could be taken to imply that the laterals have greater chances of being misarticulated. This variable correlated positively and significantly with all the other 9 variables in the set at the 0.01 level. Similarly, variables X21 (fricatives), X20 (affricates), and X19 (plosives) correlated around 57%, 56%, and 55% with the outcome of the other variables. Accordingly these variables also correlated positively and significantly with all the other 9 variables in the set. Following laterals, the fricatives, affricates and plosives, in that order, have greater chances of being misarticulated. Variable X18 of misarticulated nasal sounds correlated 52% with the entire set and correlated positively at the 0.01 level with the 8 other variables of misarticulated sound groups - high-, mid-, low-vowels, nasals, plosives, affricates, fricatives, laterals and trills. But, it correlated with misarticulation of semivowels only at the 0.05 level.

The other variables, namely, X24 (semivowels), X23 (trills), X15 (high vowels), X16 (mid vowels), and X17 (low vowels) correlated 48%, 43%, 38%, 35% and 24%, respectively. Of all the sound groups the vowels seem to have relatively less chance of being misarticulated.

In the third set of 'no responses', there seemed to be considerable correlation between each component variable with the composite of other variables in the set. Predictably, each member variable had positive and significant correlation at the 0.01 level with each other individual variable of the set. The variables X28 (nasals), X3 1 (fricatives), X25 (high vowels), X26 (mid vowels), X32 (laterals), X30 (affricates), X29 (plosives), X27 (low vowels), X33 (trills), and X34 (semivowels) correlated around 83%, 82%, 81%, 81%, 81%, 77%, 73%, 65%, 61% and 60%, respectively, with the combined outcome of the other variables. -

4.9.1.2 Canonical Correlations between Variables in Set I and Set II

The details of canonical correlation function analysis between variables in Set I and Set II are presented in Tables 4.37 to 4.42. Analysis of interset correlation begins with Bartlett's test to determine the number of canonical variables required to warrant meaningful interpretation.

Eigenvalue	Canonical Correlation	Number of Eigenvalues	Bartlett's Test for remaining Eigenvalues		
			chi-square	d.f	tail prob.
			185.57	140	0.0060
0.34849	0.59033	1	142.94	117	0.0518
0.31342	0.55984	2	105.53	96	0.2377
0 29087	0.53933	3	71.33	77	0 6609
0 22260	0.47180	4	46.27	60	0.9035

0.14428	0.37984	5	30.77	45	0.9477
0.12869	0.35873	6	17.06	32	0.9857
0.07988	0.28263	7	8.78	21	0.9908
0.05148	0.22689	8	3.52	12	0.9906
0.02659	0.16305	9	0.84	5	0.9744
0.00841	0.09172				

Table 4.37 : Bartlett's test results for canonical correlation between variables in Set I and Set II.

Number	Variable	cnvr l-l
XI	Rhythm 1	0.412
X2	Rhythm 2	0.524
X3	Speech Rhythm	0.328
X4	Tongue Mobility	0.072
X5	Lip Mobility	-0.238
X6	Jaw Mobility	0.299
X7	DDK Tongue	0.037
X8	DDK Lips	0.056
X9	DDK Jaw	0.342
X10	Berges-Lezine's	0.182
XI1	Finger Tipping	0.235
XI2	Motor Memory	0.457

X13	Tongue Agnosia	0.025
X14	Thumb Turning	0.072

Table 4.38 : Canonical variable loadings for variables in Set I (when correlated with Set II).

No.	Variable	R^2	Adjusted R^2	F	df	p
XI	Rhythm 1	0.238	0.163	3.19	10,102	0.00
X2	Rhythm2	0.232	0.157	3.10	10,102	0.00
X3	Speech Rhythm	0.105	0.017	1.20	10,102	0.30
X4	Tongue Mobility	0.177	0.097	2.21	10,102	0.02
X5	Lip Mobility	0.158	0.076	1.92	10,102	0.05
X6	JawMobility	0.108	0.021	1.25	10,102	0.27
X7	DDKTongue	0.092	0.003	1.04	10,102	0.41
X8	DDKLips	0.106	0.018	1.21	10,102	0.29
X9	DDK Jaw	0.160	0.077	1.94	10,102	0.04
X10	Berges-Lezine's	0.071	-0.019	0.79	10,102	0.63
XII	Finger Tipping	0.141	0.057	1.68	10,102	0.09
X12	Motor Memory	0.121	0.034	1.41	10,102	0.18
X13	Tongue Agnosia	0.094	0.005	1.06	10,102	0.39
X14	Thumb Turning	0.134	0.049	1.58	10,102	0 12

Table 4.39 : Squared multiple correlations of each variable in Set I with all variables in Set II.

Number	Variable	cnvr II-I
XI5	High Vowels	-0.252
X16	Mid Vowels	-0.271
X17	Low Vowels	0.083
X18	Nasal	0.055
X19	Plosive	-0.187
X20	Affricates	0.288
X21	Fricatives	-0.354
X22	Laterals	-0.523
X23	Trills	0.003
X24	Semivowels	-0.382

Table 4.40 : Canonical variable loadings for the variables in Set II.

No.	Variable	R^2	Adjusted R^2	F	df	p
X15	High Vowels	0.217	0.105	1.94	14,98	0.04
X16	Mid Vowels	0.135	0.011	109	14,98	0.37
XI7	Low Vowels	0.203	0.090	1.79	14,98	0.07
X18	Nasal	0 091	-0.038	0.70	14,98	0.72

X19	Plosive	0 123	-0.001	0.99	14,98	0.45
X20	Affricates	0.133	0.009	1.08	14,98	0.38
X21	Fricatives	0.111	-0.015	0.88	14,98	0.55
X22	Laterals	0.150	0.029	1.24	14,98	0.27
X23	Trills	0.095	-0.034	0.74	14,98	0.68
X24	Semivowels	0.144	0.021	1.18	14,98	0.31

Table 4.41 : Squared multiple correlations of each variable in Set II with all variables in Set I.

Canon. Var.	Average Squared Loading for each Canonical Variable Set I	Av. Sq. Loading Times Squared Canon. Correl. Set I	Average Squared Loading for each Canonical Variable Set II	Av. Sq. Loading Times Squared Canon. Correl. Set II	Squared Canon. Correl.
1	0.08054	0.02807	0.08104	0.02824	0.34849

Table 4.42 : Redundancy index or average squared correlation coefficient for canonical correlation function analysis between variables in Set I and Set II.

Results of the Bartlett' s test above indicated the number of canonical variables necessary to express the dependency between the two sets of variables The necessary number of canonical variables was the smallest number of eigenvalues such that the test of the remaining eigenvalues were not significant. At the 0.01 level one variable could be considered. At the 0.05 level also, only one variable could be considered.

From the above derived results, it could be inferred that of the 14 tests for dyspraxia, the tests for rhythm-1 and rhythm-2 at the 0.01 level, and tests for tongue mobility, DDK jaw and lip mobility at the 0.05 level were significant in predicting the outcome of the test for articulation in terms of misarticulated sounds.

Of the 10 groups of sounds misarticulated, only the occurrence of misarticulation of high vowels could be successfully predicted and explained by the tests for dyspraxia as a group. The correlation matrix reveals a predominantly inverse pattern of relationship between performance on tests for dyspraxia and the occurrence of misarticulation. Low scores in dyspraxia coincided with high occurrence of misarticulation. Such significantly high relationships are noticed between test for rhythm-1 and low- and semi vowels; test for rhythm-2 and low-, mid- and high vowels; test for speech rhythm and trills, test for tongue mobility and low vowels; test for lip mobility and high vowels; test for DDK-jaw and semivowels; and test for finger tipping and low vowels.

The average squared loading multiplied by the squared canonical correlation gave the average squared correlation coefficient of a variable in one set with the canonical variable from the other set. It is also known as the redundancy index and is an index of the average proportion of variance in the variables in one set that is reproducible in the variables in the other set. This means that predictable misarticulations of a person on the test for articulation could be computed by using this coefficient with his scores on the tests for dyspraxia.

4.9.1.3 Canonical Correlation between Variables in Set I and Set III

The results of canonical correlation function analysis between variables in Set I and Set III are presented in Tables 4.43 to 4.48. As done earlier, analysis of interset correlation begins with Bartlett' s test to determine the number of canonical variables required to warrant meaningful interpretation.

As in the earlier analysis, Bartlett's test here indicates the number of canonical variables necessary to express the dependency between the variables of Set I and Set III. The necessary number of canonical variables was the smallest number of eigenvalues and the remaining eigenvalues were not significant. Here, at the 0.01 level, no variable could be considered and at the 0.05 level only one variable could be considered.

Eigenvalue	Canonical Correlation	Number of Eigenvalues	Bartlett's Test for remaining Eigenvalues		
			chi-square	d.f.	tail prob.
			174.93	140	0.0242
0.44608	0.66789	1	116.16	117	0.5047
0.27133	0.52089	2	84.66	96	0.7894
0.23628	0.48609	3	57.84	77	0.9495
0.19559	0.44226	4	36.18	60	0.9936
0.12588	0.35480	5	22.80	45	0.9976
0.08465	0.29095	6	14.00	32	0.9976
0.06387	0.25273	7	7.43	21	0.9971
0.03777	0.19435	8	3.60	12	0.9897
0.03373	0.18366	9	0.18	5	0.9993
0.00184	0.04290				

Table 4.43 : Bartlett's test results for canonical correlation between variables in Set I and Set III.

Number	Variable	cnvr I-I
XI	Rhythm 1	-0.511
X2	Rhythm 2	-0.402
X3	Speech rhythm	-0.122
X4	Tongue Mobility	-0.805
X5	Lip Mobility	-0.698
X6	Jaw Mobility	-0.480
X7	DDK Tongue	-0.570
X8	DDK Lips	-0.337
X9	DDK Jaw	-0.332
X10	Berges-Lezine's	-0.459
II1	Finger Tipping	-0.401
X12	Motor Memory	0.046
X13	Tongue agnosia	-0.394
X14	Thumb Turning	-0.574

Table 4.44 : Canonical variable loadings for variables in Set I (when correlated with Set III).

No.	Variable	R^2	Adjusted R^2	F	df	p
XI	Rhythm 1	0.155	0.073	1.88	10,102	0.05
X2	Rhythm2	0.107	0.019	1.22	10,102	0.28
X3	SpeechRhythm	0.120	0.034	1.40	10,102	0.19
X4	Tongue Mobility	0.317	0.251	4.76	10,102	0.00
X5	LipMobility	0.263	0.191	3.65	10,102	0.00
X6	JawMobility	0.194	0.116	2.47	10,102	0.01
X7	DDK Tongue	0.187	0.108	2.36	10,102	0.01
X8	DDKLips	0.130	0.045	1.53	10,102	0.14
X9	DDK Jaw	0.145	0.061	1.73	10,102	0.08
X10	Berges Lezine's	0.131	0.046	1.55	10,102	0.13
XII	Finger Tipping	0.124	0.038	1.45	10,102	0.16
X12	Motor Memory	0.096	0.007	1.09	10,102	0.38
X13	Tongue Agnosia	0.101	0.012	1.15	10,102	0.33
X14	ThumbTurning	0.202	0.124	2.59	10,102	0.00

Table 4.45 : Squared multiple correlations of each variable in the Set I with all variables in Set III.

Number	Variable	cnvr III-1
X25	High Vowels	0.763
X26	Mid Vowels	0.843
X27	Low Vowels	0.549
X28	Nasal	0.446
X29	Plosive	0.493
X30	Affricates	0.437
X31	Fricatives	0.412
X32	Laterals	0.368
X33	Trills	0.076
X34	Semivowels	0.033

Table 4.46: Canonical variable loading for variables in Set III

No.	Variable	R^2	Adjusted R^2	F	df	p
X25	High Vowels	0.289	0.188	2.86	14,98	0.00
X26	Mid Vowels	0.357	0.266	3.90	14,98	0.00
X27	Low Vowels	0.189	0.073	1.63	14,98	0.10
X28	Nasai	0.141	0019	1.16	14,98	0.33
X29	Plosive	0.147	0.025	1.21	14,98	0.29
X30	Affricates	0.162	0 042	1.35	14,98	0 21

X31	Fricatives	0.180	0.063	1.54	14,98	0.13
X32	Laterals	0.108	-0.018	0.85	14,98	0.57
X33	Trills	0.121	-0.004	0.97	14,98	0.47
X34	Semivowels	0.080	-0.050	0.61	14,98	0.79

Table 4.47 : Squared multiple correlations of each variable in Set III with all variables in Set I.

Canon. Var.	Average Squared Loading for each Canonical Variable Set I	Av. Sq. Loading Times Squared Canon. Correl. Set I	Average Squared Loading for each Canonical Variable Set II	Av. Sq. Loading Times Squared Canon. Correl. Set II	Squared Canon. Correl.
1	0.22930	0.10229	0.25384	0.11324	0.44608

Table 4.48 : Redundancy index or average squared correlation coefficient for canonical correlation function analysis between variables in Set I and Set III.

With regard to 'no responses', tests for mobility of tongue, lips and jaw, test for diadochokinetic rate of jaw, and thumb turning could successfully make predictions at the 0.01 level

In the 'no response' category, the high and mid vowels could be predicted and explained adequately. Here also, the correlation matrix revealed predominantly inverse relationship between performance on tests for dyspraxia and frequency of no responses. Low scores on dyspraxic tests means more number of 'no responses'. Significantly high inverse relationship was observed between test for rhythm-1 and high- and mid vowels, nasals, plosives, affricates, and fricatives; test for rhythm-2 and high-, mid- and low vowels, and fricatives; test for speech rhythm and laterals; test for tongue mobility and vowels, nasals, plosives, affricates, and fricatives; test for lip mobility and high-, mid- and low vowels, nasals, plosives, affricates, fricatives, and laterals; test for jaw mobility and high- and low vowels; test for DDK tongue and mid vowels; test for DDK lips and mid vowels; Berges and Lezine's test for intransitive hand positions and mid vowels; test for finger tipping and high-, mid- and low vowels, and fricatives; test for tongue agnosia and high- and mid vowels; test for thumb turning and high-, mid- and low vowels.

As mentioned earlier, the average squared loading multiplied by the squared canonical correlation yielded the average squared correlation of a variable in one set with the canonical variable from the other set. It is also called the redundancy index. This indicated the average proportion of variance in the variables in one set that is reproducible in the variables in the other set. Using this coefficient with the scores on the tests for dyspraxia, the outcome of the test for articulation could be successfully appraised.

4.10 Effects of Therapy

As mentioned earlier, all 113 deaf children were considered to be dyspraxic. It was decided to divide the entire group into two, and provide motor therapy for one and speech therapy for the other group. Accordingly, the 113 deaf subjects were at random divided into two groups of 56 and 57. 56 children of the first group (Group A) underwent motor therapy while children in the second group (Group B) were given speech therapy. There were equal number of male and female children in each age group, with the difference not exceeding 2 at any age. Table 4.49 gives the details of the subjects who underwent the two kinds of therapies.

After random grouping into motor and speech therapy groups, the children were administered therapy for 15 to 20 days. Posttherapeutically, the children were again tested for dyspraxia and speech articulation.

4.10.1 Effects of Motor Therapy

The posttherapeutic mean scores of the 56 children in the motor therapy group have been compared with their pretherapeutic scores by means oft-test for paired samples. The results of posttherapeutic testing of the motor therapy group are given in Tables 4.50 to 4.55 for the different age groups. The results in these tables are organized in the same way as in Table 4 1.

Age	Group A Motor Therapy Male	Fem.	Total	Group B Speech Therapy Male	Fem.	Total
4 years	5 +	4	9	5 +	4	9
5 years	5 +	4	9	5 +	4	9
6 years	5 +	4	9	5 +	4	9
7 years	6 +	4	10	6 +	5	11
8 Years	6 +	4	10	5 +	4	9
9 years	5 +	4	9	6 +	4	10
Total			56			57

Number of subjects

Table 4.49 : Details of subjects who underwent motor therapy or speech therapy.

	Pretherapy		Posttherapy				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	0.44	0 53	1.22	1.20	-2.13	8	NS
Rhythm 2	0.00	0 00	0.00	0.00	--	--	--
Sp. Rhythm	0.22	0.44	0.44	0.53	-1.51	8	NS
Tong. Mobility	7.00	1.80	13.33	2.12	-5.66	8	0.01
Lip Mobility	2.56	0.73	5.11	0.93	-7.56	8	0.01
JawMobility	2.33	0.50	4.33	0.71	-8.49	8	0.01
DDK-Tongue	0.91	0.40	1.33	0.50	-2.72	8	NS
DDK-Lip	1.24	0.35	2.04	0.09	-6.86	8	0.01
DDK-Jaw	1.62	0.39	2.20	0.20	-4.04	8	0.01
Berges-Lezine's	10.33	2.12	13.44	1.93	-3.37	8	0.01
Finger Tipping	11.78	1.72	16.56	2.65	-4.86	8	0.01
Motor Memory	1.67	1.23	3.44	1.24	-3.11	8	0.01
Tong. Agnosia	4.78	1.92	5.78	0.67	-1.55	8	NS
Thumb Turning	0.22	0.44	1.00	0.50	-3.50	8	0.01
Test for Articulation							
Correct	8.08	7.34	33.50	7.12	-9 24	8	0.01
Incorrect	52.69	24 05	66.50	7.12	-1.49	8	NS
No Response	39.23	27 67	0.00	0.00	4.25	8	0.01

Distortion	0.68	0.80	3.20	2.45	-2.67	8	NS
Addition	1.52	2.40	1.01	1.70	0.63	8	NS
Substitution	11.95	8.59	17.17	5.08	-1.86	8	NS
Omission	38.55	15.67	45.12	10.41	-0.98	8	NS

Table 4.50 : Pre- and posttherapeutic mean and standard deviation (SD) of Group A (motor therapy) subjects - 4 years of age, on tests for dyspraxia and articulation and the result oft-test analysis for the significance of difference of means at the 0.01 (p) level. 'df stands for degrees of freedom.

	Pretherapy		Posttherapy				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	1.00	0.50	1.50	0.73	-3.16	8	0.01
Rhythm2	0.11	0.33	0.44	0.53	-2.00	8	NS
Sp. Rhythm	0.22	0.44	0.44	0.53	-1.51	8	NS
Tong. Mobility	7.67	1.80	12.89	1.76	-5.56	8	0.01
LipMobility	2.56	0.53	5.22	1.39	-6.05	8	0.01
JawMobility	2.56	1.01	4.67	0.87	-3.92	8	0.01
DDK-Tongue	0.94	0.30	144	0.39	-3 00	8	0.01

DDK-Lip	1.50	0.42	1.98	0.38	-3.47	8	0.01
DDK-Jaw	1.88	0.71	2.51	0.63	-2.59	8	NS
Berges-Lezine's	10.78	1.88	13.44	1.88	-4.00	8	0.01
Finger Tipping	10.44	5.94	12.67	7.04	-1.58	8	NS
Motor Memory	2.44	0.73	3.11	1.45	-1.41	8	NS
Tong. Agnosia	3.78	1.99	4.67	1.65	-2.10	8	NS
Thumb Turning	0.11	0.33	0.78	0.97	-2.00	8	NS
Test for Articulation							
Correct	11.62	7.76	38.21	6.33	-6.44	8	0.01
Incorrect	51.18	26.28	61.79	6.33	-1.13	8	NS
No Response	37.20	29.86	0.00	0.00	3.74	8	0.01
Distortion	0.17	0.51	4.55	2.14	-5.96	8	0.01
Addition	3.17	5.31	3.03	4.01	0.34	8	NS
Substitution	14.31	7.46	18.18	3.39	-1.46	8	NS
Omission	32.99	8.43	36.03	8.43	-0.31	8	NS

Table 4.51 : Pre- and posttherapeutic mean and standard deviation (SD) of Group A (motor therapy) subjects - 5 years of age, on tests for dyspraxia and articulation and the result oft-test analysis for the significance of difference of means at the 0.01 (p) level, 'df stands for degrees of freedom.

	Pretherapy		Posttherapy				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	1.78	1.48	2.78	1.48	-3.46	8	0.01
Rhythm2	0.33	1.00	0.78	1.30	-2.53	8	NS
Sp. Rhythm	0.00	0.00	0.44	0.53	-2.53	8	NS
Tong. Mobility	9.11	1.17	13.44	3.81	-3.00	8	0.01
LipMobility	2.78	0.67	6.00	0.87	-8.84	8	0.01
JawMobility	2.89	1.05	5.78	1.09	-9.34	8	0.01
DDK-Tongue	1.14	0.24	1.82	0.54	-5.22	8	0.01
DDK-Lip	1.38	0.33	2.30	0.25	-10.14	8	0.01
DDK-Jaw	2.01	0.32	3.53	0.59	-6.17	8	0.01
Berges-Lezine's	9.44	1.86	13.06	3.04	-4.34	8	0.01
Finger Tipping	8.33	4.24	15.00	7.38	-3.80	8	0.01
MotorMemory	1.56	1.13	3.33	1.87	-3.25	8	0.01
Tong. Agnosia	5.11	1.54	5.44	0.89	-1.41	8	NS
Thumb Turning	0.78	0.67	1.33	0.87	-2.29	8	NS
Test for Articulation							
Correct	38.89	18.33	55.39	13.36	-5.81	8	0.01
Incorrect	60.44	17.84	44.61	13.36	5.60	8	0.01
No Response	0.67	2.02	0 00	0.00	1.00	8	NS

Distortion	3.87	4.68	5.73	1.47	-1.09	8	NS
Addition	3.03	4.22	3.54	2.94	-0.39	8	NS
Substitution	22.56	9.17	19.86	7.93	0.91	8	NS
Omission	30.98	17.99	15.49	6.33	3.17	8	0.01

Table 4.52 : Pre- and posttherapeutic mean and standard deviation (SD) of Group A (motor therapy) subjects - 6 years of age, on tests for dyspraxia and articulation and the result of t-test analysis for the significance of difference of means at the 0.01 (p) level, 'df stands for degrees of freedom.

	Pretherapy		Posttherapy				
Tests for Dyspraxia							
Rhythm 1	1.80	0.92	2.40	1.27	-2.25	9	NS
Rhythm2	0.50	0.71	1.70	1.83	-3.09	9	0.01
Sp. Rhythm	0.40	0.52	0.70	0.95	-1.41	9	NS
Tong. Mobility	9.60	1.17	15.70	1.25	-10.76	9	0.01
LipMobility	3.00	0.67	6.50	0.53	-21.00	9	0.01
JawMobility	2.80	0.92	6.60	0.70	-13.08	9	0.01
DDK-Tongue	1.09	0.19	2.04	0.49	-6.86	9	0.01

DDK-Lip	1.50	0.24	2.50	0.24	-13.42	9	0.01
DDK-Jaw	1.91	0.39	3.92	0.61	-8.98	9	0.01
Berges-Lezine's	10.15	3.08	14.50	0.85	-4.30	9	0.01
Finger Tipping	12.00	3.94	23.00	2.36	-11.39	9	0.01
Motor Memory	1.70	1.16	4.70	1.77	-6.71	9	0.01
Tong. Agnosia	5.60	0.84	6.00	0.00	-1.50	9	NS
Thumb Turning	1.30	0.95	2.70	0.48	-5.25	9	0.01
Test for Articulation							
Correct	40.75	11.41	50.76	6.36	-4.30	9	0.01
Incorrect	40.61	10.83	49.24	6.36	-2.03	9	NS
No Response	18.64	16.78	0.00	0.00	3.51	9	0.01
Distortion	0.00	0.00	8.19	2.28	-11.35	9	0.01
Addition	1.82	2.46	2.73	1.57	-0.83	9	NS
Substitution	15.45	8.83	15.91	5.86	-0.17	9	NS
Omission	23.33	6.97	22.58	8.19	0.22	9	NS

Table 4.53 : Pre- and posttherapeutic mean and standard deviation (SD) of Group A (motor therapy) subjects - 7 years of age, on tests for dyspraxia and articulation and the result oft-test analysis for the significance of difference of means at the 0.01 (p) level, 'df stands for degrees of freedom.

	Pretherapy		Posttherapy				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	2.33	1.41	3.56	2.30	-2.63	8	NS
Rhythm 2	0.89	0.60	2.67	2.00	-3.60	8	0.01
Sp. Rhythm	0.11	0.33	0.67	0.87	-2.29	8	NS
Tong. Mobility	10.78	2.86	16.00	1.65	-4.74	8	0.01
LipMobility	2.78	1.09	6.44	1.01	-15.56	8	0.01
JawMobility	3.00	0.87	6.78	0.97	-9.43	8	0.01
DDK-Tongue	1.22	0.44	2.17	0.35	-9.43	8	0.01
DDK-Lip	1.50	0.38	2.33	0.43	-7.14	8	0.01
DDK-Jaw	2.23	0.69	3.70	0.57	-5.84	8	0.01
Berges-Lezine's	11.33	3.30	14.78	1.66	-3.21	8	0.01
Finger Tipping	14.33	5.87	22.67	4.18	-7.14	8	0.01
MotorMemory	2.11	0.93	4.56	1.94	-4.05	8	0.01
Tong. Agnosia	5.00	1.94	5.78	0.44	-1.42	8	NS
Thumb Turning	1.56	1.01	2.33	0.50	-2.80	8	NS
Test for Articulation							
Correct	46.63	12.16	59.43	12.40	-4.85	8	0.01
Incorrect	42.59	11.94	40.40	12.38	0.50	8	NS
No Response	10.78	8.59	0.00	0.00	3.77	8	0.01

Distortion	1.01	1.31	6.40	3.77	-4.02	8	0.01
Addition	1.80	2.49	1.01	2.51	0.55	8	NS
Substitution	14.98	7.28	11.45	6.65	0.92	8	NS
Omission	25.42	11.48	21.38	6.22	1.03	8	NS

Table 4.54 : Pre- and posttherapeutic mean and standard deviation (SD) of Group A (motor therapy) subjects - 8 years of age, on tests for dyspraxia and articulation and the result oft-test analysis for the significance of difference of means at the 0.01 (p) level, 'df stands for degrees of freedom.

	Pretherapy		Posttherapy				
	Mean						
Tests for Dyspraxia							
Rhythm 1	1.90	1.29	3.00	1.89	-3.97	9	0.01
Rhythm2	0.90	0.88	1.50	1.08	-2.17	9	NS
Sp. Rhythm	0.90	0.74	1.90	0.88	-2.74	9	NS
Tong. Mobility	11.30	2.26	16.10	2.77	-5.80	9	0.01
Lip Mobility	3.40	0.84	7.00	0.67	-10.59	9	0.01
Jaw Mobility	3.70	0.82	6.80	0.92	-7.15	9	0.01
DDK-Tongue	1.30	0.61	2 75	0.26	-7.35	9	0.01

DDK-Lip	1.63	0.54	3.15	0.24	-7.67	9	0.01
DDK-Jaw	1.87	0.75	4.42	0.77	-5.66	9	0.01
Berges-Lezine's	12.25	1.65	14.65	1.62	-4.13	9	0.01
Finger Tipping	13.20	5.88	19.90	7.61	-5.41	9	0.01
Motor Memory	2.20	0.79	6.00	1.89	-6.63	9	0.01
Tong.Agnosia	4.70	2.50	6.00	0.00	-1.65	9	NS
Thumb Turning	1.60	0.84	2.40	0.70	-6.00	9	0.01
Test For Articulation							
Correct	42.73	8.14	62.88	4.64	-7.08	9	0.01
Incorrect	50.75	10.43	37.12	4.64	3.39	9	0.01
Distortion	1.06	1.02	4.09	2.03	-6.00	9	0.01
Addition	1.06	1.44	0.90	1.46	0.23	9	NS
Substitution	14.24	5.27	16.52	4.43	-0.89	9	NS
Omission	34.39	12.37	15.61	2.15	4.81	9	0.01

Table 4.55 : Pre- and posttherapeutic mean and standard deviation (SD) of Group A (motor therapy) subjects - 9 years of age, on tests for dyspraxia and articulation and the result of t-test analysis for the significance of difference of means at the 0.01 (p) level, 'df' stands for degrees of freedom.

	Pretherapy		Posttherapy				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	0.78	0.44	1.00	0.50	-1.51	8	NS
Rhythm2	0.00	0.00	0.22	0.44	-1.51	8	NS
Sp. Rhythm	0.22	0.44	0.56	0.53	-2.00	8	NS
Tong. Mobility	5.78	3.23	11.00	2.35	-6.57	8	0.01
LipMobility	2.22	0.83	3.89	0.78	-4.47	8	0.01
JawMobility	2.67	0.50	4.33	0.71	-10.00	8	0.01
DDK-Tongue	0.94	0.17	1.41	0.40	-3.81	8	0.01
DDK-Lip	1.37	0.38	2.17	0.25	-7.69	8	0.01
DDK-Jaw	1.94	0.45	2.43	0.59	-4.40	8	0.01
Berges-Lezine's	8.28	2.08	10.61	1.83	-5.29	8	0.01
Finger Tipping	2.22	1.64	11.33	5.87	-4.46	8	0.01
MotorMemory	1.89	1.05	3.22	1.09	-3.02	8	0.01
Tong. Agnosia	3.44	2.51	4.44	1.67	-1.90	8	NS
Thumb Turning	0.11	0.33	0.11	0.33	--	--	--
Test for Articulation							
Correct	6.91	7.65	26.77	10.16	-7.26	8	0.01
Incorrect	41.92	28.02	59.60	19.67	-1.97	8	NS
NoResponse	51.18	34.12	13.64	27.13	3.40	8	0.01

Distortion	0.51	1.07	3.87	3.22	-3.36	8	0.01
Addition	0.67	1.34	3.71	3 40	-3.33	8	0.01
Substitution	12.29	11.32	18.52	8.43	-1.84	8	NS
Omission	28.45	18.19	33.67	14.25	-0.81	8	NS

Table 4.56 : Pre- and posttherapeutic mean and standard deviation (SD) of Group B (speech therapy) subjects - 4 years of age, on tests for dyspraxia and articulation and the result of t-test analysis for the significance of difference of means at the 0.01 (p) level, 'df stands for degrees of freedom.

	Pretherapy		Posttherapy				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	0.67	0.50	0.78	0.44	-1.00	8	NS
Rhythm 2	0.00	0.00	0.33	0.50	-2.00	8	NS
Sp. Rhythm	0.22	0.44	0.22	0.44	--	--	--
Tong. Mobility	8.89	1.70	12.89	2 32	-5.51	8	0.01
LipMobility	1.89	0.78	4.00	0.71	-10.54	8	0.01
JawMobility	2.33	1.12	4 56	0.88	-10.00	8	0.01
DDK-Tongue	1.07	0.29	1.52	0.47	-3.47	8	0.01

DDK-Lip	1.39	0.22	2.17	0.25	-8.85	8	0.01
DDK-Jaw	2.10	0.42	2.58	0.44	-3.53	8	0.01
Berges-Lezine's	9.72	2.49	12.22	1.39	-3.49	8	0.01
Finger Tipping	6.00	2.96	12.11	3.86	-3.19	8	0.01
MotorMemory	2.33	0.71	3.11	1.05	-2.80	8	NS
Tong. Agnosia	4.11	2.62	5.00	1.73	-1.40	8	NS
Thumb Turning	0.67	0.71	0.78	0.67	-1.00	8	NS
Test for Articulation							
Correct	10.27	9.84	33.67	5.29	-5.97	8	0.01
Incorrect	45.79	28.39	66.33	5.29	-2.37	8	NS
No Response	43.94	34.60	0.00	0.00	3.81	8	0.01
Distortion	0.68	0.80	4.88	2.11	-5.33	8	0.01
Addition	3.03	4.29	3.87	3.04	-0.39	8	NS
Substitution	15.99	9.82	21.38	8.59	-1.88	8	NS
Omission	26.09	20.65	36.19	7.40	-1.35	8	NS

Table 4.57 : Pre- and posttherapeutic mean and standard deviation (SD) of Group B (speech therapy) subjects - 5 years of age, on tests for dyspraxia and articulation and the result of t-test analysis for the significance of difference of means at the 0.01 (p) level, 'df stands for degrees of freedom.

	Pretherapy		Posttherapy				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	1.00	1.00	2.22	1.48	-2.82	8	NS
Rhythm2	0.11	0.33	0.44	0.73	-1.41	8	NS
Sp. Rhythm	0.00	0.00	0.00	0.00	--	--	--
Tong. Mobility	9.44	0.88	13.67	1.50	-7.09	8	0.01
LipMobility	2.89	0.78	4.78	0.83	-7.25	8	0.01
JawMobility	2.67	0.71	5.00	0.71	-9.90	8	0.01
DDK-Tongue	1.19	0.30	1.39	0.31	-1.60	8	NS
DDK-Lip	1.69	0.46	1.94	0.45	-4.82	8	0.01
DDK-Jaw	2.31	0.62	2.84	0.51	-2.85	8	NS
Berges-Lezine's	9.11	2.41	11.06	3.11	-3.72	8	0.01
Finger Tipping	7.00	3.46	11.78	4.99	-5.17	8	0.01
Motor Memory	1.44	1.13	2.56	1.24	-2.29	8	NS
Tong. Agnosia	5.44	1.01	5.78	0.44	-1.00	8	NS
Thumb Turning							
Test for Articulation							
Correct	32.99	13.12	44.61	11.14	-7.02	8	0.01
Incorrect	66.16	12.47	55.39	11.14	5.44	8	0.01
No Response	0.84	2.02	0.00	0.00	1.25	8	NS

Distortion	3.37	3.10	6.90	2.53	-2.86	8	NS
Addition	3.70	4.29	3.87	3.40	-0.18	8	NS
Substitution	29.91	7.65	16.50	5.89	3.11	8	0.01
Omission	34.17	11.69	28.11	6.86	2.18	8	NS

Table 4.58 : Pre- and posttherapeutic mean and standard deviation (SD) of Group B (speech therapy) subjects - 6 years of age, on tests for dyspraxia and articulation and the result of t-test analysis for the significance of difference of means at the 0.01 (p) level, 'df stands for degrees of freedom.

	Pretherapy		Posttherapy				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	0.91	0.70	1.10	0.70	-1.49	10	NS
Rhythm2	0.00	0.00	0.36	0.51	-2.39	10	NS
Sp. Rhythm	0.18	0.41	0.27	0.47	-1.00	10	NS
Tong. Mobility	10.10	1.30	13.55	2.07	-5.19	10	0.01
LipMobility	3.18	0.75	4.73	0.01	-3.56	10	0.01
Jaw Mobility	2.45	1.21	4.27	0.91	-4.10	10	0.01
DDK-Tongue	1.18	0.34	1.41	0.20	-2.19	10	NS

DDK-Lip	1.64	0.39	1.93	0.45	-2.41	10	NS
DDK-Jaw	1.85	0.68	3.14	1.16	-4.77	10	0.01
Berges-Lezine's	11.68	1.33	13.00	0.87	-2.42	10	NS
Finger Tipping	11.82	4.62	15.91	3.42	-2.80	10	0.01
MotorMemory	1.73	1.10	2.64	0.81	-1.99	10	NS
Tong. Agnosia	4.91	1.30	5.91	0.30	-2.62	10	NS
Thumb Turning	**1.10**	0.94	2.45	0.93	-2.59	10	NS
Test for Articulation							
Correct	29.20	13.50	45.87	7.76	-5.84	10	0.01
Incorrect	45.73	22.88	54.13	7.76	-1.06	10	NS
No Response	25.07	28.66	0.00	0.00	2.90	10	0.01
Distortion	0.55	1.02	10.33	2.43	-14.88	10	0.01
Addition	1.38	0.91	2.76	0.91	-2.66	10	NS
Substitution	17.49	17.54	18.32	6.15	-0.18	10	NS
Omission	26.31	21.62	22.73	8.27	0.50	10	NS

Table 4.59 : Pre- and posttherapeutic mean and standard deviation (SD) of Group B (speech therapy) subjects - 7 years of age, on tests for dyspraxia and articulation and the result of t-test analysis for the significance of difference of means at the 0.01 (p) level, 'df stands for degrees of freedom.

	Pretherapy		Posttherapy				
	Mean	SD	Mean	SD	t aaad f		p
Tests for Dyspraxia							
Rhythm 1	0.70	0.82	1.40	0.97	-2.33	9	NS
Rhythm2	0.30	0.48	0.70	0.95	-1.31	9	NS
Sp. Rhythm	0.40	0.70	0.50	0.97	-1.00	9	NS
Tong. Mobility	9.70	1.25	14.60	1.35	-9.71	9	0.01
LipMobility	2.70	1.10	5.30	0.82	-6.50	9	0.01
JawMobility	3.30	0.82	5.40	0.97	-7.58	9	0.01
DDK-Tongue	0.98	0.06	1.30	0.35	-3.01	9	0.01
DDK-Lip	1.40	0.39	1.75	0.35	-2.33	9	NS
DDK-Jaw	1.93	0.60	3.37	0.52	-5.87	9	0.01
Berges-Lezine's	12.65	1.40	13.05	1.67	-0.51	9	NS
Finger Tipping	11.90	4.65	15.60	2.72	-2.79	9	NS
MotorMemory	1.90	1.45	2.50	1.18	-1.33	9	NS
Tong. Agnosia	5.10	0.88	5.80	0.63	-2.69	9	NS
Thumb Turning	1.20	1.03	2.00	0.82	-4.00	9	0.01
Test for Articulation							
Correct	31.06	15.19	51.52	7.49	-3.14	9	0.01
Incorrect	30.45	15.48	48.03	7.53	-3.48	9	0.01
No response	38.48	26.72	0.45	1.44	4.39	9	0.01

Distortion	0.61	0.79	4.55	2.67	-4.63	9	0.01
Addition	0.30	0.64	0.15	0.48	0.56	9	NS
Substitution	8.33	8.40	17.12	6.06	-4.06	9	0.01
Omission	21.21	11.84	26.21	6.19	-1.28	9	NS

Table 4.60 : Pre- and posttherapeutic mean and standard deviation (SD) of Group B (speech therapy) subjects - 8 years of age, on tests for dyspraxia and articulation and the result of t-test analysis for the significance of difference of means at the 0.01 (p) level, 'df stands for degrees of freedom.

	Pretherapy		Posttherapy				
	Mean	SD	Mean	SD	t	df	p
Tests for Dyspraxia							
Rhythm 1	1.11	0.78	1.89	1.27	-2.80	8	NS
Rhythm2	0.11	0.33	0.56	0.73	-2.53	8	NS
Sp. Rhythm	0.33	0.50	0.44	0.53	-1.00	8	NS
Tong. Mobility	9.78	1.09	16 33	1.12	-17.40	8	0.01
LipMobility	3.44	0.88	5 78	0.83	-14.00	8	0 01
JawMobility	3.33	1.00	5.56	0.73	-10.00	8	001
DDK-Tongue	1.06	0.17	1.67	0.56	-3.77	8	0 01

DDK-Lip	a1.54	0.56	2.00	0.43	-2.64	8	NS
DDK-Jaw	1.72	0.80	3.43	0.40	-6.17	8	0.01
Berges-Lezine's	12.11	1.56	13.44	1.42	-2.60	8	NS
Finger Tipping	12.33	4.87	15.56	5.73	-1.83	8	NS
Motor Memory	2.33	1.32	3.22	0.44	-2.53	8	NS
Tong. Agnosia	4.67	2.40	5.22	1.64	-1.00	8	NS
Thumb Turning	1.22	0.83	2.22	0.83	-6.00	8	0.01
Test for Articulation							
Correct	32.65	11.24	55.72	7.38	-6.89	8	0.01
Incorrect	52.53	16.18	44.28	7.38	1.62	8	NS
No Response	14.82	21.72	0.00	0.00	2.05	8	NS
Distortion	0.68	0.80	5.56	1.31	-9.94	8	0.01
Addition	0.84	1.34	0.84	1.34	0.00	8	NS
Substitution	15.99	7.11	17.68	4.55	-0.76	8	NS
Omission	35.02	10.45	20.20	9.49	'3.24	8	0.01

Table 4.61 : Pre- and posttherapeutic mean and standard deviation (SD) of Group B (speech therapy) subjects - 9 years of age, on tests for dyspraxia and articulation and the result of t-test analysis for the significance of difference of means at the 0.01 (p) level, 'd'f stands for degrees of freedom.

The results in Tables 4.50 to 4.55 can be summarized as follows:

a) All deaf children in the motor therapy group improved their performance on all tests for dyspraxia following motor therapy. However, the difference was significant, at the 0.01 level, only for tests on mobility of articulators (tongue, lips, jaw), diadochokinesis (tongue, lip, jaw), Berges and Lezine's test for intransitive hand positions, finger tipping test, and test for sequential visual-motor memory. Results on tests for rhythm (rhythm-1, and rhythm-2) were inconsistent. Rhythm- 1 mean scores were significantly different for age 5, 6 and 9 years, while the rhythm-2 test means were significantly different only for children aged 7 and 8 years. Mean scores on test for speech rhythm and tongue agnosia were not significantly different for any age group. Difference in mean scores on test for thumb turning was statistically significant for children in the age group of 4, 7 and 9 years.

b) Though all children undergoing motor therapy improved their performance on all the tests for dyspraxia posttherapeutically, the difference between pre- and posttherapeutic performance was most noticeable on tests for mobility of articulators (tongue, lips, jaw) wherein they almost doubled their mean scores at all age levels, posttherapeutically. The differences in mean scores was also noticeable especially in older children of 7, 8, and 9 years on tests for diadochokinesis (tongue, lips, jaw) where again they doubled their score.

c) As far as articulation test was concerned, children in all the age groups, improved their mean score of correct articulation posttherapeutically. Also, the mean percentage of 'no responses' at all age levels, decreased significantly following therapy. Both the differences in mean scores were significant at the 0.01 level. Mean percentage of incorrect responses increased posttherapeutically in the case of children of 4, 5, and 7 years, but the difference was not statistically significant. But, the percentage of incorrect responses decreased posttherapeutically in the case of children of 6, 8 and 9 years, but the difference was statistically significant only in the case of children aged 6 years and 9 years. This implies that the decrease in the number of 'no responses' was due to the increase in the number of correct responses.

d) Mean percentage of different type of articulation errors, in terms of substitution, omission, distortion, and addition remained the same posttherapeutically with a few exceptions.

4.10.2 Effect of Speech Therapy

A similar comparison of the performance of deaf children who underwent speech therapy was done and the results are given in Tables 4.56 to 4.61. Statistical procedures employed in this analysis were the same as with the motor therapy results. These results can be summarized as follows:

a) Children of all ages improved their performance on test for dyspraxia posttherapeutically. However, the pre- and posttherapeutic mean scores were statistically significant (0.01 level) only for tests of mobility of articulators (tongue, lips, jaw) in all the age groups. Pre- and posttherapy scores were significantly different for Berges and Lezine's test for intransitive hand positions (4, 5 and 6 years) but, not so in the older groups of children (7, 8 and 9 years). In general, children aged 4 and 5 years showed significant increase on tests for mobility of articulators, diadochokinesis, Berges-Lezine's, and finger tipping. Older children of 6, 7, 8 and 9 years showed significant improvement on tests for diadochokinesis of either jaw, lips or tongue. None of the children showed significant improvement on tests for rhythm (rhythm - 1, rhythm-2, speech rhythm) and tongue agnosia.

b) As for as articulation test was concerned, all the children in all the age groups significantly improved on their mean percentage of correct articulation, and significantly decreased on their percentage of 'no responses'. The percentage of distortion errors significantly increased, following therapy, in the case of children of all ages except 6 years while substitution errors increased significantly in the case of older children.

Chapter 5

DISCUSSION

5.1 Objectives of the Study

The present study was an investigation of the prevalence of dyspraxia in profound deaf children. An assessment battery for identifying dyspraxia in deaf children was assembled/developed for this purpose. The nature of dyspraxic errors and their effects on the articulation of speech sounds in deaf children was investigated employing this battery along with a picture-word test for articulation in Tamil. Following the initial testing and identification of dyspraxic errors, the deaf children, in two groups, were put under a course of either motor therapy or speech therapy. The effects of the remedial therapy in strengthening motor skills, or speech articulation, or both were investigated. The reciprocal influence of motor therapy on speech articulation and speech therapy on the development of motor skills were also investigated.

5.2 Subjects

The 113 subjects, included in the study, generally constituted a homogeneous group of profound deaf children. The children were in the age group of 4 to 9 years, were of average or above average intelligence, had no additional physical, mental or neurological problems, and came from upper or lower middle socioeconomic class.

All these children attended special schools for the hearing impaired with Tamil as the medium of instruction at school. It was ensured that children who had received or were receiving any kind of specific training in manual form of communication or any purposive therapy for speech articulation problems were not included in the study. The children were generally receiving training in elementary science, social science and mathematics. A small number of children in this group varied in certain characteristics like handedness, hereditary inheritance of hearing impairment, etc.

Similarly, a control group of 60 normal hearing children, fulfilling all the selection criteria as the children in the deaf group except the one pertaining to hearing loss was formed. As in the deaf group, the normal children were in the age group of 4 to 9 years of age, were of average or above average intelligence, had no physical, mental or neurological problems, and came from upper or lower middle socioeconomic strata. All the 60 children had Tamil as their native tongue. However, all normal children were undergoing formal instruction in different subjects as appropriate for their age. The control group included equal number of boys and girls.

5.3 Assessment for Dyspraxia and Articulation

5.3.1 Tests for Dyspraxia

A review of pertinent literature revealed that presence of speech dyspraxia was a reflection of deficits in the development of rhythm, lack of control over purposive intransitive movements (especially of the articulators), impaired sequential visual-motor memory, among others. It also suggested, but not yet experimentally confirmed, a close association between articulatory dyspraxia and certain inadequacies like poor oro-sensory perception and not fully established lateralization. Therefore, an assessment battery was set up for identifying children with articulatory dyspraxia, and it included testing for the above mentioned characteristics. The component tools of the test battery are described below.

5.3.1.1 Tests for Rhythm

This test included repetition of simple rhythmic sequences following a demonstration by the experimenter. The children were required to imitate the production of a series of monosyllables. The syllables included /ba/, /va/, /9a/, /na/, or /ka/ to reflect the labial, dental, alveolar, palatal and velar levels of articulatory production.

i) Test for Rhythm-1: The purpose was to test the ability of the children to imitate 4 simple rhythmic sequences (consisting of specific number of syllables sequenced with specific patterns of intervals in between). The oral production of the rhythmic sequences by the experimenter was accompanied by simultaneous manual tapping of the same pattern on a flat surface.

ii) Test for Rhythm-2: This test was based on van Uden's (1970) test for oral rhythm. It was a variation of test for rhythm-1 in that it included an added feature of stress being placed on selected syllables in the 10 sequences. A second difference from the test for rhythm-1 was that production of these syllable sequences by the experimenter was not accompanied by manual tapping in the test for rhythm-2.

iii) Test for speech rhythm: This test was not just a mechanical repetition of rhythmic sequence of syllables but the rhythm of the sequence of syllables was actually patterned on phrases of everyday Tamil speech. The stimulus sequences were styled on 10 simple conversational sentences in Tamil. They included an added feature of vowel prolongation.

5.3.1.2 Tests **for** Mobility **of** Articulators

These tests were intended to test the control of the subjects on the volitional fine motor movements of the articulators, namely, the tongue, lips and the mandible.

Test for tongue mobility : This tool was for the testing of the control of purposive, voluntary, intransitive movements of the tongue using 10 stimulus movements which the children had to imitate after the tester. It was an adapted version of Chilla and Kozielski's (1977) tongue motility test. Mobility of the lips (imitation of four movements) and jaw was also tested in a similar manner.

5.3.1.3 Tests for Diadochokinetic Rate of the Articulators

Diadochokinesis of the articulators, namely, the tongue, the lips and the lower jaw was sought to be tested here.

i) Diadochokinetic rate of the tongue: The test consisted of rapid repetitive movements of the tongue tip to touch the alveolar ridge as in the production of the sound /0a/. It was not essential that the children produce the speech sound also, but execution of the intended movement was enough.

ii) Diadochokinetic rate of the lips: This included rapid opening and closing movements of the lips, as in the repetition of /pa/. Again, it was not necessary to produce the actual sound.

iii) Diadochokinetic rate of the jaw: This included rapid opening and closing movements of the lower jaw, as in the repetition of /ja/ with or without the sound.

5.3.1.4 Test for Intransitive Hand Movements

The purpose here was to test for control of intransitive motor movements of the hands. This was a test for eupraxia with lateralization and differentiation of finger movements.

i) Berges and Lezine's test for intransitive hand positions (1963): This test consisted of sixteen intransitive hand positions. The experimenter formed these hand positions, one by one and out of the subject's sight and later displayed the complete form to the subjects. The subjects were required to imitate the displayed configuration.

ii) Finger Tipping Test (van Uden, 1967): The test involved establishing contact repetitively and at a given tempo, between the tip of the thumb and the tip of the other four fingers.

5.3.1.5 Test for Sequential Memory

The purpose of this test was to study the sequential visual-motor memory in the children by testing their ability to recall and imitate motor movements of the hand presented/demonstrated sequentially in time by the experimenter.

i) Test for Memory of Motor Movements of Hand: This was adapted from the subtest of memory for hand movements from Kaufman's (1983) assessment battery for children. Combinations of two or more configurations of the three motor movements of the hand were used for the purpose. The tester demonstrated sequences of three movements - of placing the hand with the palm down, or palm placed vertically facing side, or only place the fist. The subjects were required to successively repeat these movements from memory as demonstrated by the tester.

5.3.1.6 Test for Tactile Agnosia of the Tongue

The purpose of this tool was to test for tactile sensitivity in the tongue. The test involved touching six specific points on the out-stretched tongue of the subjects who were seated with their eyes closed. The subjects were required to identify and point, with their finger tip, the part of the tongue touched.

5.3.1.7 Thumb Turning Test

The purpose of this test was to test for the control of lateralization of movements. This test involved twisting either of the thumbs independently and then both together. Accompanying movements in the mouth (especially of the lips and the tongue), or other parts of the body were taken to be signs of incomplete lateralization.

5.3.2 Articulation Test : Picture-word Articulation Test

The purpose of this test was to test the ability of the children to produce the 35 and odd phonemes in the word -initial, -medial and -final position. The language of testing was Tamil.

This was an adapted version of Usha's test for articulation (1986). The child's ability of articulate different sounds was tested using 66 stimulus words which carried one of these 35 phonemes in the initial, medial or final position. These stimulus words were presented in the form of unambiguous pictures which the children had to name. Thus the children produced the test phoneme spontaneously. In case the children were unable to name any of the pictures, the stimulus word was provided by the tester which they had to repeat. The children's incorrect responses were categorized and analysed in terms of omission, addition, substitution and distortion of phonemes.

5.4 Analyses

The study addressed 3 issues: first, the prevalence of dyspraxia in profound deaf children; second, effects of dyspraxia on speech articulation in these children; and third, the influence of motor and speech therapy in strengthening speech articulation and motor skills.

The prevalence of dyspraxia was analysed by comparing the performance of each deaf child with the mean performance of the control group of normal hearing children of the given age group. Linear discriminant analysis (Fisher, 1936) was employed to verify whether this procedure of identifying dyspraxics among deaf children was adequate. This is a statistical technique for appraising the competency of a diagnostic tool in identifying any characteristic. This procedure also validated the classification of children into dyspraxic and nondyspraxic categories along with identifying the tools which are efficient in discriminating the children on the basis of the specified characteristic. The specified characteristic was, of course, the presence or absence of dyspraxia.

The second issue was to study the nature of dyspraxic errors and their implications for speech sound articulation in deaf children. The canonical correlation analysis (Thompson, 1984) was employed for this purpose. This statistical procedure computed 2 sets of correlations. First, it computed correlations between variables of a given set. For example, the relationship between the different types of dyspraxic tests, or the relationship between the different types of dyspraxic tests, or the relationship between the different groups of sounds in their misarticulation. Second, correlations were computed to assess the relationship of each variable in one set with the composite of the variables of the other set. For example, the influence of any one type of dyspraxic error on the occurrence of misarticulations. Thus, this procedure provided for understanding the nature of dyspraxic errors and their implication for the speech sound articulation in deaf children.

The third issue was to evaluate the influence of motor and articulation therapies in alleviating dyspraxic and speech articulation errors in deaf children. This was done by comparing between pre- and posttherapeutic performance of children who underwent motor or articulation therapy. Comparison was done on the performance of children on both the tests for dyspraxia and articulation. The analysis was carried out using the t-test for paired samples. Again 2 types of comparisons were made : the effect of motor therapy on motor and speech skills, and the effect of speech therapy on articulatory and motor skills.

Agewise comparison between the performance of the deaf and the normal hearing children on tests for dyspraxia and articulation was made. One-way analysis of variance (ANOVA) with Student-Newman-Keuls posthoc test was carried out for this purpose. A similar comparison of the performance of male and female children within the deaf and the normal hearing groups was made using t-test for independent samples.

5.5 Assessment Battery For Dyspraxia

The first major aim of this study was to set up a battery of tools to test for dyspraxia. Dyspraxia in this study was assessed in terms of deficits children have in the development of rhythm, control over voluntary oral intransitive movements, diadochokinesis of the articulators, control over intransitive movements of the hands, sequential visual-motor memory, tactile agnosia in the tongue, and lateralization. Comparison of the performance of each individual deaf child with the mean scores of the normal hearing children of the respective age level revealed that all the deaf children had performed lower than normal children of their age level in more than one test for dyspraxia.

These results partially agree with those of an earlier investigation (van Uden, 1981) which recommended a test battery for the examination of dyspraxic errors and specifically recommended inclusion of tests for sequential visual-motor memory (subtest of Hiskey-Nebraska Learning ability test, 1966), eupraxia of fingers (Berges-Lezine's test, 1963), and for eurhythmia. The test battery of the present study included all the tests recommended by van Uden (1983). It included Berges-Lezine's test for intransitive hand positions for testing eupraxia in the fingers, test for eurhythmia adapted from van Uden's original test (1970), and also test for speech rhythm that was specifically constructed for this study. Broesterhuizen (1997) also recommended inclusion of tests for examining the independent skills of eupraxia of hand and mouth, successive memory, and eurhythmia. He opined that these are three important aspects of eupraxia of speech.

Other than these, the test battery also included certain other tests which have been suggested by researchers to be considered in testing for speech dyspraxia in the normal hearing. For example, tasks on repetition of monosyllables (Wertz and Rosenbek, 1971; Dabul, 1979). The present test included diadochokinetic tests for tongue, lips and jaw. The deaf and the normal children indeed performed differently on these tests. Recommendation of Dabul (1979) to include measures for oral and limb apraxia were considered by including the tests for mobility of the tongue, lips and jaw, and the Berges and Lezine's test for intransitive hand positions. In addition, the present test battery also included the test for thumb turning following the proposition of Brain (1965) that developmental verbal apraxia was often associated with incomplete lateralization. The present test battery is different from the previous test approaches in two respects: it has included more number of tests than in any other previous battery, thereby making it more comprehensive; and in testing for rhythm, the present study has included a test for testing speech rhythm as found in everyday speech.

5.5.1 Results of Linear Discriminant Analysis

The linear discriminant function analysis identified 7 tests as being more effective than the others in identifying the presence of dyspraxia in children. The following tests, in the order given, were identified by the linear discriminant function analysis as the more efficient tests of the battery in the identification of dyspraxia:

a) Rhythm-2,
b) Thumb turning,
c) Berges and Lezine's intransitive hand positions,
d) Speech rhythm
e) Diadochokinetic rate of jaw,
f) Tongue mobility, and
g) Jaw mobility.

As said earlier, the linear discriminant function analysis identified 7 tests as more efficient in identifying dyspraxia. This result is more or less in agreement with previous findings. The results of the present study confirm the efficacy of certain tests, reported by. past research, in identifying dyspraxia. For example, diadochokinetic movements of jaw (Wertz and Rosenbek, 1977), tongue and jaw mobility (Dabul, 1979), Berges and Lezine's test for intransitive movements (Dabul, 1979), and test for thumb turning (Brain, 1965) have all been found very effective in identifying dyspraxia. In addition, test for rhythm2 (where the children were required to produce a series of syllables at a given rhythm and stress) and speech rhythm have also been found to be very effective tools in identifying dyspraxia.

Deficient performance of deaf children on tests of diadochokinesis of jaw, tongue and jaw mobility, Berges-Lezine's test for intransitive movements and thumb turning test can be interpreted to mean that the deaf children lack these required motor skills. However, the poor performance on tests of rhythm-2 and speech rhythm (where the children were expected to produce the rhythm as found in conversational tamil speech) may be because of a deficiency in either motor skills or perceptual skills. The children have to perceive and comprehend the rhythmic patterns of conversational speech before they can produce them. Therefore, the deficient performance of deaf children on tasks of rhythm, particularly speech rhythm, need not necessarily implicate deficient motor skills.

One of the tests which had been found to be efficient in identifying dyspraxia (van Uden, 1983), but which was not selected by the linear discriminant function analysis in this study was the test for sequential visual-motor memory (motor memory). This may be because deficiency in sequential visual-motor memory may not be an innate neural dysfunction but rather results from inadequate usage of speech mechanism. There might be subgroups of dyspraxic children where the dyspraxia is a developmental problem.

It is tentatively concluded that

a) it is possible to identify dyspraxic errors in deaf children with a battery of tests designed to analyse rhythm, articulatory mobility, diadochokinesis and intransitive movements, among others, and

b) that specifically a battery including tests of (i) rhythm-2 (with stress pattern included), (ii) thumb turning, (iii) Berges-Lezine's test for intransitive hand positions, (iv) speech rhythm, (v) diadochokinetic test for jaw movement, (vi) tongue mobility and (vii) jaw mobility is sufficient to identify dyspraxia.

5.6 Prevalence of Dyspraxia

The linear discriminant analysis classified all the 113 deaf children included in the study as dyspraxics (100%) based on the results from the 7 tests of the battery of tools which it considered as more efficient in identifying dyspraxia. This finding is in contrast to the findings of van Uden (1971) who reported that only 20 - 25% of the prelingually profound deaf children have associated problems of speech dyspraxia. This again may be attributed to the inadequate usage of speech structures by these deaf children. A general observation is that deaf children in this country seek speech therapy services quiet late in their development. By the time they seek speech therapy, they would have developed their own manual modes of communication and thus tend to use their speech mechanism very less. Therefore, the percentage of speech dyspraxia in these children would be quiet high. Also, in the list of 7 tests identified by linear discriminant analysis, there are 5 tests which deal directly with the functioning of the speech structures. The implication of this finding is two fold: one, that the deaf children are more likely to be identified as dyspraxic if the motor skills (or perceptual skills) related to the speech mechanism are affected and two, the normal and the deaf children, of corresponding age, are more likely to be equal in their motor skills related to nonspeech mechanism.

Another reason for the high prevalence rates of dyspraxia in our children could be attributed to the fact that we had not included children who had received any kind of corrective therapy for speech misarticulation or improvement of motor skills.

In general, the high prevalence rates of dyspraxia in deaf children corroborates the findings of Tsuzuku and Kaga (1991) who opined that development of motor function is very frequently retarded in children with congenital deafness and that lack of auditory stimulation during their development leads to deficiencies in the coordination of actions (Savelsbergh, Netelenbos and Whiting, 1991). It can be assumed that speech dyspraxia is widely prevalent among the congenital

* deaf children probably as a developmental problem.

Test for thumb turning was one of the tests identified by the linear discriminant analysis as a more efficient test in the identification of dyspraxia. However, one finds that (Tables 4.1 to 4.6) the mean scores of the deaf and normal children on this test was not statistically significant at any age group. A question to be answered is this : How a test on which the deaf and normal children performed at the same level can be taken as a sensitive tool in the identification of dyspraxia? This incongruity, if at all there is one, needs to be addressed in future research.

There are no studies in the Indian context on the prevalence of speech dyspraxia in deaf children. Thus, this report is the first attempt to quantify the problem in the Indian context. These findings need to be confirmed by other studies in this country.

5.7 Comparison of Deaf and Normal Children

Comparison of the performance of the deaf and the normal hearing children, as a function of their age, revealed significant differences between the two groups on almost all the tests of dyspraxia and articulation, and at all age levels.

5.7.1 Rhythm

The performance of deaf children was significantly different from normal children of corresponding age on tests of rhythm. This finding confirms previous findings of van Uden (1983) and Broesterhuizen (1997) that eurhythmia is a constituent aspect of eupraxia. Of the 3 tests for rhythm, the deaf seemed to perform relatively better on the test for rhythm- 1 which offered additional manual support to oral production of rhythmic sequences in the form of tapping. This may imply that inadequate oral practice had led to deficiency in oral eurhythmia while manual rhythm is relatively less affected. There are also other studies (Calvert, 1980; 1982) which reported that severe congenital hearing loss by itself can impair control of rhythm in speech. On the tests for rhythm, both the deaf and the normal children appeared to improve with increasing age, but the rate seemed to be higher in normal compared to deaf children (however, not statistically tested). One factor that could be influencing greater improvement in normals children is the constant use of articulators by the normal children.

5.7.2 **Mobility of Articulators**

The eupraxic normal hearing had performed consistently and significantly better than the deaf in all the 3 tests for oral eupraxia (tongue, lips and jaw) in all the age groups. This corroborates the findings of Broesterhuizen (1997) that eupraxia of mouth is an essential aspect of eupraxia for speech. Again, both the deaf and normal continued to improve their articulatory motility skills with increase in age, but the change was more pronounced in the normal hearing group. Deaf children showed greater improvement with age on skills of tongue mobility compared to lip and jaw mobility.

5.7.3 **Diadochokinesis**

The diadochokinetic skills in the normal hearing were almost twice better than that of the deaf children. The difference was more pronounced in the older age groups. This finding justifies the inclusion of tests for diadochokinesis in the test battery for dyspraxia. Although not much information about diadochokinetic performances in the dyspraxic deaf are available, a more detailed study of the performance of children on these highly volitional acts may reveal more about dyspraxia. For one thing, diadochokinetic movements are not just movements of the articulators in isolation. Production of /pa/ represents a shifting of articulatory configuration from a completely closed vocal tract to a completely open vocal tract. It also reflects the coordination between articulators and the transitions of articulatory postures. The obtained results on diadochokinetic skills in the present study indicated that the deaf children were more proficient in the usage of tongue (though still depressed compared to normals) in comparison with that of lips and jaw. This finding has definite implications for dyspraxia and speech therapy.

Another noticeable result on these tests was that the rate of repetitive movements of the articulators in the normal hearing children is at times less than that reported by previous studies. Sprague (1961) reported an average rate of 3 to 3.5 tongue movements/second in normal children. In this study, only 8 and 9 year old normal hearing children were able to reach this level. But, all children were well within the average range for movements of the lips reported for normal children - 3 to 6 movements/second (Blomquist, 1950; Sprague, 1961). Details on the rate of jaw movements in younger children of 4, 5 and 6 years are not available, but data is available for older children. The older normal hearing children of 7, 8 and 9 years of this study reached the levels reported earlier by Jenkins (1940).

5.7.4 Intransitive Movements of the Hands

The performance of the normal hearing and the deaf children who were classified as nondyspraxics and dyspraxics in this study was not consistently significantly different in all the age groups. This is contrary to the findings of van Uden (1983) and Broesterhuizen (1997) that eupraxia of speech is closely associated with fine motor skills of hand. On the test for finger tipping, the normal hearing children were significantly better than deaf from age 6 years onwards upto 9 years. The mean scores of normal hearing children of 4 and 5 years of age were not significantly different from that of deaf children. This implies that the deaf begin with eupraxia in the hands, but it weakens with increasing age although the reasons for this is not known. If the deaf children in this country develop their own manual systems of language, as we have claimed earlier, then there is no reason for the deaf children to lose some of their skills of eupraxia of hand. In any case, the linear discriminant analysis did not select the finger tipping test as one of the more efficient tests in the identification of dyspraxia.

On the Berges-Lezine's test for intransitive hand positions, the dyspraxic deaf actually exceeded the performance of normal children of corresponding age, but the difference was statistically significant only for children of 4 and 5 years. This implies that verbal dyspraxia need not necessarily be associated with dyspraxia of hands.

5.7.5 **Sequential Visual-Motor Memory**

Results of the present study on the sequential visual-motor task provide proof of earlier findings of Affolter (1984) that learning disabled deaf children are deficient in the processing of sequences of events or stimuli. Similar findings have been reported by Welsh et al (1975), and Larsen et al (1976) in normal children. The investigations of van Uden (1983) and Broesterhuizen (1997) have specifically linked dyspraxia of speech with deficient sequential processing of data. The present study found statistically significant differences between the performance of deaf and normal hearing children on this task. At each age level, the mean scores of normal hearing children were 2 or 3 times more than the mean scores of the deaf. The magnitude of the difference in the performance level increased with increase in age. Bebko (1984) and Bebko, Lacasse and Turk (1992) have reported that profound deafness by itself can result in inactive recall of ordered, temporal information. The sequential memory initially weakened by inadequate auditory stimuli might have further deteriorated with developing dyspraxia in the deaf children of this study.

However, a surprise result was that the linear discriminant analysis did not pick the test for sequential motor memory as a sensitive tool in the identification of dyspraxia. It is very difficult to explain as to how a test on which the two groups performed so differently, at all age levels and on which the normal children had mean scores which were 2 to 3 times higher than their deaf peers was not considered a sensitive tool. One factor that may explain this incongruity is the validity of the statistical tool (linear discriminant analysis), but only further research in this area can answer this.

5.7.6 **Tactile Agnosia in the Tongue**

The mean performance of deaf and normal hearing children was not significantly different, at any age, on the test for tongue agnosia, a specific test for lingual sensory-perception. This is contrary to findings of Rosenbek et al. (1973), Ayers (1972), Larimore (1970) and Guilford and Hawk (1968). This result implies that dyspraxia is essentially motoric in nature and that aspects related to sensory functioning may or may not determine/influence dyspraxia.

5.7.7 **Thumb Turning**

On the lateralization task, the performance of the deaf children was not different from that of the normal hearing. This is contrary to suggestions of Brain (1965) that developmental verbal dyspraxia may coexist with incomplete lateralization.

5.7.8 Speech Articulation

The performance of deaf children on the articulation test was significantly poorer than that of normal hearing children. The lowest difference, at any age, in the percentage of correct articulation was 55%, the normal children always performing at a higher level. A significant observation was that the difference in correct articulation (between normal and deaf children) which was 69% at 4 years progressively decreased to 62%. It must be remembered that these deaf children, in any age group, had not received any speech therapy for their speech problem. The implication of this result is that, even deaf children, improve their articulation skills as they grow and without any training - speech or motor therapy.

The finding of lower percentage of articulation in the deaf children is no surprise because it has always been known to workers in the field that deaf children would be deficient in their articulatory skills. Severe deficit in the speech articulation of the dyspraxic deaf can be attributed to the coexistence of two factors ; inadequate auditory input of speech due to deafness that impedes development of competency for speech production (Newby and Popelka, 1985), and imprecise motor programming that results from dyspraxia which disrupts accurate speech performance (Tomblin, Morris and Spriestersbach, 1994).

The fact that all the deaf children in this study were also found to be dyspraxic tends to support the findings of Jordan (1994) that imprecise motor programming may lead to articulatory errors in the deaf. However, it must be remembered that what has been shown in this study is that dyspraxic and articulatory errors coexist in deaf children, but assuming a cause and effect relation might be wrong.

It goes without saying that the mean percentage of incorrect articulation was higher in deaf children, at all age levels, and the difference was significant at the 0.01 level. The mean percentage of 'no responses' was higher in deaf children compared to normal (the difference was statistically significant at the 0.01 level), but it decreased with increase in age in the deaf group. But, there was a corresponding increase in the mean percentage of incorrect articulation in the deaf. This implies that, with increase in age, deaf children tend to produce the words rather than keeping quiet and this tendency increases with age. There is a corresponding increase in the mean scores of deaf children on different tests for dyspraxia. The implication is that with increased attempts at articulation, the motor skills improve and with increase in motor skills, articulation of speech sounds improves, though the increase in correct articulation with age is not statistically significant. It can be said, without being contradicted that speech articulation and oral motor skills have a mutual influence on each other.

The most common type of errors of articulation found in deaf children was the omission of sounds followed by substitutions. There is no perceptible change in the percentage of different types of errors with increase in age. In the initial years (4, 5 and 6 Years), the percentage of distortion type errors are more and substitution-omission type errors less in the normal hearing children. However, these differences between normal and deaf children were not always statistically significant. The implication of this observation is that the normal children attempt to articulate, even though they may be distorted, whereas the tendency of deaf children is to omit them.

The most common errors of articulation in the deaf are omissions, followed by substitutions and distortions (Calvert, 1982). The normal hearing children in this study emitted more distortions or came out with near-perfect productions while the deaf made more omissions, followed by substitution, addition and distortion type of error.

From the discussion on the prevalence of dyspraxic errors in normal and deaf children, it is tentatively concluded that

a) the prevalence of dyspraxic errors in deaf children of this country is much higher than predicted on the basis of western norms,

b) the deaf children are deficient in the acquisition of motor skills compared to their normal peers. Deaf children seem to be deficient in such skills as rhythm (particularly rhythm as found in everyday conversational speech), mobility of the articulators, intransitive movements of hands and sequential visual-motor memory, and

c) deaf children are certainly deficient as is well known, in the development of articulatory skills. Deaf children tend, when they cannot articulate a sound, to keep quiet, but when they come out with the word they are more likely to omit the difficult sounds.

5.8 Performance of Normal and Deaf Children: Agewise Comparison

The performance of children of different age levels on dyspraxic tests was compared using the one-way ANOVA with Student-Newman-Keuls posthoc test to isolate the source of variance. The test results revealed that the normal children improved their performance with increase in age except on the test for jaw mobility. In general, the older children of 7, 8 and 9 years had performed significantly better than children of 4, 5 and 6 years. This is in agreement with earlier findings of Mills and Streit (1942), and Reid (1947) who found that children in the first 3 or 4 grades in school, (that is, after the 6th year upto 8 or 9 years) significantly improved their performance after which there was nil or only insignificant improvement. The difference between age groups was statistically insignificant on the test for tongue mobility, in contrast to reports of Chilla and Kozielski (1977) that performances of 3 to 5 year children on their test for tongue mobility was specially related to the age. Dawson (1929) studied rate of articulation on a diadochokinetic task and reported that there was a rapid increase in the rate during the first 3 grades, but thereafter, only a gradual increase was observed.

There are other reports (Wellman et al., 1931; Major, 1940; Albright, 1948; Maxwell, 1953) which indicated that general body coordination and control of motor movements highly correlated with age and that defects in motor coordination and control directly reflected on skills like rhythm and speech articulation. But, this trend was not observed in the present study of deaf children. There were several tests like rhythm-1, tongue agnosia, diadochokinetic rate of articulators (tongue, lips and jaw), and sequential motor memory where there was no difference in the mean scores of different age groups. This might have been due to inadequate development of vocalization skills in the deaf beyond the initial stages due to poor practice. These results contradict the findings of van Uden (1983) who found that deaf children between 7 to 10 years of age in his study improved their performance with increasing age, however meagre it was, on all the tests for dyspraxia. The improvement shown by deaf children, in the present study, on the tests for intransitive movements like the Berges-Lezine's test for intransitive hand positions and finger tipping test was quite significant for children aged 3, 4, 5 and 6 years after which their performance showed a plateau.

5.9 Performance of Normal Hearing Male and Female Children

Results of the t-test on the comparison of mean scores between sexes showed no significant difference in any age group and on any test. Exceptions were : test for lip mobility, 6 year normals; deaf : DDK - tongue, 6 years, Berges-Lezine's: 7 years, tongue mobility, and thumb turning: 9 years. Four significant differences out of a total 252 t-score comparisons may be considered as instances of Type I error.

These findings are in support of previous reports (Chilla and Kozielski, 1977) that performance on the test for tongue motility, developed by them, was related less to the sex of the subject. Chilla and Kozielski (1977) found their normal hearing girls to perform slightly ahead of the level of the boys in the younger ages upto 6 and 7 years in the tests for mobility of tongue and oral rhythm after which the boys gained lead. The boys were better at all ages in the mobility of the other two articulators, namely, lips and jaw. But, these findings were mere observations, outside statistical significance. In general, the resuits of the present study as well as those reported earlier show that development of motor skills is* not a function of the sex of the subjects. Whatever influences the acquisition of motor skills, whether innate abilities or practice, it's influence is the same on both the sexes. This is true with regard to the acquisition of articulatory skills also.

On the test of articulation in the present study, the normal hearing boys of 4, 5 and 8 years were better than girls of the same age, but the difference was not statistically significant. On the other hand, girls of 6, 7 and 9 years were slightly better than boys of the same age, but the difference was, again, not statistically significant. Studies by Sayler (1949) and Roe and Milisen (1942) indicated that the difference between the performance of boys and girls on articulation tests was not statistically significant. But, outside statistical significance, they reported that the boys were prone to commit more number of errors. The results of the present study do not support the later observation. Others like Young (1940), Root (1925) have stated that boys tend to develop articulatory skills more slowly than girls which again was not supported by this study.

5.10 Nature of Dyspraxic Errors

Canonical correlation analysis was employed to analyse the nature of dyspraxic errors and their effect(s) on speech articulation.

The coefficients of determination, or the squared multiple correlation coefficients for the variables of the test battery, namely, tasks for eupraxia, presented in Table 4.34 imply that eupraxia for tongue mobility, and diadochokinesis of the tongue can be assumed to be the salient features of eupraxia for speech. Following these, control over rapid voluntary repetitive movements of the jaw is also considerably affected. Dyspraxia for speech is also reflected in incomplete lateralization, difficulty in controlling intransitive movements of the hand, poor development of rhythm, inadequate control over voluntary diadochokinetic movement of the lips, and poor sequential visual-motor memory, but their importance is less than that of tongue mobility and diadochokinesis of tongue. Tactile agnosia in the tongue seemed to be least associated with the presence of dyspraxia.

These findings are very much in agreement with previous research findings of Broesterhuizen (1997) who reported that eupraxia of mouth is characteristic of eupraxia for speech, and of van Balen (1974) who stated that presence of dyspraxia affected tempo of speech in terms of rapidity of syllable delivery. The suggestions of Brain (1965) that developmental verbal apraxia is associated with incomplete lateralization are also supported by these findings. These results are also in line with findings of van Uden that presence of dyspraxia is reflected in improper control over intransitive movements of the hand (1971; 1983), inadequate development of rhythm (1955; 1983), and inferior sequential visual-motor memory (1971; 1983) in dyspraxic deaf children. Similar interdependency between rhythm, memory and eupraxia for speech have been reported in normal hearing children also (Breuer and Weuffen, 1975; 1977).

The findings of this study contradict the findings of Rosenbek, Wertz and Darley (1973), Ayers (1972), Larimore (1970), and Guilford and Hawk (1968) that oro-sensory deficits coexisted with motor deficits. But, these findings had been reported on patients who had apraxia as a neuromotor disease, but deaf children, in the present study, had no known neurological disorder. More recent studies like that of Deutsch (1981) and Square and Weinder (1973) have not confirmed the assertion that oro-sensory perceptual deficits are a part of the symptomatology of dyspraxia.

5.10.1 Influence of Dyspraxic Errors on Speech Articulation

This has been analysed in three ways. First, by computing the coefficients of determination within the set of variables related to misarticulation of phonemes. Outcome of this analysis, shown in Table 4.35 indicated that among the different groups of phonemes, the laterals, fricatives, affricates and plosives, in that order, had greater probability of being misarticulated as a result of the presence of dyspraxia.

This suggests that dyspraxia affects the speech articulation in deaf children much like it does in the normal hearing. Dunlop and Marquardt (1977), Trost and Canter (1974), Johns and Darley (1970), and Shankweiler and Harris (1966) found normal hearing children with dyspraxia to have greater difficulty in producing fricatives, affricates and plosives. Only one study (John$and Darley, 1970) reported that normal dyspraxic children have difficulty producing laterals. The laterals might have been found as the most difficult phonemes to be misarticulated, in this study, because the present study selected Tamil speaking children and included two retroflexes among the laterals. The vowels (high, mid and low) were found to be the relatively less affected ones among the different groups of sounds. But, a previous report (Nickerson, 1974) in the deaf has noted that vowel production in a group of deaf children was relatively poor compared to the production of consonants.

This hierarchy of difficulty of phoneme production in deaf dyspraxics, as noted in the present study, compares favourably with the order of difficulty of different speech sounds that the deaf children will have as reported by Calvert and Silverman (1975).

Laterals, fricatives, affricates and plosives were the sounds in which deaf children had greatest difficulty in this study. These results are in partial agreement with those reported by Calvert and Silverman

(1975) in that they also found that the deaf children will have more difficulty on these sounds except the plosives. But, they also had the trills among the most difficult sounds. Contrary to the findings of this study, Calvert and Silverman (1975) found the plosives to be the least difficult sounds for their deaf children. However, it must be pointed that there are several methodological differences between these two studies. The two most important differences are the articulation test employed and the first language of the children of the study. Calvert and Silverman (1975) studied deaf children who had no additional learning disability whereas deaf children with dyspraxia have been investigated in the present study. Calvert and Silverman (1975) studied deaf children whose primary language was perhaps English while the present study included deaf children whose primary language was Tamil - a Dravidian language. Therefore, the results of the two studies cannot really be compared.

Second, the squared multiple correlation coefficients or coefficients of determinants for the component tools of the dyspraxia battery with the entire set of misarticulated phonemes were computed (Table 4.39). The results led to the conclusion that, of the 14 tests for dyspraxia, the tests for rhythm-1 and rhythm-2 (0.01 level) and the test for tongue mobility, lip mobility and rapid repetition of jaw movements (0.05 level) can predict the outcome of the test for articulation in terms of groups of sounds misarticulated. This also suggests that deficiency in the development of rhythm followed by inadequate control over voluntary intransitive movements of the articulators are the two foremost characteristics of speech dyspraxia that may lead to deficient speech production in the dyspraxic deaf.

Third, the coefficients of determinants for the different groups of misarticulated sounds with the entire battery of tests for dyspraxia were computed and are shown in Table 4.41. The results of this analysis implied that none of the different groups of sounds misarticulated (except the high vowels at the 0.05 level) could be successfully predicted by the battery of tests for dyspraxia. Support to this, as a general notion, is available in the findings of Jordan (1994), Palmer and Yantis (1990), Wertz et al. (1984), and van Uden (1981). These researchers opined that the most predictable aspect of speech errors in articulatory dyspraxia is its unpredictability. They reported that the cardinal feature of speech errors resulting from dyspraxia is the inconsistency of their nature and their frequency of occurrence.

The influence of the presence of dyspraxia on the frequency of 'no responses' in the test for articulation was studied as a separate set because 'no responses' constitute a high percentage of misarticulation in the present study. Results of this analysis are given in Table 4.36 which showed that, in general, all groups of sounds had considerably high chances of not being responded to. The nasals had the highest probability of not being responded to while the semivowels had the least probability. The coefficients of determinants for variables in the battery of test for dyspraxia with 'no responses' are given in Table 4.45. The implication of these results is that, among the tests for dyspraxia, the tests for mobility of articulators (tongue, lips and jaw), test for diadochokinetic rate of jaw, and the thumb turning task can successfully predict the occurrence of 'no responses' at the 0.01 level when 'no responses' is considered in its entirety. The coefficients of determinants for the different groups of sounds in the 'no response' category, presented in Table 4.47, imply that dyspraxic tests cannot predict the occurrence of 'no responses' on any individual group of sounds. The results suggest that only 'no responses' in the case of high and mid vowels can be predicted (at the 0.01 level).

5.10.2 Redundancy Coefficient/Index

Apart from these, the correlational analysis revealed a predominantly inverse relationship between the performance on the tests for dyspraxia and the occurrence of misarticulations and 'no responses' on the test for articulation. Another important outcome of the canonical correlation analysis was that it provided with a 'redundancy index' or 'redundancy coefficient' that enables predictions on the articulatory performance for individuals with the help of their scores on the tests for dyspraxia. The 'redundancy index' for predicting misarticulations on the test for articulation in Tamil for children in the age group of 4 to 9 years is 0.34849 (Table 4.42). A similar index for predicting the 'no responses' on the same test is 0.44608 (Table 4.48). This 'redundancy index' or 'redundancy coefficient' is actually an index of the average proportion of variance in the variables in one set (like the variable set of sounds misarticulated) that is reproducible from the variables in the other set like the set of tools for testing dyspraxia (Stewart and Love, 1968).

From an analysis of the effects of dyspraxia on misarticulation of speech sounds, it is tentatively concluded that

a) the intervariable correlations among the different groups of sounds misarticulated leads to an identification of the groups of sounds likely to be misarticulated. Accordingly, it was found that deaf children will find laterals, fricatives, affricates and plosives, in this order, to be the most difficult groups of sounds to articulate,

b) tests for dyspraxia can, in general, predict the occurrence of misarticulations as a whole. However, they cannot predict the particular group of sounds which may be misarticulated. Test for rhythm-1, and rhythm-2 (0.01 level) and tests for tongue and lip mobility, and diadochokinesis of jaw (0.05 level) can predict the occurrence of misarticulation as a whole, and

c) among the 'no responses', all the groups of sounds had a high chance of not being responded to. Among the tests for dyspraxia, the tests for mobility of the articulators, test for diadochokinetic rate of the jaw, and test for thumb turning can successfully predict the occurrence of 'no responses' in its entirety. 'No responses' on any individual group of sounds cannot be successfully predicted, except on high and mid vowels.

The present study has arrived at two redundancy indices for dyspraxic tests in order to predict the occurrence of misarticulation or the occurrence of 'no responses' on a articulation test. With the help of this redundancy index, the probability that misarticulations will occur can be computed if the results from one or more of the dyspraxic tests are available. However, this is limited to only dyspraxic tests used in the battery employed in this study and to the specific articulation test employed in this study

5.11 Effects of Therapy

Both motor therapy and speech therapy resulted in consistent improvement on all tests for dyspraxia and the test of articulation. But, they differ among themselves in the extent by which they have influenced the improvement. A general observation reveals certain typical similarities and differences between the posttherapy enhancements in mean scores effected by therapy for dyspraxic errors and speech misarticulation. Both the therapies failed to bring about significant change in rhythm. However, the relative inefficiency of speech therapy was more pronounced. A quick inspection of the results on the comparison between the pre- and posttherapy performances show that motor therapy was relatively more effective in influencing both speech articulation and motor skills than speech therapy.

5.11.1 Effects of Motor Therapy

Results of the comparison between pre- and posttherapeutic performance of children assigned to motor therapy are given in Tables 4.50 to 4.55. The results show that the performance of dyspraxic deaf children was enhanced at all age levels and on all tests following motor therapy. However, in certain instances like in the tests for rhythm; tongue agnosia, thumb turning, etc., the improvement did not reach the level of statistical significance at the 0.01 level. But, the motor therapy consistently produced significant improvement in the performance of children on the test of articulation at all age levels.

5.11.1.1 Voluntary Intransitive Movements of Articulators and Hands

Routine exercising of the articulators and limbs did have a definite impact on the performance of children on tests for mobility of the articulators as evident from the statistically significant higher post-therapeutic mean scores ($p<0.01$) on all tests of dyspraxia and at all age levels. Similar was the case with regard to intransitive movements of the hands. Motor training also resulted in significant and positive impact on the diadochokinetic skills (DDK-tongue and DDK-jaw in children aged 4 and 5 years).

5.11.1.2 Rhythm, Sequential Memory, Tongue Agnosia, and Lateralization

Motor therapy did not significantly influence the childrens' performance on rhythm tasks. Though there was a positive difference for all the tests and at all age levels (except in the case of test for rhythm-1 at 4 years where there was no difference between the pre- and post therapy scores), the difference did not reach statistical significance. The influence on sequential visual-motor memory (except at 4 years), tactile sensitivity of the tongue, and the improvement on lateralization (except in the 5, 6 and 8 year old children), though positive, were not statistically significant.

5.11.1.3 Speech Articulation

Motor therapy resulted in improvement of articulatory skills. Not only the percentage of correct articulation increased following motor therapy, the percentage of 'no responses' also significantly decreased at all age levels. The percentage of incorrect articulation initially showed an increasing trend (4 and 5 years, but statistically not significant), but decreased in the older age groups (statistically significant for the 6 and 9 year age groups only). It can perhaps be said that motor therapy improves the motor skills of articulators which in turn improved the speech articulation skills.

The significance of these results is that motor therapy leads to improvement in articulatory skills. One another aspect of the results in Tables 4.50 to 4.55 (motor therapy) and Tables 4.56 to 4.61 (speech therapy) is the extent of improvement in the percentage of correct articulation in the motor therapy and speech therapy groups and the extent of decrease in the percentage of incorrect responses in these two groups. A visual inspection suggests that extent of increase in the percentage of correct articulation and the extent of decrease in the percentage of incorrect articulation was more in the case of children who underwent motor therapy than in children who underwent speech therapy. It would be premature to say that motor therapy is more effective than speech therapy, but the results do tend to suggest so.

The positive influence of motor therapy on the development of motor skills was, in a way, predictable. There are several studies (Husak and McGill, 1979; Wallace and McLoughlin, 1979; White, 1979; Hallahan and Kaufman, 1978) which have reported a positive relationship between training in motor skills and the childrens' performance on academic tasks which included motor and speech tasks. These studies were conducted on normal children with learning disabilities. The present study has shown that motor therapy is helpful in the development of motor skills in a group of deaf children also. However, very little information is available on the influence of motor therapy on speech skills. Suzanne de Parrel (1965) has reported that motor exercising of the articulators with some gross and fine motor relaxation will have an influence on the speech motor skills in deaf and other individuals with psycho-neuro motor defects. Darley et al. (1975) emphasized the need for exercising the muscles of mastication and expression and use of rhythm as part of the remedial training progress for speech dyspraxia.

5.11.2 Effects of Speech Therapy

Speech therapy also produced positive results on the acquisition of motor and articulatory skills, but the influence was less consistent compared to that of motor therapy. Also, the difference in the pre- and posttherapeutic mean scores on different tests, whether statistically significant or not, were much smaller in the case of deaf children who underwent speech therapy compared to children who underwent motor therapy. There was more than one instance where speech therapy did not produce any change in the childrens' performance (on the test for speech rhythm at 5 and 6 years), eventhough there was no deterioration. The impact of speech therapy on the tests for dyspraxia was more pronounced in the younger subjects while its impact on articulation was apparent in children of all the age groups.

5.11.2.1 Voluntary Intransitive Movements of Articulators

Speech therapy resulted in significantly higher posttherapeutic performance on tests for mobility of articulators. This finding is in agreement with our presumption that deaf children acquire developmental dyspraxia of articulators as a result of insufficient use of the speech mechanism. These results are consistent with the view of Calvert (1982) who stated that precise articulation of single phonemes in isolation enhances memory for the motor acts associated with them.

Speech therapy was consistent in its influence on diadochokinetic tasks and intransitive hand movements in the younger age groups (4 and 5 years), but not so in the later age groups.

5.11.2.2 Voluntary Intransitive Movements of Hands, and Lateralization

The tests for intransitive movements also witnessed significant improvement in children of 4, 5 and 6 years of age following speech therapy. The influence seemed to wane with increasing age. In contrast, there was no improvement on the test for thumb turning (at 4 years) or there was only insignificant improvement in the younger children (at 5, 6 and 7 years). In children of 8 and 9 years, when lateralization is expected to be complete, the posttherapeutic gain was statistically significant ($p < 0.01$). Therefore, change in the performance of children postherapeutically may be a function of both the establishment of complete lateralization and the therapies administered.

5.11.2.3 Rhythm, Sequential Memory, and Tongue Agnosia

Therapy for speech articulation did not alter the performance of children on tests for oral rhythm. There was either no change in the posttherapeutic performance or the change observed was insignificant. It is probable that speech therapy administered in this study did not adequately emphasize on the development of skills of rhythm. Speech therapy for misarticulation also did not significantly influence the performance on other tests for dyspraxia like the test for sequential visual-motor memory (except in the 4 year old children), and tongue agnosia.

5.11.2.4 Speech Articulation

Speech therapy, as can be predicted, resulted in significant gains in the correct articulation. This was evident in a significant increase in the percentage of correct responses (in all the age groups) as well as a significant decrease in the percentage of 'no responses' (except at 6 and 9 years). The implication of this result is that speech therapy with deaf children enhances their articulation skills. Deaf children who, before therapy, did not give a response tended to articulate the sounds following speech therapy. Some of these additional responses were correct and some were incorrect articulations. Furthermore, the improvement in articulatory skills following speech therapy was irrespective of improvement in dyspraxia because the effects of speech therapy on the performance of children on dyspraxia was inconsistent. These results are a reassurance that good progress can be made in speech articulation in the deaf dyspraxics with speech therapy.

According to van Uden (1983), allowing children to observe their own speech during training for speech was effective in improving the tempo of speech, memory for spoken sentences, and also visual discrimination of speech in a group of profound deaf children with associated dyspraxia. Hough and deMarco (1996) suggested that interaction between articulatory programming and various components of working memory should be considered essential in devising treatment programs for speech dyspraxia. Wertz, LaPointe and Rosenbek (1984) recommended motor drill of speech articulators and inclusion of rhythm in speech exercises for better results in managing speech dyspraxia. In tune with aforementioned research reports, the findings of the present study also recommends a combined application of speech and motor therapies for optimal effects. Perhaps the insignificant influence of speech and motor therapy on the acquisition of rhythm was a result of noninclusion of an adequate number of tasks to train rhythm in the therapy program of the present study. Therefore, tasks to enhance skills of rhythm should form an essential element of any therapy approach. Future studies in this area should explore this.

From a discussion of the effects of therapy on dyspraxia and speech articulation, it is tentatively concluded that

a) both motor therapy and speech therapy are effective in developing better motor and articulatory skills. There is some evidence which indicated that motor therapy may be more effective of the two. A visual inspection of the data suggested that the extent of increase in the percentage of articulation and extent of decrease in percentage of incorrect articulation following motor therapy was much more than following speech therapy;

b) motor therapy is effective in developing motor skills in the deaf children. Speech therapy was also effective in improving motor skills, but its influence was less consistent, and

c) inadequate development of rhythm seemed to be part of the syndrome of dyspraxia. However, neither speech therapy nor motor therapy seemed to have beneficial influence on the development of rhythmic skills in deaf children. Therefore, therapy programme should specifically include tasks for improvement of rhythmic skills of speech.

Chapter 6

SUMMARY AND CONCLUSIONS

6.1 Scope of the Study

India has a vast population of the hearing impaired including the congenitally deaf. Traditionally, the emphasis in the management of these children has been oralism. Oralism has produced results, no doubt, but it has not always produced the desired results. One reason for this could be that there are associated learning problems known as speech dyspraxia in deaf children which perhaps prevents the development of required motor skills for correct articulation. Speech dyspraxia is a disorder related to control of voluntary movements required for speech.

Presence of associated learning disabilities in the form of dyspraxia in deaf has caught the attention of researchers only in the recent past. Much of the research output in this area has come from Institut voor Doven, Netherlands. There are no studies reported in this country in this area. We do not even have the basic information on the prevalence of dyspraxia in the deaf population; on the ways of identifying the presence of dyspraxic errors; the nature of dyspraxic errors; the influence of dyspraxic errors on articulatory skills; and the means of management of dyspraxic errors.

6.2 Objectives of the Study

Therefore, the present study had the following objectives:

a) construct/assemble a relevant test battery to investigate the nature of dyspraxic errors in deaf children,

b) investigate the prevalence of dyspraxic errors in a population of school going deaf children,

c) investigate the effects of dyspraxic errors on speech articulation,

d) design techniques of therapy for errors of dyspraxia and speech sound misarticulation, and

e) investigate the effects of therapy for dyspraxia on speech sound articulation in deaf children as well as the effect of speech therapy on dyspraxic errors.

6.3 Scheme of the Study

The scheme of the study provided for two groups of subjects; one group consisted of 113 deaf children, and the other was a control group of 60 normal children. Children in both the groups were in the age group of 4 to 9 years. Identification of dyspraxic errors was done by means of test battery which consisted of

(a) rhythm Tests - rhythm-1, rhythm-2 and speech rhythm, (b) tests for oral dyspraxia - test for tongue mobility, lip mobility and jaw mobility, (c) tests for diadochokinetic rate (tongue, lips and jaw), (d) tests for intransitive movements- Berges-Lezine's test for intransitive hand positions, finger tipping test, (e) test for sequential memory, (f) test for tactile agnosia of the tongue, and (g) thumb turning test. Totally there were 14 tests in the battery. In addition, a picture-word articulation test in Tamil (a Dravidian language) with 66 items was developed and employed to test for articulation.

Children studying in schools were screened for hearing loss and only those children who had an hearing loss of more than 90 dB in both the ears were included in the study. Thus we were left with 113 deaf children. All children were tested on the battery for assessment of dyspraxia followed by administration of picture word articulation test. After the identification of deaf dyspraxic children, they were randomly assigned to two groups: Children in one of the groups were administered motor therapy while the children in the other group were administered speech therapy. Therapy lasted for 15 to 21 days and following termination of therapy, the children in both the groups were assessed on both the battery of tools for dyspraxia and picture-word articulation test for analysing the effect of therapy on motor and articulatory skills. Initial and final testing of all the children were audio- and video recorded for later analysis. The appropriate angles of video recording and placement of the tester and children were decided following pilot studies.

The performances of the subjects on the tests for dyspraxia were analysed together by the tester and an another judge who was a special educator working with the hearing impaired. Each response of the subjects was classified as normal or deviant only after a thorough discussion and total agreement between the two judges (including the tester). The subjects' performance on the picture-word articulation test was analysed by the tester and a speech pathologist. Misarticulations in terms of omission, distortion, substitution and addition were written down. Errors were recognized and classified in the same manner as was done for dyspraxic responses. That is, a response was classified as a misarticulation only when both the judges agreed on that.

6.4 Analysis

The following analyses were carried out to meet the objectives of the study:

a) Identification of the dyspraxic group of deaf children.

b) Analysis of the nature of dyspraxic and articulatory errors in deaf subjects.

c) Age-wise prevalence of dyspraxic errors and degree of the problem in deaf children.

d) Correlational analysis of dyspraxic errors and different types of articulatory errors.

e) Analysis of articulatory errors following intervention for correcting dyspraxic errors.

f) Analysis of the change in the nature of dyspraxic errors consequent to speech therapy.

6.5 Statistical Procedures

Generally, all data have been analysed statistically using Student's t-test for independent samples or paired samples. The difference in the performance on different tests by children of different age groups has been tested with one-way analysis of variance (ANOVA). Only the mean effects have been tested in this instance. Appropriate posthoc test (Student-Newman-Keuls, in this instance) has been performed to isolate the source of significance for any variable with ANOVA's that had 'p' values less than 0.01. Linear discriminant function analysis (Fisher, 1936) was employed to classify the subjects into the two groups under question - dyspraxic and normals. Canonical correlation analysis (Thompson, 1984) was used to find the relationship between two sets of variables. This correlational analysis allowed for intervariable correlation within each set. This analysis yielded information on the extent to which each single variable in the set could predict the outcome of other variables of the set, or the extent to which it relates to other variables in the set. The canonical correlation analysis also enabled similar predictions in terms of each variable on the outcome of variables in the other set.

6.6 Important Results

The main results of the study can be summarized as follows :

a) Pretherapeutically, the performance of the deaf and the normal children were significantly different, at the 0.01 level, in all the age groups and on all the tests for dyspraxia and speech sound articulation. Expectedly, the normal children scored higher than deaf children on all tests except the Berges-Lezine's test of intransitive hand positions.

b) The prevalence rate of dyspraxia was found to be 100 percent. That is, all the 113 deaf children of the study, in all the age groups, evidenced dyspraxic errors. None of the normal children were found to be dyspraxic.

c) Of the 14 tests for dyspraxia, the linear discriminant analysis selected 7 tests as more efficient than others in identifying dyspraxia. They are arranged below in the order of their efficiency.

i) Rhythm-2,
ii) Thumb turning,
iii) Berges and Lezine's intransitive hand positions,
iv) Speech rhythm
v) Diadochokinetic rate of jaw,
vi) Tongue mobility, and
vii) Jaw mobility

The meaning of this result is that it is not essential to have a large battery of tests to identify dyspraxia. The 7 tests mentioned above can identify 100 percent of the dyspraxics. A notable omission in the list of 7 most efficient tests is the test for visual-motor memory on which the difference in mean scores between the normal and deaf children was significant in all the age groups and in which the normals had scored 2 or three times more than the deaf children. Another incongruity is the inclusion of the test for thumb turning in the list of most efficient tests, but the difference between normal and deaf children on this test was not significant at any age group.

d) Expectedly, the normal children performed better than the deaf child on the articulation test. The normal children had a significantly higher percentage of correct articulation, significantly lower percentage of incorrect articulation and significantly lower percentage of 'no responses' than deaf children of corresponding age.

e) On all the tests of dyspraxia, normal children of 4, 5, and 6 years seemed to perform at a lower level compared to the normal children of 7,8 or 9 years. However, this difference between different age groups was inconsistent among the deaf children. In general, it can be said that normal children improved in their motor skills with increase in age, but the same cannot be said about the deaf children.

f) There was no difference between the male and female children, either in the normal or the deaf group, at any age level, in their performance on either the tests for dyspraxia or articulation tests. The implication is that the prevalence, or nature, or the influence of dyspraxic errors on articulation of speech sounds is not a function of sex of the subjects.

g) Tongue mobility, diadochokinesis of the tongue control over rapid voluntary repetitive movements of the jaw incomplete lateralization, difficulty in controlling intransitive movements of the hand, poor development of rhythm, inadequate control over voluntary diadochokinetic movement of the lips, and poor sequential visual-motor memory, seemed to be associated with dyspraxia in the order given. Tactile agnosia in the tongue seemed to be least associated with the presence of dyspraxia.

h) Computation of coefficients of determination within the set of variables related to misarticulation of phonemes indicated the laterals, fricatives, affricates and plosives, in that order, have greater probability of being misarticulated as a result of the presence of dyspraxia in deaf children.

i) Computation of the squared multiple correlation coefficients or coefficients of determinants for the component tools of the dyspraxia battery with the entire set of misarticulated phonemes led to the conclusion that, of the 14 test for dyspraxia, the tests for rhythm-1 and rhythm-2 (0.01 level) and the test for tongue mobility, lip mobility and rapid repetition of jaw movements (0.05 level) can predict the outcome of the test for articulation in terms of groups of sounds misarticulated. This also suggests that deficiency in the development of rhythm followed by inadequate control over aspects on which both motor therapy and speech had statistically significant influence, the magnitude of improvement following motor therapy was more that following speech therapy.

The magnitude of improvement in articulatory skills following motor therapy seemed to be more than that following speech therapy. Motor therapy resulted in greater improvement in the percentage of correct articulation (as well as greater decrease in the percentage of incorrect articulation and the percentage of 'no responses') compared to speech therapy.

6.7 Conclusions

From the results of this study, the following tentative conclusions are made:

a) Prevalence of dyspraxic errors seems to be much higher in the Indian deaf population than could be predicted based on the Western norms.

b) A much smaller number of psycho-educational motor tests seem to be sufficient for the identification of 100 percent of the deaf dyspraxic children than recommended by past research.

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6.7 **Conclusions**

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b) A much smaller number of psycho-educational motor tests seem to be sufficient for the identification of 100 percent of the deaf dyspraxic children than recommended by past research.

c) Deficient tongue mobility, lack of control over rapid voluntary repetitive movements of the tongue and jaw, incomplete laterali-zation, difficulty in controlling intransitive movements of the hand, poor development of rhythm, inadequate control over voluntary diadochokinetic movement of the lips, and poor sequential visual-motor memory seem to be important, in the order given, in defin-ing the dyspraxia complex.

d) Laterals, fricatives, affricates and plosives, in that order, are the more probable sound groups to be misarticulated as a result of the presence of dyspraxia in deaf children.

e) Deficiency in the development of rhythm followed by inadequate control over voluntary intransitive movements of the articulators seem to be two foremost characteristics of speech dyspraxia that may lead to deficient speech production in the dyspraxic deaf.

f) The prevalence, or nature, or the influence of dyspraxic errors on articulation of speech sounds is not a function of sex of the sub-jects.

g) Both motor therapy and speech therapy are effective in developing better motor and articulatory skills. There is some evidence to show that motor therapy may be the more effective of the two.

Motor therapy resulted in improvement of both motor skills and articulatory skills. Also, the consistency of change (in different age groups), and the magnitude of improvement in motor and articulatory skills was greater following motor therapy compared to speech therapy.

6.8 Future Research

Further research is warranted on the following issue. These issues have emanated not only from the perspective of lacunae in information, but also from the limitations of this study.

a) This study is the first of its kind in this country. Therefore, further studies are warranted not only to confirm or reject the findings of this study, but also to analyse certain aspects of the issue in greater depth. For example, are there specific aspects of dyspraxia which determine what type of sounds will be misarticulated? or the question of whether a combined motor and speech therapy results in greater improvement of articulatory skills? or the question of duration of therapy and its schedule for optimal results? or the question of whether the severity of dyspraxia can be graded, and if so, what yardstick to follow?

b) Administration of motor therapy brought about improvement in articulatory skills. In fact, the magnitude of improvement in articulatory skills following motor therapy was much more than that brought about by speech therapy. From this perspective, future research can look into the question of what management procedures bring about optimal results.

c) Inadequate development of rhythm and deficient mobility of the articulators seem to be important aspects of dyspraxia complex. In general, children in whom the mobility of the articulators improved following therapy also showed better improvement in articulation of speech sounds. Generally, neither therapy brought about improvement in rhythm. Future research should study these two factors (mobility of the articulators and rhythm) in depth for a more precise understanding of their relationship to dyspraxia and speech sound articulation.

d) The 113 deaf children included in this study generally formed a homogeneous group. However, there were certain children who varied in terms of etiology of hearing loss, in heritance pattern and handedness. We do not know the implications of these factors to dyspraxia and needs to be investigated. Furthermore, we have taken the words of the parents or teachers that these children did not have any training either in motor and speech skills at their face value, but it may be difficult to assume that children who were 9 years old and who were receiving formal education in a special school have had no training in speech or motor skills. If some of these child had received some training on speech or motor skills, however informal it may be), then the results may be confounded. Therefore, there is a need for further research on this issue with a more vigorously selected sample.

REFERENCES

Affolter, F. (1984). Development of perceptual processes and problem-solving activities in normal, hearing-impaired, and language-disturbed children: A comparison study based on Piaget's conceptual framework. In D.S. Martin (Ed), International symposium on Cognition, Education, and Deafness (pp 19-33). Washington D C : Gallaudet College.

Albright, R. (1948). The motor abilities of speakers with good and poor articulation. Speech Monogr, 15, 164-172.

Allen, T.E. (1986). Patterns of academic achievement among hearing impaired students: 1974 & 1983. In A.N. Schildroth & M.A. Karchmer (Eds), Deaf children in America. San Diego. College Hill Press.

Ayers, J. (1972). Southern California Sensory Integration Tests. Los Angeles: Western Psychological Services.

Balen, C. van. (1974). De verstaanbaarheid van excerpten uit opgelezen tekst en conversatie in het Nederlands: invloed van spreeksnelheid en duur van het excerpt. Amsterdam.

Bebko, J.M., Lacasse, M.A., Turk, H., & Oyen, AS. (1992). Recall performance and central-incidental memory task by profoundly deaf children. American Annals of the Deaf, 137(3), 271-277.

Bebko, (1984) as cited in Bebko, J.M , Lacasse, M.A., Turk, H., & Oyen, AS. (1992).

Beertema, A., Koetsenruyter, P., Postema, P., & de Saint Aulaire, R. (1980). Spreekmotoriek en doofheid. Logopedie en Foniatrie, 52, 68-71.

Benton, A.L. (1953). Der Benton Test. Deutsche Bearbeitung von O. Spreen, Bern.

Berges, J.,&Lezine, S.J. (1963). The imitation of gestures: A technique for studying the body scheme and praxis of children 3 to 6 and 6 to 10 years of age. Paris.

Berry, M.D., & Eisenson, J. (1956). Speech disorders: Principles and practices of therapy. New York: Appleton-Century-Crofts.

Birch, H I , & Belmont, L. (1965). Auditory visual information in brain-damaged and normal children. Developmental Medicine and Child Neurology, 134-144.

Blank, M., & Bridger, W. (1966). Conceptual cross-modal transfer in deaf and hearing children. Child Development, 29-38.

Blomquist, B.L. (1950). Diadochokinetic movements of 9, 10 and 11 year-old children. Journal of Speech and Hearing Disorders, 15, 159-164.

Brain, R. (1965). Speech disorders: Aphasia, Apraxia, Agnosia. London. Butterowrths.

Brankel, O. et al. (1965). Vergleichende phoniatrische, Rontgenkymographische und ventilatorische Untersuchungen an horenden und gehorlosen Versuchsoersonen wahrend der Ruhe und wahrend des Sprechens. Phonetica, 13, 162-182.

Branon, J.B. Jr. (1964). Visual feedback of glossal notions and its influence on speech of deaf children. Doctoral thesis, Northwestern University.

Breuer, H., & Weuffen, M. (1975). Gut vorbereitet auf das Lesen und Schreibenlernen. Deutscher Verlag der Wissenschaften, Berlin.

Breuer, H., & Weuffen, M. (1977). Untersuchung zum sprachlichen und verbosensomotorischen Niveau agrammatisch sprechender Vorschulkinder. Folia Phoniatrica, 29, 177-190.

Broesterhuizen, M.L. (1997). Psychological assessment of deaf children. Scand Audiol Suppl, 46, 43-49.

Bruner, J. (1978). On prelinguistic prerequisites of speech. In R.N. Campbell and P.T. Smith (Eds), Recent advances in psychology of language (Vol. 4a) (pp. 199-214). New York: Plenum Press.

Bush, W.J., & Waugh, K.W. (1982). Diagnosing Learning Problems. Ohio: Charles E. Merril Publishing Company.

Caccamise, F., Blasedell, R., and Meath-Lang, B. (1976). Hearing-impaired persons' simultaneous reception of information under live and two visual-motion media conditions. Working paper presented in National Technical Institute for the Deaf, Rochester, New York.

Calvert, DR., & Silverman, S.R. (1975). Speech and Deafness. Washington, D C : Alexander Graham Bell Association.

Calvert, DR. (1980). Descriptive Phonetics (pp. 165-169). New York: Thieme-Stratton.

Calvert, DR. (1982). Articulation and hearing impairment. In N.J. Lass, L.V. McReynolds, L.J. Norhtern, & D.E. Yoder, (Eds.), Speech hearing and language (Vol. 2). Philadelphia: W.B. Saunders.

Cardinaux, H. (1975). Zur diagnostik der Mehrfachbehinderung. Anamnesebogen zur Ermittlung des Entwicklungsalters und zur Erstellung einer ganzheitlechen padagogisch-therapeutischen psychologischen (medizinisch-neurologischen) Diagnose. Neckar-Verlag, Villingen-Schwenningen.

Carter, A.L. (1975). The transformation of sensorimotor morphemes into words. Child Language Development, 10, 31-47.

Chilla, R., & Kozielski, P. (1977). Tongue as a reflector of cerebral and articulatory dysfunction, tongue motility test for 3 to 5-year old children. MMW-Munch-Med-Wochenschr, 119(12), 403-408.

Cobb, S. (1948). Borderland of Psychiatry. Cambridge, M.A.: Harvard University Press.

Colton, R.H., & Cooke(/Cooker), H.S. (1968). Perceived nasality in the speech of the deaf. Journal of Speech and Hearing Research, 11, 553-559.

Conrad, R. (1979). The deaf school child: Language and cognitve function. London: Harper & Row.

Cornett, R.O. (1967). Cued speech. American Annals of the Deaf, 3-13.

Dabul, B. (1979). Apraxia Battery for Adults. Tigard: C.C.Publications.

Darley, F.L., Aronson, A.E., & Brown, J.R. (1975). Motor speech disorders. Philadelphia: W.B.Saunders.

Darley, F.L. (1968). Apraxia of speech: 107 years of terminological confusion. Paper presented to American Speech and Hearing Association (unpublished), Denver, Colorado.

Darley, F.L. (1969). Aphasia. Input and output disturbances in speech and language processing. Paper presented to the American Speech and Hearing Association, Chicago, Illinois.

Dawson, L. (1929). A study of the development of the rate of articulation. Elem Sch J, 29, 610-615.

de Arjuriaguerra, J., & Tissot, R. (1969). Disorders of speech perception and symbolic behaviourism. In P. Vinken & G. Bruyn (Eds), Handbook of clinical neurology (Vol.4). New York: North Holland Publishing Company.

de Filippo, C.L., Sims, D.G., & Gottermeier, L. (1995). Linking visual and kinesthetic imagery in lip reading instruction. Journal of Speech and Hearing Research, 38(1), 244-256.

de Parrel, S. (1965). Speech disorders: Multisensory techniques for remedial education in disorders of speech, language and psychoneural motor system. Oxford: Pergamon Press.

de Renzi, E., Pieczuro, A., & Vignolo, LA. (1966). Oral apraxia and aphasia. Cortex, 2, 50-73.

de Werd, Zr. R. (1964). Iets uit de praktijk van het spreekonderwijs aan dove kinderen. Sint-Michielsgestel: Instituut voor Doven.

Deutsch, S.E. (1981). Oral form identification as a measure of cortical sensory dysfunction in apraxia of speech and aphasia. Journal of Communication Disorders, 14, 65-73.

di Francesca, S. (1972). Academic achievement test results of a national testing program for hearing-impaired students (Series D, No. 9). Washington, D C : Gallaudet College, Office of Demographic Studies.

Dimond, S.J. (1980). Neuropsychology: A textbook of systems and psychological functions of the human brain. London: Butterworths.

Dunlop, J.M, & Marquardt, T.P. (1977). Linguistic and articulatory aspects of single word production in apraxia of speech. Cortex, 13, 17-29.

Dworkin, J.P., & Culatta, R.A. (1980). Tongue strength: Its relationship to tongue thursting, open-bite, and articulatory proficiency. Journal of Speech and Hearing Disorders, 13, 731-740.

Eisenson, J. (1954). Examining for aphasia (Rev.Ed). New York: The Psychological Corp.

Ekwall, E.E. (1973). Psychological factors in the teaching of reading. Colombus, Ohio: Charles E. Merrill Publishing Company.

Elstner, W., & Karlstad, H. (1978). Dysphaise in Kindesalter: Terminologie, Aetiologie, Rehabilitation, Integration. Oslo-Bergen-Tromso: Universitets Forlaget.

Everhart, R.W. (1953). The relationship between articulation and other developmental factors in children. Journal of Speech and Hearing Disorders, 18, 332-338.

Ewanowski, S.J. (1964). Selected motor speech behaviour of patients with parkinsonism. Doctoral thesis, University of Wisconsin.

Ewing, A.W.G., & Ewing, E.C. (1964). Teaching deaf children to talk. Manchester: University Press.

Ewing, A.W.G., & Stanton, D.A.G. (1943). A study of children with defective hearing. The Teacher for the deaf, 3-8, 26-30, 56-59.

Ewing, A.W.G. (1957). Educational guidance and the deaf child. Manchester: University Press.

Fairbanks, G., & Spriestersbach, D.C. (1950). A study of minor organic deviations in functional disorders of articulation: 1. Rate of Movement of oral structures. Journal of Speech and Hearing Disorders, 15, 60-69.

Faustman, N.M. (1968). Some effects of perception training in kindergarten on first grade reading. In H.K. Smith (Ed.), Perception and reading. Proceedings of the 12th Annual Convention of the International Reading Association. Newark, Del: International Reading Association.

Fisher, R.A. (1936). The use of multiple measurements in taxonomic problems. Ann Eugen, 7, 179-188.

Fletcher, S.G. (1972). Time-by-count measurement of diadochokinetic syllable rate. Journal of Speech and Hearing Research, 15, 763-770.

Frisch, F.G., & Handler, L. (1974). A neuropsychological investigation of functional disorders of speech articulation. Journal of Speech Hearing Research, 17, 432-445.

Furth, H. (1964). Research with the deaf: Implications for language and cognition. Psychol Bull, 62, 145-162.

Galen, G.P. van. (1974). Ambient versus focal information processing and single-channelness. Nijmegen: Psychologisch Laboratorium, Kath Universiteit.

Gallaher, T.M., & Shriner, T.H. (1975). Articulatory inconsistencies in the speech of normal children. Journal of Speech and Hearing Research, 18, 168-175.

Goodglass, H., & Kaplan, E. (1972). The Assessment of Aphasia and Related Disorders. Philadelphia: Lea & Febiger.

Guilford, A.M. & Hawk, A.M. (1968). A comparative study of form identification in neurologically impaired and normal adult subjects. Speech and Hearing Science Research Reports. Ann Arbor: University of Michigan.

Gupta. (1967). As cited in M.N. Nagaraja, (1985).

Hallahan, D.P., & Kaufman, J.M. (1978). Exceptional children. Englewood Cliffs, N.J.: Prentice-Hall.

Halliday, M.A.K. (1975). Learning how to mean: Explorations in the development of language. New York: Elsevier.

Hamp, N.W. (1972). Reading attainment and some associated factors in deaf and partially hearing children. Teacher of the Deaf, 70, 203-215.

Hanson, M.L. (1983). Articulation. Philadelphia: W.B.Saunders Company.

Hardy, W.G., Pauls, M., & Haskins, H.L. (1958). An analysis of language development in children with impaired hearing. Acta Otolaryngol, Suppl 141.

Hine, W.D. (1970). The attainments of children with partial hearing. Teacher of the Deaf, 68, 129-135.

Hiskey, M.S. (1966). Hiskey Nebraska Test of learning aptitude. Lincoln, Nebraska: Union College Press.

Hood, R.B. (1966). Some physical concomitants of the perception of speech rhythm of the deaf. Unpublished doctoral thesis, Stanford University.

Hough, M.S., & de Marco, S. (1996). Phonemic retrieval in Apraxia of speech. In D.A. Robin, K.M. Yorkston, & D.R. Beukleman (Eds), Disorders of motor speech: assessment, treatment, and clinical characterization. Baltimore, Maryland: Paul H. Brookes Co., Inc.

Hoven, M.v.d., & Speth, Br. L. (1982). Psycho-motor exercises. Paper presented in International Course on the Education of Deaf Children of Normal Intelligence by means of the Maternal Reflective Method, Instituut voor doven, Sint-Michilesgestel.

Hudgins, C.V., & Numbers, F.C. (1942). An investigation of the intelligibility of the speech of the deaf. Genet Psych Monographs, 25, 289-392.

Hudgins, C. V. (1937). Voice production and breath control in the speech of the deaf. American Annals of the Deaf, 82, 338-363.

Huntington, D., Harris, K., Shankweiler, D , & Sholes, G. (1968). Some observations on monosyllabic production by deaf speakers and dysarthric speakers. American Annals of the Deaf, 13, 134-146.

Husak, W.S., & McGill, R. A. (1979). Correlations among perceptual-motor ability, self-concept and reading achievement in early elementary grades. Perceptual and Motor Skills, 49, 447-450.

Irwin, J.V., & Becklund, O. (1953). Norms for maximum repetitive rates for certain sounds established with Slyrater. Journal of Speech and Hearing disorders, 18, 149-160.

Irwin, O.C. (1947). Infant speech: I. Consonantal sounds according to place of articulation, II. Consonanatal sounds according to manner of articualtion, and III. Development of vowel sounds. Journal of Speech and Hearing Disorders, 397-401, 402, 404, 31-34.

Itoh, M., Sasanuma, S, & Ushijima, T. (1979). Velar movements during speech in a patient with apraxia of speech. Brain and Language, 7,227-239.

Itoh, M., Sasanuma, S., & Hirose, H. (1980). Abnormal articulatory dynamics in patients with apraxia of speech: X-ray microbeam observations. Brain and Language, 11, 66-75.

Jackson, J.H. (1878). Remarks on nonprotusion of the tongue in some cases of aphasia. In Taylor, J. (Ed), (1932), Selected Writings of John Hughlings Jackson (Vol.2). London: Hodder & Stoughton.

Jenkins, R.L. (1940). The rate of the diadochokinetic movement of the jaw at the ages of 7 to maturity. Journal of Speech Disorders, 6, 13-22.

John, J.E., & Howrath, J.N. (1965). The effect of time distortion on the intelligibility of deaf children's speech. Language and Speech, 8, 127-134.

Johns, D.F., & Darley, F.L. (1970). Phonemic variability in apraxia of speech. Journal of Speech and Hearing Research, 13, 556-583.

Johnson, H.A. (1988). A sociolinguistic assessment scheme for the total communication student. J Monogr Suppl Acad Rehabil Audiol, 21, 101-127.

Johnson, W., & House, E. (1937). Certain laterality characteristics of children with articulatory disorders. Elementary School Journal, 38, 52-58.

Jordan, L.S. (1994). In J.B. Tomblin, H.L. Morris, & DC. Spriestersbach (Eds.), Diagnosis in speech-language pathology. San Diego, California: Singular Publishing Group, Inc.

Joshi, & Rege. (1954). As cited in M.N. Nagaraja, (1985).

Kahn, D., & Birch, H.G. (1968). Development of auditory-visual integration and reading achievement. Perceptual and Motor Skills, 27, 459-468.

Kameshwaran. (1967). As cited in M.N. Nagaraja, (1985).

Kaplan, E. (1972). Test for Apraxia. In J.W. Brown (Ed.), Aphasia, apraxia and agnosia, clinical and theoritical aspects. Springfield, Illinois: C.C.Thomas.

Kaufman, A.S., & Kaufman, NX. (1983). Kaufman assessment battery for children. Circle Pines, Minnesota: American Guidance Service, Inc.

Kent, R., & Rosenbek, J.C. (1983). Acoustic patterns of apraxia of speech. Journal of Speech and Hearing Research, 26, 231-249.

Kern, E. (1958). Theorie und Praxis eines ganzheitlichen Sprachunterrichtes fur das gehorgeschadigte Kind. Freiburg.

Knox Cube Test. (1976). Schroots, Leidse Diagnostische Test. Lisse: Swets.

Kreul, J.E. (1972). Neuromuscular control examination (NMC) for parkinsonism: Vowel prolongation and diadochokinetic and reading rates. Journal of Speech and Hearing research, 15, 72-83.

Lach, R., Ling, D., Ling, A., & Ship, N. (1970). Early speech development in deaf infants. American Annals of the Deaf, 522-526.

Lapointe, L.L., & Wertz, R.T. (1974). Oral-movement abilities and articulatory characteristics of brain-injured adults. Perceptual Motor Skills, 39, 39-46.

Larimore, H.W. (1970). Some verbal and nonverbal factors associated with apraxia of speech. Unpublished doctoral thesis, University of Denver.

Larsen, S., Rogers, D., Sowell, V. (1976). The use of selected perceptual tests in differentiating between normal and learning-disabled children.

Lenneberg, E.H., Rebelsky, F., & Nichols, J. (1965). The vocalisations of infants born to deaf and hearing parents. Human Development, 8(1), 23-37.

Leshin, S. (1948). A study of diadochokinetic movements of lips and tongue in children. M. A. thesis, University of Michigan.

Liepmann, H. (1905). Die linke hemisphaere und das handeln. Muchener medizinische Wochenschrift, 52, 2322-2326, 2375-2378.

Ling, D. (1976). Speech and the hearing impaired child: Theory and practice. Washington, D C : Alexander Graham Bell Association.

Lotzman, G. (1979). Psychologie der Stimm-, Sprech- und Sprachrehabilitation. Stuttgart. G. Fischer Verlag.

Lowell, E.L., & Pollack, D.B. (1974). Remedial practices with the hearing impaired. In S. Dickson (Ed.), Communication Disorders: Remedial principles and practices. Glenview, 111., Scott: Foresman & Company.

Lundeen, D.J. (1950). The relationship of diadochokinesis to various speech sounds. Journal of Speech and Hearing disorders, 15, 54-59.

Major, C. (1940). A compariosn of the performance of speech defectives and normal speakers on certain motor tests. Master's thesis, Purdue University.

Markides, A. (1970). The speech of deaf and partially hearing children with special reference to factors affecting intelligibility. British Journal of Disorders of Communication, 5, 126-140.

Markides, A. (1976). Comparative linguistic proficiencies of deaf children, taught by two different methods of instruction: Manual versus oral. The Teacher of the Deaf, 307-347.

Mavilya, M.P. (1969). Spontaneous vocalisation and babbling in hearing impaired infants. New York. Columbia University.

Mavilya, M.P. (1970). Spontaneous vocalization and babbling in hearing impaired infants. In G. Fant (Ed), International symposium on speech communication ability and profound deafness. Washington, D C : Alexander Graham Bell Association for the Deaf.

Maxwell, K.L. (1953). A compariosn of certain motor performances of normal and speech defective children, ages seven, eight, and nine years. Doctoral thesis, University Mich.

McClure, A. (1977). Academic achievement of mainstreamed hearing-impaired children with congenital rubella syndrome. Volta Review, 79, 379-384.

McCormick, L., & Goldman, R. (1984). Designing an optimal learning programme. In L. McCormick & R.L. Schiefelbusch (Eds.), Early language intervention. Columbus, Ohio: Charles E. Merrill Publishing Co.

McDonald, E.T. (1964). A Deep Test of Articulation: Sentence Form. Pittsburgh: Stanwix House.

McGarr, N.S., Osberger, M.J., & Gold, T (1976). Relationship between pitch deviancy and intelligibility of deaf children's speech. Paper presented before Acoustical Society of America, Wahington, DC.

McGinnis, MA. (1963). Aphasic children, identification and education by the associative method. St.Louis.

Miller, G.A. (1960). Speech and language. In S.S. Stevens (Ed.), Handbook of experimental psychology, New York: John Wiley & Sons.

Mills A.,& Streit, H. (1942). Report of a speech survey, Holyoke, Massachusetts. J Speech Disorders, 7, 161-167.

Mishra, Bhatia, &Bhatia(1961). Cited in M.N. Nagaraja, (1985).

Mitrinovitch, A. (1937). Modification de la respiration chez les sourds-muets attients de troubles de la parole. Rev Francaise Phoni, 5, 209-239.

Mohr, J.P. (1980). Revision of Broca aphasia and the syndrome of Broca's area infarction and its implications in aphasia theory. In R.H. Brookshire (Ed.), Clinical aphasiology: Conference proceedings (pp. 1-16). Minneapolis: B.R.K..Publishers.

Monsen, R.B. (1976b). Normal and reduced phonological space: the production of English vowels by deaf adosescents. Journal of Speech and Hearing Research, 21, 197-219.

Montpellier, G.de. (1935). Les alterations morphologiques des mouvements rapides. Louvain: Institut Superieur de Philosophic

Morsh, J.E. (1937). A comparitive study of deaf and hearing students. American Annals of the Deaf, 223-233.

Mukherjee, A.L., & Roy, R. (1976). A sample survey in school children regarding prevalence of deafness and its relationship with academic proficiency. Journal of the All India Institute of Speech and Hearing, 7, 78-80.

Myklebust, H., & Brutton, M. (1953). A study of the visual perception of deaf children. Acta Otolaryngol Suppl, 105, 1-126.

Myklebust, H. (1964). The psychology of deafness, 2nd ed. New York: Grune & Stratton.

Nagaraja, M.N. (1985). The study pattern of speech, language and hearing disorders in rural population. Bangalore, India: National Institute of Mental Health and Neuro Sciences.

Naiman, D.W. (1974). A Proposed midel for preparation of personnel. In J.D. Schien (Ed.), Education and rehabilitation of deaf persons with other disabilities. New York: Deafness Research and Training Center, New York University.

Newby, H.A., & Popelka, G.R. (1985). Audiology. Englewood Cliffs, N.J.: Prentice-Hall.

Nickerson, R.S., Stevens, K.N., Boothroyd, A., & Rollins, A. (1974). Some observations on timing in deaf and hearing speakers. BBN Report No. 2905, 33, 611-621.

Nickerson, R.S. (1975). Characteristics of the speech of deaf persons. VoltaReview, 77, 342-362.

Nikam. (1970). As cited in M.N. Nagaraja, (1985).

Odom, P.B., Blanton, R.L., & Nunnally, J.C. (1967). Some 'cloze' technique studies of language capability in the deaf. Journal of Speech and Hearing Research, 816-827.

Osberger, M.J., Levitt, H., & Slosberg, R. (1979). Acoustic characteristics of correctly produced vowels in deaf children's speech. Journal of the Acoustical Society America, 66, S13.

Palmer, J.M., & Yantis, PA. (1990). Survey of communication disorders. Baltimore: Williams & Wilkins.

Pea, R.D. (1980). The development of negation in early language. In DR. Oslon (Ed), The social foundations of language and thought. Essays in honour of Jerome S. Bruner. New York: W.W.Norton.

Snijders, J. Th., & Snijders-Oomen, A.W.M. (1970). Niet-verbaal intellengentieonderzoek van horenden en doofstommen. Groningen.

Snyder, J. (1955). A study of diaochokinesis of lips, tongue and the palate of adults with non-defective speech. M.A. thesis, University of Michigan.

Speth, L. (1958). Adem en accent. Sint-Michielsgestel: Instituut voor Doven.

Sprague, A.L. (1961). The relationship between selected measures of expressive language and motor skill in 8 year old boys. Doctoral thesis, University of Iowa.

Square, P.A., and Weinder, W.E. (1976). Oral sensory perception in adults demonstrating apraxia of speech. Paper presented to the American Speech and Hearing Association (unpublished). Houston, Texas.

Stambak, M. (1965). Epreuves de niveau et de style moteurs. In R. Zazzo (Ed.), Manuel pour l'examen psychologique de 1'enfant, nr, 2, Neuchatel.

Stewart, D.K., & Love, W.A. (1968). A general canonical index. Psychological Bulletin, 70, 160-163.

Putnam, A.H.B., & Ringel, R.L. (1972). Some observation of articulation during labio sensory deprivation. Journal of Speech and Hearing Research, 15, 529-594.

Quigley, S. & Kretchmer, R.E. (1982). The Education of deaf children. Baltimore: University Park Press.

Quigley, S.P. (1969). The influence of fingerspelling on the development of language, communication and educational achievement in deaf children. Urbana: University of Illinois.

Raven, J. (1948). Progressive Matrices. NY: Psychological Corp.

Redgate, G.W., Palmer, J., Wilkins, C.G., Smart, C.A.M., & Black, E. (1972). The teaching of reading to deaf children: An experimental study. Manchester: Department of Audiology and Education of the Deaf, Manchester University.

Reich, C, Hambleton, D., & Houldin, B. (1977). The integration of hearing-impaired children in regular classrooms. American Annals of the Deaf, 122,534-543.

Reid, G. (1947). The efficacy of speech re-education of functional articulatory defectives in the elementary school. J speech disorders, 12, 301-313

Reilly, A.P. (1979). Vowel duration in the speech of hearing and deaf children. Journal of the Acoustical Society of America 65, S69.

Ringel, R.L., & House, A.S., Buck, K.W., Dolinski, J.P., & Scott, CM. (1970). Some relations between orosensory discrimination and articulatory aspects of speech production. Journal of Speech and Hearing Disorders, 35, 3-11.

Riper, C. van. (1978). Speech correction: Principles and methods. Englewood cliffs, N.J.: Prentice-Hall.

Roe, V., & Milisen, R. (1942). The effect of maturation upon defective articulation in elementary grades. J Speech Disorders, 7, 37-50.

Root, A. (1925). A survey of speech defectives in the public elementary schools of South Dakota. Elem Sch J, 26, 531-541.

Rosenbek, J.C., Wertz, R.T., & Darley, F.L. (1973b). Oral sensation and perception in apraxia of speech and aphasia. Journal of Speech and Hearing Research, 16, 22-36.

Rosenstein, J. (1957). Tactile perceptions of rhythmic patterns by normal, blind, deaf and aphasic children. American Annals of the Deaf, 102, 399-403.

Ross, A.O. (1976). Psychological aspects of learning disabilities and reading disorders. New York: McGraw Hill.

Sands, E.S , Freeman, F.G., & Harris, K.S. (1978). Progressive changes in articulatory patterns in verbal apraxia: A longitudinal case study. Brain and Language, 6, 97-105.

Savelsbergh, G.J., Netelenbos, J.B., & Whiting, H.T. (1991). Auditory perception and the control of spatially coordinated action of deaf and hearing children. J Child Psychol Psychiatry, 32(3), 489-500.

Sayler, H. (1949). The effect of maturation upon defective articulation in grades seven through twelve. J Speech Hearing Disorders, 14, 202-207.

Schiff, W., & Dytell, R.S. (1972). Deaf and hearing children's performance on a tactual perception battery. Perceptual and Motor Skills, 36, 683-706.

Scripture, M.K., & Jackson, E. (1972). A manual of exercises for the correction of speech disorders. Philadelphia: F.A.Davis.

Seashore, C.E. (1938). Psychology of music. New York.

Senf, G.M. (1972). An information-integration theory and its application to normal reading acquisition and reading disability. In N.B.

Bryant & C.E. Kass (Eds.), Leadership training institute in learning disabilities: Final Report (Vol.2). Arizona: University of Arizona.

Shah, V.A. (1971). As cited in M.N. Nagaraja, (1985)..

Shankweiler, D., & Harris, K.S. (1966). An experimental approach to the problem of articulation in aphasia. Cortex, 2, 277-297.

Shildroth, A.N., Rawlings, B.W., & Allen, T.E. (1989). Hearing impaired children under age 6: A demographic analysis. American Annals of Deaf, 134, 63-69.

Sigurd, B. (1973). Maximum rate and minimal duration of repeated syllables. Language and Speech Journal, 16, 373-395.

Silverman, & S.R., Lane, (1978). Deaf children. In H. Davis & S.R. Silverman (Eds.), Hearing and Deafness, 4th ed. New York: Holt, Rinehart & Winston.

Smith, C. (1972). Residual hearing and speech production in deaf children. Doctoral thesis, The City University of New York, University Microfilms International, Ann Arbor, Michigan.

Smith, C. (1973). Residual hearing and speechproduction in deaf children. Communication Sciences Laboratory Report No. 4. CUNY Graduate Center, New York.

Snijders, J. Th., & Snijders-Oomen, A.W.M. (1970). Niet-verbaal intellengentieonderzoek van horenden en doofstommen. Groningen.

Snyder, J. (1955). A study of diaochokinesis of lips, tongue and the palate of adults with non-defective speech. M. A. thesis, University of Michigan.

Speth, L. (1958). Adem en accent. Sint-Michielsgestel: Instituut voor Doven.

Sprague, A.L. (1961). The relationship between selected measures of expressive language and motor skill in 8 year old boys. Doctoral thesis, University of Iowa.

Square, P. A., and Weinder, W.E. (1976). Oral sensory perception in adults demonstrating apraxia of speech. Paper presented to the American Speech and Hearing Association (unpublished). Houston, Texas.

Stambak, M. (1965). Epreuves de niveau et de style moteurs. In R. Zazzo (Ed.), Manuel pour l'examen psychologique de 1'enfant, nr, 2, Neuchatel.

Stewart, D.K., & Love, W.A. (1968). A general canonical index. Psychological Bulletin, 70, 160-163.

Stuckless, E.R., & Subtenly, J.D. (1976). Research on communication and deafness. Proceedings of the Conference of Executives of American Schools for the Deaf, Rochester, New York.

Taylor, J. (1932). Selected writings of John Huglings Jackson (Vol.2). London: Hudder & Stoughton.

Teel, J., Winston, M , Aspinall, K., Rousey, C, & Goetzinger, C.P. (1967). Thresholds of hearing by respiration using a polygraph. Arch Otolar, 172-174.

Thomassen, A.J.W.M. (1970). On the representation of verbal items on short term memory. Nijmegen: Psychol Laboratorium, Kath Universiteit.

Thompson, B. (1984). Canonical correlation analysis: Uses and interpretation. Beverely hills, California: Sage Publications.

Torgesen. (1979). As cited in B. Wong, (1979).

Trost, J.E., & Canter, G.J. (1974). Apraxia of speech in patients with Broca's aphasia: A study of phoneme production accuracy and error patterns. Brain and Language, 1, 63-79.

Trybus, R.J., & Karchmer, MA. (1977). School achievement status of hearing-impaired children: National data on achievement status and growth patterns. American Annals of the Deaf, 122, 62-69.

Tsuzuku, T., & Kaga, K. (1991). The relations between motor function development and vestibular function tests in four children with inner ear anomaly. Acto Otolaryngol Suppl (Stcckh), 481, 443-446.

Uden, A. van. (1955). Taalonderwijs en hoortraining. Sint-Michielsgestel: Instituut voor Doven.

Uden, A. van. (1959). Erfahrungsbericht uber drei Jahre Hauerziehung tauber Kleinkinder. Neue Blatter fur Taubstummenbildung, 13, 76-82.

Uden, A. van. (1967). As cited in A. van Uden. (1983). Diagnostic testing of deaf children: The syndrome of dyspraxia. Lisse: Swets & Zeitlinger.

Uden, A. van. (1968-69). Der Rhythmus bei der Horerziehung gehorloser Kinder: Theorie und praxis, besonders bei der Hausspracher-zeihung und im Kindergarten. Arbeitstagung fur Horerziehung, Erlangen.

Uden, A. van. (1970). Eupraxie en spraak. Doctoraal Scriptie. Nijmegen: Psychologisch Laboratorium.

Uden, A. van. (1971). Het ritme bij de hoortraining van prelinguaal gehoorgestoorde kinderen: Theorie en praktijk, speciaal bij de hometraining en in de voorschool. Een origramma voor ritmiek bij de hometraining en in de voorschool. Het Gehoorgestoorde Kind, 129-143.

Uden, A. van. (1973). Taalverwerving door taalarme kinderen. Rotterdam: University Press.

Uden, A. van. (1974). Dove kinderen leren spreken. Rotterdam: University Press.

Uden, A. van. (1977). A world of language for deaf children. Part I: Basic principles: A maternal reflective method, 3rd ed. Lisse: Swets & Zeitlinger.

Uden, A. van. (1978). How to come into conversation with a still speechless and langugeless child. Sint-Michielsgestel, St.Louis: Instituut voor Doven.

Uden, A. van. (1979). Eupraxia of speech: A summary of findings. In I.G. Taylor (Ed), Proceedings of the Conference for Heads of Schools and Services for the Hearing Impaired, University of Manchester

Uden, A. van. (1980). Het belang van geheugentraining. Van Horen Zeggen, 21, 52-64.

Uden, A. van. (1981). Early diagnosis of those multiple handicaps in prelingually profound deaf children which endanger an education according to the purely oral way. J Brit Assn Teachers of the Deaf, 4(5), 112-127.

Uden, A. van. (1982). Diagnosis of such learning disabilities, which endanger the purely oral education of deaf children. In G.J. Verlag (Ed), Proceedings Hamburg, Heidelberg.

Uden, A. van. (1983). Diagnostic testing of deaf children. The syndrome of dyspraxia. Lisse: Swets & Zeitlinger.

Usha, D. (1986). Test for Articulation in Tamil. In S.K. Kacker & V. Basavaraj (Eds), (1990), The ISHA Battery. Mysore, India: All India Institute of Speech and Hearing.

Veldt, J.v.d. (1928). L'apprentissage du mouvementet l'automatisme. Leuven.

Vellutino, F.R. (1977). Alternative conceptualisations of dyslexia: Evidence in support of verbal deficit hypothesis. Harvard Educational Review, 47, 334-354.

Wallace, G., & McLoughlin, J.A. (1979). Learning disabilities. Colombus, Ohio: Charles E Merrill Publishing Company.

Wechsler, D. (1949). Wechsler Intelligence Scale for Children. New York: The Psychological Corporation.

Wechsler, D. (1967). Wechsler Preschool and Primary Scale of Intellegence. New York: The Psychological Corpaoration.

Wellman, B., Case, I, Mengert, I, & Bradbury, D. (1931). Speech sounds of young children. Univ Iowa Studies in Child Welfare, 5, No.2.

Welsh, M.W., Allison, R.B., & Dahle, A. (1975). Psychometric differences in learning disordered and normal children. J Develop Disabil, 1, 17-24.

Wertz, R.T., Lapointe, L.L., & Rosenbek, J.C. (1984). Apraxia of speech in adults: The disorder and its management. London: Grune & Stratton Inc.

Wertz, R.T., & Rosenbek, J.C. (1971). Appraising apraxia of speech. Journal of Colorado Speech and Hearing Association, 5, 18-36.

West, R. (1947). The pathology of speech and the rationale of its rehabilitation. New York: Harper & Brothers.

White, AH. (1972). The effects of Total Communication, manual communication, oral communication and reading on the learning of factual information in residential school for the deaf. Michigan: Department of Special Education, Michigan State University.

White, MA. (1979). A first-grade intervention program for children at risk for reading failure. Journal of Learning Disabilities, 12(4), 26-32.

Wilbur, R. (1987). American Sign Language. Linguistic and applied dimensions. San Diego: College Hill Press.

Wilson, S.A.K. (1908). A contribution to the study of apraxia. Brain, 31, 164-216.

Wing, H. (1968). Tests of musical ability and appreciation: An investigation into the measurement, distribution and development of musical capacity. Cambridge: Harvard University Press.

Winitiz, H. (1969). Articulatory acquisition and behaviour. Englewood Cliffs, N.J.:Prentice-Hall.

Woldring, S. (1956). Over de ademhaling tijdens het spreken van dove kinderen. Nederlands Tijdschriftvoor Doofstommenonderwijs, 153-160.

Wong, B. (1979). The role of theory in learning disabilities research. Part II: A selective review of current theories of learning and reading disabilities. Journal of Learning Disabilities, 12, 649-658.

Woodworth, R.S., & Schlosberg, H. (1971). Experimental psychology. London: Academic Press.

Yoss, K.A., & Darley, F.L. (1974). Developmental apraxia of speech in children with defective articulation. Journal of Speech and Hearing Research, 17, 399-416.

Young, J. (1940). Speech rehabilitation in rural schools of Waukesha County, Wis. J Speech Disorders, 5, 25-28.

Zazzo, R., Gallifret-Granjon, N., Manthon, T , & Stambak, M. (1964). Manual pour l'examen psychologique de l'enfant. Paris.

Zemlin, W.R. (1988). Speech and hearing science: Anatomy and physiology. Englewood Cliffs, N.J.: Prentice Hall.

Appendix 1

Picture Word Articulation Test in Tamil

The test material consisted of sixty six stimulus words testing for thirty five phonemes in Tamil in word-initial, word-medial and word-final positions.

Sl.No.	Sound	Words
1.	/a /*	/aṇil/ [squirrel]
2.	/a /**	/kaṇ/ [eye]
3.	/a:/*	/a:rañdʒu/ [orange]
4.	/a:/ **	/ka:ḷ/ [leg]
5.	/a:/***	/rodʒ a/ [rose]
6.	/i /	/ilaɪ/ [leaf]
7.	/i /***	/koḻi/ [hen]
8.	/i:/	/i:/ [house fly]
9.	/i:/**	/vi:du/ [house]
10.	/i:/***	/ti:/ [tea]
11.	/u /	/uðadu/ [lips]
12.	/u /**	/mudi/ [hair]
13.	/u:/	/u:kku/ [safety pin]
14.	/u:/**	/pu:naɪ/ [cat]
15.	/e /	/eli/ [rat]
16.	/e:/	/e:ḻu/ [seven]
17.	/e:/**	/te:ŋa:j/ [coconut]

18.	/o /	/ottagam/ [camel]
19.	/o:/*	/o:du/ [tiles]
20.	/k /*	/kaɪ/ [hand]
21.	/k /**	/kaθθarika:j/ [brinjal]
22.	/g /**	/kuraŋu/ [monkey]
23.	/kʰ /**	/puθθakʰam/ [book]
24.	/tʃ /*	/tʃa:vi/ [key]
25.	/tʃ /**	/pu:tʃtʃi/ [insect]
26.	/dʒ /*	/dʒannal/ [window]
27.	/dʒ /**	/mañdʒaḷ/ [yellow]
28.	/t /**	/pu:ttu/ [lock]
29.	/d /*	/dappa:/ [box]
30.	/d /**	/ma:du/ [cattle]
31.	/θ/*	/θakka:ḷi/ [tomato]
32.	/θ/**	/paθθu/ [ten]
33.	/p /*	/puli/ [tiger]
34.	/p /**	/pa:ppa:/ [baby]
35.	/b /*	/bommaɪ/ [doll]
36.	/b /**	/karumbu/ [sugarcane]
37.	/ʃ/*	/ʃu:/ [shoe]
38.	/s /*	/si:ttu/ [playing cards]
39.	/s /**	/ka:su/ [coins]
40.	/ŋ /**	/ma:ŋa:j/ [raw mango]
41.	/ṇ /**	/vaṇdi/ [cart]
42.	/ṇ /***	/kaṇ/ [eye]
43.	/n /*	/na:j/ [dog]
44.	/n /**	/dʒannal/ [window]

45.	/n/***	/me:n/ [fish]
46.	/ṅ/**	/pariSu/ [ball]
47.	/n̂/**	/u:nd3al/ [swing]
48.	/m/*	/maram/ [tree]
49.	/m/**	/erumbu/ [ant]
50.	/m/***	/maram/ [tree]
51.	/ḻ/**	/va:laippalam/ [banana]
52.	/ḻ/***	/tamil/ [Tamil]
53.	/ḷ/**	/valajal/ [bangle]
54.	/ḷ/***	/a:ppij/ [apple]
55.	/l/*	/lari/ [lorry]
56.	/l/**	/palli/ [lizard]
57.	/l/***	/ka:l/ [leg]
58.	/r/*	/ruba:j/ [rupee]
59.	/r/**	/karumbu/ [sugar cane]
60.	/r/***	/ka:r/ [car]
61.	/ṛ/**	/erumbu/ [ant]
62.	/v/*	/va:li/ [bucket]
63.	/v/**	/tavalar/ [frog]
64.	/j/*	/ja:nai/ [elephant]
65.	/j/**	/mujal/ [rabbit]
66.	/j/***	/na:j7 [dog]

* : sound in word initial position

** : sound in word medial position

*** : sound in word final position

Appendix 2

Techniques of Therapy for Dyspraxia

1. Oral Exercises

a) Exercises for relaxation of Oral Cavity/ Facial Muscles:

i) Sitting in upright position, tense all facial muscles that were relaxed earlier.

ii) Close eyes and drop head to rest on the arms. Let your jaw relax by letting it drop open on its own weight. Then close it and repeat the movement.

iii) Sitting comfortably, drop hands loosely on the lap. Close the eyes and relax entire face and jaw. Slowly drop the head forward on the chest. Slowly, maintaining the relaxation of jaw and facial muscles, lift the head and let it drop backward as far as it will go easily. Your jaw will drop loosely of its own weight. Alternate head between both positions.

iv) Begin as in the third exercise Rotate the head from side to side, maintaining relaxation. Rotate from right to left and reverse.

v) Repeat the third exercise in the standing position.

vi) Repeat the fourth exercise in the standing position.

b) Exercises for Mandible / Lower Jaw:

i) Allow the jaw to drop under its own weight, then raise it to close the mouth (keeping the tongue tucked inside).

ii) Drop the jaw and swing it forwards and backwards and then from side to side.

iii) Drop the jaw and gently rotate it.

iv) Keeping the lips tightly closed 'chew' an imaginary lump of gum for twenty seconds.

v) Say the following words, emphasizing the mouth opening on the initial sound:

/a:tto:, a:du, a:ru, e:ni, e:lu, e:rram, ainðu, aippasi, aivar/

vi) Try saying these sentences feeling the opening of the jaw on the vowel sounds:

/auvai o:ðina molija:m a:θθtʃtʃu:di/
/elu malai θa:ndi o:dina nila:/

c) Exercises for Soft Palate:

i) Yawn so that the velum is elevated to come into contact with the pharyngeal wall. Or say 'ah' and slowly change it to 'ng'

ii) Repeat the following words rhythmically:

/inða, arða, enða/, /ma:n, me:n, maina:/,

/noŋu, kaŋu, saŋu/, /andʒu, mandʒu, pandʒu/

iii) Practice the following sentences:

/ma:ma: θanða ma:nga:j θe:ngaj/

/na:n vaŋina u:ndʒ al panðu/

d) Exercises for Tongue

i) Flap the tongue against the top teeth rapidly.

ii) Scrape the tongue behind the bottom teeth as if you were trying to remove some toffee trapped there.

iii) Push the tongue out of the mouth, then curl the tongue tip up and down aiming to touch the nose and then the chin.

iv) Force the right and left cheeks with the tongue tip from the inside of the mouth.

v) Drop the jaw and curl the tongue tip up and down inside the mouth.

vi) Separate the jaws as for the production of the vowel /a:/ and holding contact between the sides of the tongue and the teeth, shift the tongue from side to side.

vii) Put the tongue straight, outside the mouth and move it from side to side rapidly.

viii) Curl the tongue into a 'U' shape and push it through a small circle formed by the lips.

ix) Drop the jaw and make the tongue flat in the mouth. Practice raising first the back of the tongue and then the front.

x) Let the tongue loll out completely relaxed, then tense the tongue to a point.

xi) Repeat the following exercises rhythmically:

/θa, θi, θo, θai, θau/ : carry on with */\l,* /s/, / l / , /n/, /k/, and *lxl* sounds

xii) Practice the following sentences emphasizing tongue movements:

/θa:θa: koduθθa puθθampuðu sattai/

/na:n ketta rajil la:vani/

e) Exercises for Lips:

i) Push the lips forwards to make a tube shape, then spread them in a wide smile and finally open the jaws so that the lips form a large circle.

ii) Repeat the first exercise adding sound and making the movements smoothly so that 'oo' blends into 'ee' which blends into 'ow'.

iii) Spread the lips and curl them in and out in quick succession.

iv) Lightly press the lips and slowly blow between them so they vibrate.

v) Retract the lips back, inside the mouth.

vi) Screw the lips and move them from side to side

vii) Perform the following exercises rhythmically, emphasizing all lip movements:

/pa, pi, po, pu, pai, pau/

carry on with /m/ and *hi* sounds

viii) Practice the following sentences feeling the firm movements of the lips on /p/, /b/, /m/, and *hi* sounds:

/malai me:le: velli mukil/

/ve:li me:le: pat/t/ai pa:mbu/

f) Exercises for cheeks:

i) Blow into left cheek,

ii) Blow into right cheek,

iii) Blow both the cheeks.

g) Exercises for Coordinated Control of Articulators:

i) Relax and drop mandible with the tongue resting flat. Then raise the mandible to say an emphatic 'No'.

ii) Relax the mandible and velum. Tongue lays at rest with its sides in touch with the inside of the two lower incisors. Raise the tongue to say *la:/.* Raise the lower jaw alternately while saying this.

iii) Drop the jaw slightly rounding the lips as in producing ***lu.l.***

iv) Practice the following sentences varying the movements of lips and tongue.

/panðalile: pavakkaj kanðalile: kala:kka:j/

/iðu ja:ru θatʃtʃa sattai, enga θa:θa: θatʃtʃa sattai/

2. Fine Motor Exercises

a) Finger and Hand Exercises

i) Stretch arms at shoulder height and turn palm upward and downward alternately with both hands.

ii) Stretch arms forward and turn palm of both hands to face each other.

iii) Spread and close fingers (to form a fist) of both hands alternately.

iv) Making a squeezing action alternately with both hands.

v) Make both index fingers meet at the tip and then raise one index finger at a time. Both hands alternate.

vi) Count alternately on the fingers of each hand unfolding and folding.

vii) Press the thumb against the fingers of the same hand starting with the little finger.

viii) Bring tips of all ten fingers and let them go.

ix) Quickly fold the hands with the fingers bent and then release them. Do this alternatively in both hands.

x) Bring tips of same fingers in both hands one at a time.

xi) Touch the left thumb with fingers of the right hand (each finger in turn) and vice versa.

xii) Clap hands at different altitudes, in front of the face, at level of abdomen, by knees.

xiii) Clap hands first with the back of the left hand turned upwards and then with the back of the right hand turned upwards.

xiv) Hit the table surface/lap with both the hands at the same time and then alternatively with each hand.

b) Exercises **with Both Hands**

i) Throwing ball to each other.

ii) Bouncing larger ball on ground using both hands.

iii) Throwing ball up in the air and catching,

iv) Bounce the ball against the wall and catch it.

v) Make circles with index finger in the air, one hand going clock-wise and the other going anticlockwise at the same time.

vi) Make long horizontal lines, with both hands at the same time in the air, in this way,

L hand	R hand
<——	——>
——>	<——
<——	——>
——>	<——
<——	——>

vii) Similarly making vertical lines with both hands, in this way,

↑|↑|↑	|↑|↑|
|||||	|↑|||
|↓|↓|	↓|↓|↓

viii) Waving both hands with arms, horizontally and vertically.