FINE-GRAINED AUDITORY DISCRIMINATION IN NORMAL CHILDREN AND CHILDREN WITH LEARNING DISABILITY

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Dedicated to

Achhan (my source of inspiration)

and

to all the sweet little ones who made this study

possible including

my little daughters Prerana & Prathiksha

DECLARATION

I declare that this thesis entitled ***"Fine-grained auditory discrimination in normal children and children with learning disability"*** *submitted by Swapna. N, for the award of the Degree of Doctor of Philosophy (Speech and Hearing) to the University of Mysore, Mysore, has been revised on the basis of the evaluation report extract provided and this revised thesis is fit for re-submission.*

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CERTIFICATE

*This is to certify that the thesis entitled "**Fine-grained auditory discrimination in normal children and children with learning disability**" submitted by Swapna. N for the Degree of Doctor of Philosophy (Speech and Hearing) to the University of Mysore, Mysore, was carried out at the All India Institute of Speech and Hearing, Mysore.*

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CERTIFICATE

*This is to certify that the thesis entitled "**Fine-grained auditory discrimination in normal children and children with learning disability**" submitted by Swapna. N for the Degree of Doctor of Philosophy (Speech and Hearing) to the University of Mysore, Mysore is the result of work done by her at the All India Institute of Speech and Hearing, Mysore, under my guidance.*

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DECLARATION

*I declare that this thesis entitled **"Fine-grained auditory discrimination in normal children and children with learning disability"** submitted herewith for the award of the Degree of Doctor of Philosophy (Speech and Hearing) to the University of Mysore, Mysore, is the result of work carried out by me at the All India Institute of Speech and Hearing, Mysore, under the guidance of Dr. S.R. Savithri, Ph.D., Reader & Head i/c, Department of Speech Sciences, A.I.I.S.H., Mysore. I further declare that the results of this work have not been previously submitted for any other Degree.*

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Date: 6; a| 2-001

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Though small is greater than the world
It is gainer's worth and pleasure
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To the strongest or the fastest one
But sooner or later the man who wins
Is the man who thinks he can "

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These are a few strings of words which proclaim my immense regard for many but........
"Do hands talk on mind's behalf?........"

Our mistakes are one of the few things we can truly call our own and if we cannot learn from them, who can?

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CHAPTER I

Introduction

"According to the saga, Heimdal was able to hear the grass grow. Our hearing ability is perhaps not of that kind, but our ear is anyhow almost sensitive enough to record the bounce of an air molecule against the eardrum, while, on the other hand, it can withstand the pounding of sound waves strong enough to set the Body vibrating. 'Moreover, the ear is capable of a selectivity which permits a close analysis of sounds, the various qualities of which determine the characteristics of the spoken word and of instrumental and vocal expression in the universe of music".

C-G- (Bernhard's comments concerning the awarding of the "Nobel (prize for (physiology or Medicine in 1961 to Georg Von (Bekesy

"Learning disability is a general term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning or mathematical abilities. These disorders are intrinsic to the individual, presumed to be due to central nervous system dysfunction, and may occur across the life span. Problems in self-regulatory behavior, social perception and social interaction may exist with learning disability but do not by themselves constitute a learning disability. Although learning disabilities may occur concomitantly with other handicapping conditions (e.g., sensory impairments, mental retardation, serious emotional disturbance) or with extrinsic influences (such as cultural influences, insufficient or inappropriate instruction), they are not the result of these conditions or influences" (National Joint Committee for Learning Disabilities, 1994).

A variety of learning problems are listed under the umbrella of learning disabilities. However, there are some discriminative characteristics that separate children with learning disability from others. These characteristics include discrepancy between intellectual capacity and actual performance (with better intellectual capability and poor performance) (Bateman, 1964), reading problems, writing problems, arithmetic problems, study problems, communication problems, auditory/visual perceptual problems, conceptual deficits, metacognitive deficits, memory deficits, behavioural problems, neurological problems, motor output deficits, spatial relationship and body awareness deficits, academic failure, emotional problems, and social problems (Valenti & Vogel, 1990). But not all children with learning disability exhibit all these problems.

Of these, the perceptual problems may either be exhibited in the auditory mode or in the visual mode. The most commonly observed auditory perceptual problems in children with learning disability include the following:

(a) Auditory attention or attending behaviours: Children with learning disability have difficulty in attending to pertinent auditory stimuli, particularly when multiple background stimuli are present.

(b) Auditory sequential memory and/or serial memory: Children with learning disability have a general difficulty in remembering and carrying out verbal instructions, particularly in a group setting. Recalling and sequencing auditory stimuli (strings of digits or words) and learning from rote memory (days of week) seem to take longer in these children.

(c) Auditory discrimination: Children with learning disability may not perceive the differences in sounds like /p-b/, /t-d/, /k-g/ and hence may confuse rhyming words like pat-bat (Tallal, Stark, Kallman & Mellits, 1981). They may not be able to perceive the difference between various consonant blends or may not be able to differentiate between the front door bell and the first ring of the telephone; they may also not hear the final consonants accurately.

(d) Auditory sound blending: These children often have problems in learning to blend the sounds of a word into a whole word (for e.g., c-a-t is cat).

(e) Spatial and temporal concepts and relationships: Children with learning disability not only experience difficulty in learning the sequencing of concepts, such as days of the week/months of the year, but also have problems with relationships of these concepts. For example, questions such as 'What day comes after Tuesday'? may pose a problem for these children. Concepts involving directions of left and right or even telling time or recalling events of time, such as their birth date, are usually more difficult for these children to learn.

(f) Auditory processing: Children with learning disability listen to conversation delivered at a normal rate; but they may comprehend only if information is presented very slowly and repeated several times.

(g) **Auditory localization:** These children have difficulty in indicating the direction of sound source,

(h) **Auditory distortion:** They hear some sounds better than the other which leads to spelling errors,

(i) **Auditory selectivity:** They may mishear frequencies in a drastic manner. For example, they may hear a tone of 6 kHz as high as 8 kHz. This kind of hearing may disturb the speech perception and result in spelling errors,

(j) **Response timing:** The response timing in children with learning disability are longer than in normal children, which leads to difficulty in gathering the information received.

Among the auditory perceptual processes, auditory discrimination has functional implication for perceiving spoken language because it allows the listener to discard differences that are irrelevant for word identification. The term auditory discrimination refers to the ability of an individual to contrast sounds. Both researchers and clinicians have used the term auditory discrimination to refer to different (phonological, phonetic and phonemic), but still overlapping, discrimination skills.

Until fairly recently the auditory perceptual functioning in children with learning disability was judged primarily from their performance on ***behavioral tests of auditory discrimination, auditory memory span and auditory sequencing.*** These tests employed naturally spoken sounds or nonsense syllables as stimuli. However, the psychoacoustical research suggests that an auditory discrimination deficit might be better explored by means of nonmeaningful ***synthetically produced speech stimuli*** in which specific acoustic characteristics, such as voice onset time (VOT), could be systematically altered and tasks that do not require a verbal response can be used. The computer produced stimulus has some times represented "good" tokens of natural speech (Tallal & Piercy, 1974) while, at other times, the synthesized syllables have represented intermediate steps along a continuum between two end point syllables (Brandt & Rosen, 1980; Godfrey, Syrdal-Laskey, Millay & Knox, 1981). Generally, the task involves identification of stimuli from a continuum of synthetic sounds, which range from one end point (e.g., /ba/) to another (e.g., /da/). Most of this research involves syllables beginning with stop consonants, as they are relatively difficult to perceive for at least two reasons. First, they occur quickly in time as compared to other consonants and second, unlike other speech sounds such as vowels, their creation involves transition and different frequencies.

Synthetic stimuli have been used for identification and discrimination of stimuli in the past. Using a continuum of synthesized consonant-vowel (CV) syllables that represented stop consonants differing in place of articulation, Elliott, Longinotti, Meyer, Raz & Zucker (1981) developed a fine-grained measure of auditory discrimination that provided scores of individual listener. The research used an auditory discrimination procedure that assesses the "smallest difference" associated with speech-like consonant (C) sounds that may be discriminated (just noticeable differences - JNDs). Because JNDs were measured the task was considered as assessing *"fine-grained auditory discrimination"*. The results of the study demonstrated that *normal children* require larger acoustic differences in both frequency and time to discriminate consonant sounds than the *normal adults.* Further more, Elliott & Busse (1987) found the performance of many high-achieving *young adults with* relatively severe *language-learning disabilities* to be as poor, or even poorer than that of normal six-year old children and poorer than that of their normally developing age-mates for this fine-grained auditory discrimination task of frequency differences associated with CV stimuli. This finding was particularly interesting because performance of these same young adults on the speech perception in noise (SPIN) test (Kalikow, Stevens & Elliott, 1977; Bilger, Neutzel, Rabinowitz & Rzeczkowski, 1984) equaled that of their normally developing peers for high-predictability sentences, where contextual information may facilitate speech perception. However, their SPIN Test performance was remarkably poorer than that of their peers for low-predictability sentences, which require precise perception of acoustic information. High- and low-predictability sentences are intermixed on the SPIN Test. Thus, cognitive processes such as attention to the task, motivation and memory components would be expected to be equivalent for both types of sentence items and should not differentially influence performance for only one type of sentence. These subjects' poor performance on low-predictability sentences, where cognitive contributions are minimal, suggested that poorer-than-normal auditory perception of the acoustic waveform might characterize some who experience language-learning problems.

Elliott & Hammer (1988) studied two groups of children - one progressing normally in school and the other exhibiting ***language-learning problems.*** They were tested in each of three years on a set of fine-grained auditory discrimination .tasks that required listening to small acoustic differences (JNDs) on a same-different task. JNDs were measured with regard to both /ba/ and /pa/ ends of the VOT continuum. The results revealed that the children with language-learning problems, despite having normal intelligence quotient (IQ) and normal pure tone sensitivity, showed poorer auditory discrimination than normal children for 'temporally' based acoustic differences. This effect continued across 3 years. Subsequently, Elliott, Hammer & Scholl (1989) studied two large groups of 295 children in the age range of 6-11 years who were divided into two groups - one progressing normally and the other exhibiting ***language-learning problems.*** Two continuums of CV stimuli were used. A five-formant, eight-item continuum that varied in VOT from 0-35 msec in 5-msec step (ba-pa) was created. The second continuum represented the place of articulation feature of speech production (ba-da-ga) and consisted of thirteen items, each having five formants. The major acoustic differences along this continuum were the onset frequencies of the second and third formants. A same-different task was used. JNDs were measured with regard to /ba-pa/ ends of the VOT continuum. For the place of articulation continuum, JNDs were measured relative to /da/ separately in the direction of /ba/ and /ga/. The results indicated that among the younger group (6-7 years) more numbers of children with language-learning problems were unable to make any of the fine-grained auditory discrimination. In contrast, among the older group (7-11 years), only two children with language-learning problems were unable to make one discrimination each. Results suggested that the children with language-learning problems experience delayed maturation of the fine-grained auditory discrimination relative to normal children. The authors concluded that fine-grained auditory discrimination makes a major contribution to language learning, particularly in the early elementary school years.

Steffens, Eilers, Gross-Glenn & Jallad (1992) investigated phonetic perceptual processing capabilities in 18 normal adults and 18 ***adults with familial dyslexia.*** Three synthetic speech continua were used. The first was a vowel continuum /a-S/, and the second was a /ba-da/ spectral continuum in which F2 and F3 were varied. The third was a /sta-sa/ continuum in which a temporal cue, silence duration, was systematically varied. The subjects participated in an identification task (categorization of the stimuli) and two discrimination tasks. The first discrimination task was a same-different paradigm and the second discrimination used an ABX paradigm. The results indicated that adults with familial dyslexia identified less stimuli compared to normals and required longer duration of silence than normals to shift their perception from /sa/ to /sta/. The responses for ***l&-dl*** continuum varied among males and females. The authors concluded that adults with dyslexia lack the precision demonstrated by normal readers in tests of identification and discrimination and their overall performance was generally less accurate.

Elliott & Hammer (1993) tested the hypothesis that as children's language development matures, factor-analytic structural changes occur that are associated with measures of fine-grained auditory discrimination. The subjects of the study were 187 normal and 197 ***children with language-learning problems*** and a small group *of* ***retarded children.*** The stimuli developed by Elliott et al., (1989) for VOT and place continuum were used. A same-different task was used to determine JNDs. The authors found that younger children with language-learning problems required a 35% longer VOT than normal children to make a discrimination. JNDs were longer in children with language-learning problems compared to normals for place continuum. Three main points pertain to mean outcomes: (a) older children performed better than younger children on virtually every task, (b) the children with language-learning problems performed more poorly than those achieving regular school progress; this difference was more prominent among 6-7 year olds than among those aged 8-11 years, and (c) mean performance of children with moderate intellectual impairments was poorer than that of the other two groups. The results suggested that the performance of young children (6-7 years) who are learning basic language skills may be described, in part, by a fine-grained auditory discrimination dimension or factor, and that, the poorer the children's language-speech competencies, the greater this dimension's salience. Among older children (8-11 years), with better speech and language skills, fine-grained auditory discrimination seemed less a unitary dimension and failed to account for a major proportion of the variance among this set of tasks.

Bradlow, Kraus, Nicol, McGee, Cunningham, Zecker & Carrell (1999) investigated the precise acoustic feature of stop consonants that pose perceptual difficulties for some ***children with learning problems.*** The discrimination thresholds (JND) along two separate synthetic /da-ga/ continua were compared on a fine-grained auditory discrimination task in a group of children with learning problems (11 children with learning disability, 41 with attention deficit disorder and 7 with both) and a group of normal children aged 6-16 years. Two /da-ga/ place of articulation continua were created using the Klatt cascade-parallel formant synthesizer (Klatt, 1980). In the first continua, the length of the formant transition duration was 40 msec and in the second continua, it was increased to 80 msec. A control condition /ba-wa/ (a stop-glide continuum) was also created. Results indicated that the discrimination thresholds were elevated in the children with learning problems in the /da-ga/ continua at both 40 and 80 msec transition duration. There was no significant difference between both the groups in the /ba-wa/ continua. Thus lengthening the formant transition duration from 40 to 80 msec did not result in improved discrimination thresholds for the group of children with learning problems. An electrophysiological response that is known to reflect the brains representation of a change from one auditory stimulus to another - the Mismatch Negativity (MMN) - was recorded which indicated diminished responses in the group of children with learning problems to /da/ vs. /ga/ when the transition duration was 40 msec. In the lengthened transition duration condition, the MMN responses from both the groups were similar and were enhanced relative to the short transition duration condition. These data suggest that extending the duration of the critical portion of the acoustic stimulus can result in enhanced encoding at a pre attentive neural level; however, this stimulus manipulation on its own is not a sufficient acoustic enhancement to facilitate increased perceptual discrimination of this place-of-articulation contrast. Taken together, these behavioral and neurophysiologic data suggest that the source of the underlying perceptual deficit may be a combination of faulty stimulus representation at the neural level as well as deficient perception at an acoustic-phonetic level, which suggest a 'biological basis' for the impaired behavioral perception.

There are seven studies that have used fine-grained auditory discrimination. Of these studies, Elliott et al., (1981) compared fine-grained auditory discrimination abilities of normal children and adults. Steffens et al., (1992), and Bradlow et al., (1999) have investigated fine-grained auditory discrimination in adults with familial dyslexia and children with learning problems, respectively. The other authors (Elliott & Hammer, 1988, 1993; Elliott, Hammer & Scholl, 1989) have investigated fine-grained auditory discrimination in children with language-learning problems and Elliott & Busse (1987) have investigated in young adults with language-learning disabilities. Spectral parameters (Elliott et al. 1981; Elliott & Busse, 1987; Bradlow et al. 1999), and various spectral and temporal parameters (voice onset time and place of articulation represented by varying F2 and F3 - Elliott & Hammer, 1988; Elliott, Hammer & Scholl, 1989; Elliott & Hammer, 1993; vowel and consonant, and silence in /sta-sa/ pair- Steffens et al. 1992) have been used to measure JNDs. Also, the only VOT continuum used is /ba-pa/ and the only continuum used for silence is (sta-sa). All the studies are conducted on English speaking children or adults. The results of these studies indicate that children and adults with language-learning problems are poor in their fine-grained auditory discrimination abilities. There is no information on fine-grained auditory discrimination in children with learning disabilities. Neither is there information about the prevalence of auditory discrimination problems in children with learning disabilities nor is it known whether performance on the fine-grained auditory discrimination task can definitely separate children with learning disabilities from normal children. Also, there is no information about the performance of children with learning disabilities on the fine-grained auditory discrimination for VOT continuum other than /ba-pa/, for closure duration continuum and on other languages. As stop consonants differ from one language to another, VOT and closure duration of these consonants also differ. To address these issues the present study was undertaken in Malayalam language. Malayalam is a language spoken by the native people of the state of Kerala, in South India. It is also classified as a Dravidian language (Ladefoged & Maddieson, 1996). It has five places of articulation for stop consonants. It is a language having the maximum number of articulatory places. The unvoiced consonants have four aspirated (p^h, $t̪^h$, $ṭ^h$, k^h) and five unaspirated consonants (p, t̪, t, t k). The voiced consonants have three weakly voiced (P, T̪, K) and four unaspirated (b, d̪, d g) consonants. Unlike English, stop consonants do not occur in word-final position in Malayalam.

Objectives of the study

The aim of this study was to investigate the auditory discrimination abilities in 7-12 year old Malayalam speaking children with learning disability.

1) More specifically, the main purpose of the study was to investigate the difference between children with learning disabilities and normal children in auditory discrimination abilities when the perceptual cues, voice onset time (VOT) and closure duration (CD) are altered in computer edited natural CV syllables. It was designed to determine whether the just noticeable difference (JND) was different for both the groups. If the JND were same for both the groups, this would indicate no difference in auditory discrimination abilities. If the children with learning disabilities showed a larger JND, it would suggest a difficulty in auditory discrimination.

2) The second purpose of the experiment was to determine whether children with learning disabilities would perform better on an auditory discrimination task when presented with multiple cues than when presented with single cues (closure duration vs. closure duration and transition duration). This was aimed to assess the efficacy of individual acoustic cues with respect to multiple acoustic cues.

3) The third purpose of the study was to determine whether children with learning disability as a group demonstrate different JNDs depending on the place of articulation of consonants.

In order to answer the questions posed in the objectives, two tasks were carried out. Task I was aimed at developing synthetic speech material that would permit the observation of the effects of altering different kinds of temporal cues and task II was aimed at evaluating the auditory discrimination abilities in Malayalam speaking children with learning disability and normal children in the age range of 7-12 years.

A total of three parameters were altered. The chapters constitute the experiments conducted and their results. The differences in auditory discrimination abilities found are discussed. Also a chapter on general discussion has been added to present an "overall picture" of the auditory discrimination abilities in children with learning disabilities as found from these experiments. The details of the experiments conducted are depicted in table 1.1.

Chapter Number	Parameter altered to cue voicing	Condition	Position of occurrence of the stop consonant
III	VOT	Single cue	Initial
IV	CD	Single cue	Medial
V	CD/Transition duration	Multiple cue	Medial

Table 1.1: Details of the experiments conducted in this thesis.

A fine-grained auditory discrimination task was adopted. This testing procedure was deemed appropriate for investigating the auditory discrimination deficits of school-aged children with learning disabilities based on the assumption that, rather than having difficulty perceiving naturally spoken speech under favorable listening conditions, these subjects have difficulty under less-than-optimal listening conditions. This task tests the subject's ability to detect small differences between synthetic speech stimuli that varied along an acoustic dimension. Thus this type of task with 'stripped down' synthetic speech allowed to test speech sound discrimination under conditions that stress the system beyond what is required in natural spoken language processing. This measure is very useful for identification and monitoring of children whose learning problems may have an auditory-phonetic basis (Bradlow et al. 1999).

Implications

It is hoped that research in this area of children with learning disabilities will delineate new insights into the mechanisms involved in the neurological basis of speech and language processing. Moreover, the results of this experiment may lead to a better understanding of the prevalence of auditory discrimination problems in children with learning disabilities, and etiology of learning disabilities that could result in improved diagnostic and therapeutic techniques. In addition, this line of research may help us to determine whether fine-grained auditory discrimination can be used as a tool to differentiate children with learning disabilities from normal children.

This study derives significance from the point of clinical application. As, a comparison of the auditory discrimination abilities in normal children and children with learning disabilities is undertaken, the results may indicate the specific synthetic material which could be used in therapy. This will help in designing auditory training procedures or compensation for learning disabled children with auditory discrimination deficits.

CHAPTER II

Review of Literature

Nature speaks -with a thousand voices and we have only begun to listen.

(llya Prigogine and I sabella Stengers, order out of chaos, Toronto: Bantam Books, 1984, P. *77)*

The field of learning disabilities has matured tremendously since the term was first introduced in 1962 (Kirk, 1962). It is one of the most challenging and popular subjects related to language disorders. In recent years, speech-language clinicians increasingly have been confronted with children who exhibit learning disorders in the absence of any obvious underlying factors such as hearing loss, mental retardation, emotional disturbance or peripheral structural deficits. The condition of learning disabilities is perplexing and presents us with a challenge. These children appear so normal, yet they demonstrate subtle and complicated patterns. Although such children are not blind, many do not see as normal children do; although they are not deaf, many do not listen or hear normally and although they are not retarded in mental development, they do not learn. In order to differentiate this more recently established condition from the others, it has been suggested that the term "learning disability" be used to indicate the various types of learning difficulties encountered by children with mild central nervous dysfunction who are not mentally retarded. Because their difficulties are not obvious, persons with learning disability are often misunderstood and maligned.

Officially, the field of learning disabilities became organized only in 1963 and was recognized as a division of the international organization of the special education, and the International Council for Exceptional Children in 1965. Since then this field has been a long-standing source of controversy, conflict, and crisis (Keogh, 1988). One of the reasons for this could be the vagaries and antagonisms surrounding the definition (Mather & Roberts, 1994). Yet another disagreement involves the basic professional responsibility for the identification, description and remediation of learning disability. Because the child with learning disability often exhibits problems that are generally treated by professionals in different disciplines, it has been difficult for individual professionals to deal effectively with the total child.

Johnson & Myklebust (1967) suggested the term "psychoneurological learning disability" to distinguish this special group of children. They point out that in cerebral palsy the common factor is motor involvement, in mental retardation it is generalized low mental ability, in the blind and deaf it is the sense, which is impaired, and in emotional disturbance it is a primary functional or psychological problem. In the case of a psychoneurological learning disability, it is the fact that all of these senses and abilities are adequate in the presence of a learning deficiency, which characterizes the common denominator of this condition.

Some prefer to use the term "perceptually handicapped" because it describes a major condition, which seems to be at the root of many learning disorders. The Oakland Schools in Michigan use this designation in reference to their special classes for these children. Cruickshank (1972) observed that more than forty English terms have been used in the literature to refer to some or all of the children subsumed under the learning disability label. Hammill, Leigh, McNutt & Larsen (1981) also noted that a variety of terms such as minimal brain damage/injury, psychoneurological learning disability, dyslexia or perceptual handicap, to name a few, have been used to refer to learning disabled population.

PREVALENCE

In 1975, the prevalence of learning disabilities was estimated to be about 1-3% of the school population (Lerner, 1993). But at present, it is 4-5% of students aged 6-17 years (Hallahan & Kauffmann, 1994). The substantial reasons why the prevalence rate in learning disabilities soared are increased public awareness of learning disabilities, and improved assessment techniques of learning disabilities across the years (Lerner, 1993).

DEFINITION

The definition of learning disabilities has seen almost constant debate that has deflected attention away from equally important issues and has made it the "phantom category" in special education (Keogh, 1987 a).

In 1920's learning disability was thought to be a nervous condition. During the 1930's and 40's the terms "brain injured", "brain injured child", and "brain crippled", suggested by Strauss & Lehtinen (1947) were used to describe behavior and learning disabilities. Although the terms "brain damage" and "brain damaged child" have gained wide spread acceptance in the literature; many authorities have expressed serious objections to the use of these terms. The two most frequent arguments were (a) learning disabilities are not always evidence of brain damage, and (b) braiii damage always does not result in deviation. The term brain damage or some variation is disturbing to both the parents and the child. Still another frequent argument is that central nervous system (CNS) impairment may exist in any one or a combination of dysfunction and the severity of symptoms may vary from mild to severe. On the other hand several authorities feel that the sequel to brain dysfunction may be sub clinical or inferred borderline, and therefore, contend that if the term brain damage is prefixed by minimal (minimal brain damage), it is appropriate.

Tracking the history of learning disabilities and the evolution of the concept of learning disability seems rather complicated. Three phases can be identified in the evolution as follows:

(a) The foundation phase (1800-1930),

(b) the transition phase (1930-1960), and

(c) the integration phase (1960-1980).

The foundation phase is marked by basic scientific investigations of brain function and dysfunction in which many clinical studies of speech and language disorders were reported. The major goals of these works was to document the specific loss of various speech and language function in adults who had previously shown these abilities and the type of brain damage associated with different kinds of functional disturbances. These works established the fact that very specific types of mental impairment can occur as a result of damage to isolated regions of brain, which was of paramount relevance to the study of learning disability. Terms such as loss of reading ability, alexia, word blindness, dyslexia, and congenital word blindness were used during this period.

In the later years scientific studies of the brain were applied to the clinical study of children and translated into ways of teaching. This phase (about 1930-1960) represents the transition phase. The professionals developed assessment and treatment methods for these children and studied specific types of learning disorders found'in children.

Among the several professionals who played important roles in developing the field, Orton (1937) was a pioneer whose theory on the lack of cerebral dominance as a cause of children's language disorders led to the development of a teaching method known as Gillingham method. Orton saw many children who appeared to be bright but had difficulty with reading, writing, spelling and speech. Many of these children also showed confusions in time, space and directional orientation. They really were not 'word blind'. They could see and copy words but were unable to understand their meanings. Orton thought that the fundamental problem lay in translating between heard and written words and proposed the term "strephosymbolia" (twisted symbols) to replace congenital word blindness. Orton's approach to reading was a stage of language development, preceded by spoken language and later, expression in writing that involved spelling. He looked upon language as a hierarchy of complex integration in the nervous system, culminating in unilateral control by one of the two brain hemispheres. He worked during an era in which many left-handed children were being trained to be right-handed. He proposed that failure in the development of a clearly dominant cerebral hemisphere resulting in indistinct image formation was the cause of strephosymbolia. He preferred the term developmental to congenital in order to take into account the interaction of heredity and environment in producing this state.

Assessment techniques, teaching strategies, a variety of theories and the enactment of legislation designed to protect the right of handicapped children and youth were developed, during the subsequent times. Another landmark during this period was the development of learning disabilities organizations like the Counsel for Learning Disabilities (CLD) and the Association for Children and Adults with Learning Disabilities (ACALD) in 1963. These organizations were effective in bringing together the parents, teachers and other professionals who deal with these children to develop school programs.

For the first time, the field of learning disabilities was acknowledged in Federal law when congress passed the Children with Specific Learning Disabilities Act of 1969 (PL 91-230, 1969). In 1975, the learning disability field achieved a firm basis in law with passage of PL 94-142 in the United States of America. Under this landmark legislation, all handicapped children and youth aged 3-12 years have the right to a free and appropriate public education. At that time, there was the problem of over and under identification. There had been a tendency both to include (Cruickshank, 1972) and exclude the mentally retarded from the ranks of the learning disabled. This had been a particularly troublesome point because 85% of the mentally retarded were mildly disabled, and when their clinical states were carefully examined, many disclosed histories of having been categorized within learning disability in the past.

An all-comprehensive and specific definition of learning disability has been elusive despite an extensive research conducted in the field. This is probably aided by the confusion in terminology, nomenclature and operational difficulties used by different researchers as seen earlier. Definitions of learning disability are fraught with terminological confusion. The early definitions within the medical framework emphasized the underlying mechanism and led to terms such as 'minimal brain damage', 'minimal brain dysfunction' and 'developmental dyslexia'. In the absence of hard evidence of the involvement of the brain and brain damage, these medical terms were discarded in favor of those within an educational framework in the 1960s.

There have been note-worthy contributions by many professions to the field of learning disability. This is instrumental for multidisciplinary dimensions to be evolved. Because of so many diverse professions that are concerned, a confusion of terminology and conflicting conceptualization pervade current discussions in the literature. Different approaches or dimensions include the following:

a neurological dysfunction,

b uneven growth pattern,

c difficulty in academic and learning tasks,

d discrepancy between achievement and potential, and

e identification by the exclusion of other causes.

The term learning disability and its first formal definition was first put forth by Kirk (1962) and according to him, learning disability refers to a retardation, disorder or delayed development in one or more of the processes of speech, language, reading, spelling, writing, arithmetic or other school subjects resulting from a psychological handicap caused by a possible cerebral dysfunction and/or emotional or behavioral disturbance. It is not the result of a mental retardation, sensory deprivation or cultural and instructional factors. This definition was the first to introduce the notion of psychological process disorders and how they interfered with academic performance. But the definition faced certain criticisms. The actual problem might be either a retardation, disorder, or delay, but the differences among these possibilities was not specified. With respect to etiology, central nervous system (CNS) dysfunction was affirmed, but some confusion was introduced by suggesting that learning disability might be caused by emotional or behavioral disturbances. This may confound with "emotionally handicapped" category. The definition also introduced the exclusion clause as a definitional component by emphasizing that learning disabilities cannot be primarily due to some other condition. Although useful in providing a separate identity, exclusion is not a positive criterion for explicating what characteristics are represented in the learning disability concept.

The definition offered by Bateman (1965) introduced and emphasized underachievement as a fundamental component of learning disability. The definition is as follows: Children who have learning disorders are those who manifest an educationally significant discrepancy between their estimated intellectual potential and actual level of performance related to basic disorders in the learning processes, which may or may not be accompanied by demonstrable central nervous system dysfunction and which are not secondary to generalized mental retardation, educational or cultural deprivation, severe emotional disturbance or sensory loss. The definitional components related to process deficits and exclusion were affirmed, and the concept of discrepancy was introduced as a critical factor. The definition, however, possessed some difficulties. First, a stipulated level for the discrepancy was not indicated, and no statement providing information on how best to measure intellectual potential or actual level of performance was provided. Second, no etiological statement was included, and the CNS dysfunction idea became equivocal with the statement "may or may not."

The National Advisory Committee on Handicapped Children (NACHC, 1968) provided a legislative definition of learning disability which is as follows: Children with special (specific) learning disability exhibit a disorder in one or more of the basic psychological processes involved in understanding or in using spoken and written language. These may be manifested in disorders of listening, thinking, reading, writing, spelling or arithmetic. They include conditions, which have been referred to as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, developmental aphasia etc. They do not include learning problems that are due primarily to visual, hearing or motor handicaps, to mental retardation, emotional disturbance or to environmental disadvantage. This definition emphasized the notion of specific learning disabilities; the learning failure was not a generalized problem like mental retardation but rather one predicted on the possession of only a discrete number of deficits. The specific notion appears to be undermined, however, by the phrase "one or more" because the number is not specified. Although not explicit with respect to CNS dysfunction, the assumption that learning disability is similar to conditions emanating from neurological impairments is indicated, but this definition again produces an inherent vagueness. Additionally, the definition offers no statement about requisite severity levels.

Several committees formed to channel these diverse perspectives, attempted to draw up a definition that was meaningful and acceptable to all concerned professional groups and provide a more educational focus. The committee presented the following definition (Kass & Myklebust, 1969).

- Learning disability refers to one or more significant deficits in essential learning processes requiring special education techniques for remediation.
- Children with learning disability generally demonstrate a discrepancy between expected and actual achievement in one or more areas such as spoken, read or written language, mathematics and spatial orientation.
- The learning disability referred to is not primarily the result of sensory, motor, intellectual or emotional handicap, or lack of opportunity to learn.
- Significant deficits are defined in terms of accepted diagnostic procedures in education and psychology.
- Essential learning processes are those currently referred to in behavioral science as involving perception, integration and expression, either verbal or nonverbal.
- Special education techniques for remediation refer to educational planning based on the diagnostic procedures and results.

There are at least four problems with this definition that have become apparent since it was proposed.

1) It does not indicate clearly enough that learning disabilities are a heterogeneous group of disorders.
2) It fails to recognize that learning disability frequently persists and are manifested in adults as well as in children.
3) It does not clearly specify that, whatever the cause of learning disability, the 'final common path' is inherent alterations in the way information is processed.
4) It does not adequately recognize that persons with other handicapping or environmental limitations may have a learning disability concurrently with these conditions.

In order to address these criticisms, the National Joint Committee for Learning Disabilities (NJCLD 1981), composed of representatives from six professional organizations, proposed a new definition, which is as follows:

"Learning disability is a generic term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning or mathematical abilities. These disorders are intrinsic to the individual, presumed to be due to central nervous system dysfunction. Even though learning disabilities may occur concomitantly with other handicapping conditions (e.g., sensory impairment, mental retardation, social and emotional disturbance) or environmental influences (cultural differences, insufficient or inappropriate instruction, psychogenic factors), it is not the direct result of those conditions or influences". This definition also had its own problems. The notion of discrepancy, and hence learning disability as under-achievement, has not been stated explicitly, and level of severity is only indicated by "significant". Unlike earlier definitions where process deficits were the most direct manifestation of CNS dysfunction, no such relationship is specified, and it is not clear what the presumed neurological impairments "cause".

Interagency Committee on Learning disabilities (ICLD) formulated an improved learning disability definition in 1987 which is as follows: "Learning disability is a generic term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning or mathematical abilities *or of social skills* (italics added). These disorders are intrinsic to the individual, presumed to be due to central nervous system dysfunction. Even though learning disabilities may occur concomitantly with other handicapping conditions *(e.g.,* sensory impairment, mental retardation, social and emotional disturbance) or *socioenvironmental influences* (italics added) (e.g., cultural differences, insufficient or inappropriate instruction, psychogenic factors), *and especially attention deficit disorder, all of which may cause learning problems* (italics added), a learning disability is not the direct result of those conditions or influences". The ICLD, rather than formulating a new definition, believed that the NJCLD definition was the best available and required only some modification (the modifications are italicized). Thus the difficulties outlined for the NJCLD definition also apply to the ICLD definition plus some new difficulties were introduced by the modifications. Although recognizing that a student with learning disability might also possess social problems, the desirability of including social skill deficits as a primary form of learning disability raises serious questions (Silver, 1988; Gresham & Elliott, 1989; Forness & Kavale, 1991). First and foremost, there is the problem of diagnosing leaning disability without academic deficits; a student without difficulties in reading, writing, or mathematics could potentially be diagnosed as learning disability and placed in a learning disability program solely for treatment of social skill deficits. Additionally, the research is equivocal with respect to the nature, extent, and assessment of social skill deficits among students with learning disability (Vaughn & Haager, 1994).

The National Joint Committee on Learning Disabilities (NJCLD) in 1994 modified its earlier definition to reflect new knowledge and eliminate inherent ambiguity. The definition is as follows: "Learning disability is a general term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning or mathematical abilities. These disorders are intrinsic to the individual, presumed to be due to central nervous system dysfunction, and may occur across the life span. Problems in self-regulatory behaviors, social perception and social interaction may exist with learning disability but do not by themselves constitute a learning disability. Although learning disabilities may occur concomitantly with other handicapping conditions (e.g., sensory impairment, mental retardation, serious emotional disturbance) or with extrinsic influences (such as cultural differences, insufficient or inappropriate instruction), they are not the result of those conditions or influences".

The Diagnostic and Statistical Manual of Mental Disorders - Fourth Edition (DSM-IV: American Psychiatric Association, 1994) established a clinical definition of learning disability which is as follows: "Learning disorders are diagnosed when the individual's achievement on individually administered standardized tests in reading, mathematics or written expression is substantially below that expected for age, schooling and level of intelligence".

The evolution of the learning disability definitions appears to have converged on the following ideas:

1. Learning disability is marked by heterogeneity.
2. Learning disability is probably the result of CNS dysfunction.
3. Learning disability involves psychological process disorders.
4. Learning disability is associated with underachievement.
5. Learning disability can be manifested in spoken language, academic, or thinking disorders.
6. Learning disability occurs across the life span.
7. Learning disability does not result from other conditions.

The concept of learning disability has matured over the years. There is a finer understanding of the group of disabilities now than ever before. Three major changes that have occurred world over in the definition and identification of learning disability in the recent past is reported by Karanth (2003).

1. **Recognition of individual differences in reading achievements:** Recent definitions reflect a gradual shift from the traditional categorical approach that broadly characterized children with learning disability into those with 'specific reading retardations' and those with 'general reading backwardness' to a newer dimensional approach of individual differences in reading achievement. This latter approach has been increasingly adopted by most researchers but is to be adopted by practitioners on a wider scale. Additionally, earlier, the trend was to remove learning-disabled students from regular class, and place them in special education classes, but now the trend is reversed and they are brought back to regular classrooms for integration. Regular teachers and special educators are beginning to share the responsibility to teach children with learning disability (Green, 1974, among others).

2. **Life span approach to learning disability:** Children identified as learning disabled in the 1960s and 1970s continued to experience difficulties with different types of information processing in adulthood, despite the early intervention and support they receive in their childhood and school years. This led to a shift from the traditional to a life span approach.

3. **The identification/recognition that learning disability is a language based difficulty:** Research findings during the last two decades have increasingly substantiated the language-oriented view of learning disability. In the west, in particular, empirical evidence of the phonological processing difficulties of children diagnosed with learning disability have increasingly stimulated language based research and theories of learning disability which characterize it basically as a linguistic/metalinguistic processing problem. As can be seen in the current definition of learning disability, the difficulties are not necessarily in reading and writing alone, but may also include difficulties in listening

and speaking. Primary characteristics of learning disability are difficulties in the acquisition and use of listening and speaking besides and or reading and writing. Language acquisition and use, as well as the child's awareness of language (metalinguistic) are increasingly identified as factors that relate or contribute to learning difficulty. A substantial number of children diagnosed with speech and language impairments including delayed speech-language acquisition, articulation and fluency disorders in the preschool years are later identified as having learning disability and vice versa. Language use or the pragmatics of language is affected in children and adolescents with learning disability leading to problems in social interaction and social acceptance. Metalinguistic awareness (the conscious awareness of language) and phonological awareness (the awareness of sound patterns and units of one's language) in particular have been identified as prerequisites for successful early reading and have been demonstrated to be poor in children with learning disability.

Another major language related factor that complicates the issue/question of learning disability is bilingualism/multilingualism. Children whose mother tongue/dialect differs from that used at school have the additional burden of learning to cope with the linguistic differences in the school environment adding to their learning difficulties particularly in the early school years.

ETIOLOGY OF LEARNING DISABILITIES

In the literature and the research, a number of causes of learning disability have been listed and some of them are being investigated. These causes can be grouped under physiological, neurological, social, motivational and perceptual factors, (Table 2.1).

Physiological	Neurological	Social	Perceptual
a) Genetic b) Pre-, peri-, post-natal c) Developmental d) Biochemical	Cross modal integration Bilateral maldevelopment of the angular gyri Symmetry of the planum temporale Cortical abnormalities Reversed asymmetry Abnormalities in the magnocellular neurons Dysfunction in the left hemisphere	Pattern of interaction with environment	Auditory processing deficits

Table 2.1: Causes of learning disability.

1) **Physiological factors**

a) Genetic factors: It is known that the incidence of learning disability increases among family members of children with the disorder, suggesting a genetic link. Hallgren (1950) concluded from his study that there was a high probability that word blindness (a specific form of dyslexia) was determined by a dominant mode of inheritance. In a related study, Hermann (1959) reported 100% concordance in monozygotic twins and 33% concordance among dizygotic twins for congenital word blindness. Dyslexic boys outnumber girls with a ratio of 3 to 1. Certain learning problems (especially those of a language or language related nature) are more common in male children (Singer, West Phal & Niswander, 1968; Rourke, 1978 b; Ansara, Gechwind, Galaburda, Albert & Gartrell, 1981). The vulnerability of the male suggests that genes carried on X chromosome plays a part, but other genes may also contribute. Owens (1978), however, in her review of research on genetic aspects, concluded that certain types of dyslexia may be transmitted via multifactor inheritance, i.e. expression and severity is a complex interaction between genetic predisposition (probable multiple genes) and environmental experience. Dyslexia has been linked to an aberration on chromosome 15 (Smith, Kimberling, Pennington & Lubs, 1983). There are also indications of considerable genetic homogeneity.

Researchers have thus concluded that learning disabilities run in families (Hallahan & Kauffmann, 1994).

b) **Pre-, peri- and postnatal causes:** The learning disabilities of some children may be the result of prenatal, perinatal or postnatal problems. Pasamanick & Knoblock (1973) mention the following factors in association with prenatal neurological damage and later learning problems.

i) Maternal-fetal blood type incompatibilities (Rh factor)
ii) Maternal endocrine disorders (hypothyroidism, diabetes etc.)
iii) Radiation
iv) Maternal age, reproductive readiness and efficiency
v) Drugs
vi) Rubella
vii) Anoxia
viii) Maternal cigarette smoking
ix) Prematurity
x) Accidents

Some of the perinatal factors that can cause learning disabilities are:

i) Labour and delivery problems such as breech presentation, very short duration of labor, hydramnios and premature rupture of membranes,
ii) Low birth weight (Wallace, 1972).

Postnatal factors can also affect the development of a child. Children who suffer from chronic ear infection, head trauma, or intracranial infection (encephalitis or meningitis) and those who ingest or inhale neurotoxins may become learning disabled. Another possible cause is oxygen deprivation, such as in cases of near drowning, carbon monoxide poisoning, lead inhalation in excess and cerebrovascular accidents (Wallace, 1972; Walzer & Richmond, 1973). Severe malnutrition and conditions producing a sustained fever may also be causative factors (Winick, 1968; Cott, 1972; Hallahan & Cruickshank, 1973). Malnutrition may directly and indirectly affect the development of the central nervous system (Cravioto, 1973) and may also modify the growth and biochemical maturation of the brain.

c) **Developmental factors:** The maturational lag hypothesis was put forth by Bender (1957) and Kinsbourne (1975). They suggested that children with learning disability merely have a slower rate of normal development of neural processes relevant to the acquisition of academic skills. The poor readers do not deviate from the good readers but they show errors which are typical of younger children. Boys have more problems than girls as boys mature less rapidly than girls because of which the pattern of mental abilities specifically the spatial processing skills is affected. Bryant (1972) suggested that a maturational lag may be the result of complications during pregnancy, early trauma, infection or poor nutrition. Children with learning disability will eventually develop the requisite neural processes and will then learn with normal or near-normal facility (Mckeever & Van Deventer, 1975).

d) **Biochemical factors:** Various metabolic disorders have been suggested as causes of learning disabilities. Some of these are hypoglycemia (Green & Pearlman, 1971; Cott, 1972), an imbalance of acetylcholinesterase (Smith & Carrigan, 1959) and hypothyroidism (Money & Lewis, 1964). Rossi (1972) has associated a deficiency of GABA, an inhibitory chemical transducer that is genetically transmitted, with various kinds of learning difficulties.

2) **Neurological factors:** As early as 1930's, Orton suggested that dyslexia is due to a failure to establish consistent lateral dominance. Birch & Belmont (1964) hypothesized that dyslexics suffer from a "cross-modal integration" difficulty such that visual and auditory

language forms are difficult to properly interrelate. Geschwind (1965) pointed out that a possible bilateral maldevelopment of the angular gyri is the cause of developmental dyslexia. The most viable link between neurology and learning disability has been established for developmental anomalies in the left temporal region of the brain as a cause of phonological disabilities that produce problem in learning to read. Geschwind and Galaburda (1987) viewed developmental dyslexia as a consequence of slowed development of the left hemisphere. This is because of early exposure to the hormone testosterone, which explains the greater instance of reading problems among young boys. A series of surgical studies of the brains of deceased dyslexics have shown developmental anomalies in the left temporal area of the brain (Galaburda, 1988). Theories of brain development suggest that these particular anomalies arise very early in development and thus, could not be the result, rather the cause of reading problems. Another evidence evolved from studies involving measurement of regional cerebral blood flow during reading which also verified that this same temporal region of the brain is differentially affected in dyslexics than in normal readers (Flowers, Wood & Naylor, 1989). Furthermore, Damasio & Geschwind (1984), Wagner & Torgesen (1987), Shankweiler & Liberman (1989), and Stanovich (1990) indicated that deficits in the ability to process the phonological features of language lead to specific difficulties in acquiring reading skills. This type of processing skill is usually located in the left temporal region of the brain. In six male and six female dyslexics, Galaburda (1991) found symmetry of the planum temporale which is located in the left hemisphere. The left hemisphere is the area implicated in language functions. Normal adults typically show asymmetry, with the left being larger than the right planum temporale. In five male and two female dyslexics, Galaburda (1991) found cortical abnormalities i.e. they found cluster of neurons where they normally did not occur in nondyslexic adults. These were found in the most superficial layer of the cortex in dyslexics. Moreover, there was loss of well-arranged, tidy patterned lamination of the neighbouring cortex.

Semrud-Clickeman, Hynd, Novey & Eliopulos (1991) investigated the relationship between structure and function in three groups of children. One group had attention deficit disorder, another had dyslexia and the last was a control group devoid of either disorder. All children received reading and language measures. The authors found that only in the group of dyslexic children was small right frontal width significantly related statistically to poor performance in reading comprehension. Moreover, these dyslexic children showed reversed asymmetry (left larger than right) or symmetry of the right frontal region. Neither of these findings was in turn significantly related to poorer word attack skills. In general, children in all three groups showed reversed asymmetry (right larger than left) or symmetry of the planum and these findings were related to substantially lower scores on the verbal comprehension factor of the WISC-R. These latter results point to the planum as a structure that concerns language processing. Wood, Flowers, Buchsbaum & Tallal (1991) tested normal and reading-disabled adults on a phoneme task. They found that in the reading disabled adults, high task accuracy was accompanied by an increase in blood flow in the left temporal region but in normal adults, it was accompanied by a reduction in blood flow in the same region.

More recently, Benasich & Tallal (1996) identified a higher prevalence of temporal processing deficits in infants with a family history of language-based learning disabilities. Such deficits, whether in these infants or in non-disabled controls, were related to later language impairments. They suggested that these early prelinguistic deficits provide support for theories that implicate dysfunction or damage to magnocellular neuronal systems as a possible neural substrate for dyslexia. Magnocellular neurons are specialized for responding to spatial information, movement and rapid transitions. Abnormalities of these neurons could impair detection of the rapidly changing stimuli that characterize temporal sequences, or detection of the small gaps that characterize the stimulus stream (Galaburda & Livingstone, 1993; Lovegrove, 1993). This hypothesis receives some support from electrophysiological and anatomical studies, both of which have revealed abnormalities in the magnocellular neurons of individuals with dyslexia (Galaburda & Livingstone, 1993). Dysfunction in the left hemisphere may also be implicated, given the fact that reading and temporal processing are both thought to be left hemisphere tasks, and that poor readers have failed to show a right ear advantage for temporal sequences (Harel & Nachson, 1997).

3) **Social factors:** Coles (1987) proposed an interactivity theory which suggests that learning disabilities arise in the context of a complex interplay of social interactions that build knowledge and create attitudes, values and motivation critical for school success. These interactions occur in both the family and the school. The theory suggests that learning disabilities arise from an experimental base, and many children's pattern of interaction with their environment (primarily social) have not prepared them to perform successfully on the tasks required to learn in school.

4) **Perceptual factors:** A perceptual dysfunction has been hypothesized to affect phonological processes involved in reading (Farnham-Diggory, 1978; Tallal, 1980; Torgesen, 1985; Stanovich, 1986; Stark, Tallal & McCauley, 1988). The possible role of temporal processing deficits in specific reading disabilities is of particular interest because of growing evidence that many individuals with reading disability are impaired in a variety of phonological skills. Findings of inferior performance in phoneme segmentation, the use of phonological codes in short and long term memory and rapid

retrieval of phonological information from long term memory are common in samples of children and adults with specific reading disability (Jorm & Share, 1983; Liberman, Rubin, Duques & Carlisle, 1985; Reed & Ruyter, 1985; Wagner & Torgesen, 1987).

CHARACTERISTICS OF LEARNING DISABILITY

Despite the wide variety of behaviors and learning problems frequently listed under the umbrella of learning disabilities, there are some discriminative characteristics that separate children with learning disability from those experiencing other types of difficulties. These children experience a particular type of learning difficulty with some discriminable characteristics that are sufficiently identifiable to lead to the deliberate use of the modifier specific in referring to problem of this type; hence the commonly applied phrase, ***'specific learning disabilities'.*** Every child with learning disability presents a unique puzzle to solve - thus not all children with learning disability will exhibit each of the conditions or behaviors mentioned below, but a general description has been outlined.

1) Discrepancy between apparent capacity and functioning

Bateman (1964) stated that the child with learning disability manifests an educationally significant discrepancy between his apparent capacity for language behaviors and his actual level of language functioning. Later in 1965, she broadened the deficit areas to include "a significant discrepancy between their estimated intellectual potential and actual level of performance related to basic disorder of the learning process....". Gallagher (1966) used uneven growth patterns as a part of a proposed dysfunction. Basically the "principle of disparity" assumes that the child in question is essentially a normal child with the capacity to operate at an average level. The problem behavior in question is assumed to be limited to a definable area(s) at a level that is disparate from or lower than the child's other behaviors. The discrepancy in behavior, noticeable and definable in a variety of ways ranging from established standard score differences to erratic fluctuations in behavior becomes the significant factor. An important corollary of the principle is that the child can and will profit and remove the deficit and/or disparity, given the correct or appropriate experience.

The child with learning disability behaves as he does due to forces beyond his control, and with proper attention has the potential for normal development and successful school achievement. This assumption removes the child from the ranks of the mentally retarded in perceived learning potential and social adaptability. This child's condition is amenable to treatment and specialized instruction. This assumption proclaims that the condition is remediable and that there are persons with the knowledge and skill to accomplish this (Gearheart, 1973).

2) **Reading problems:** The following reading problems are exhibited by the children with learning disability:

- Poor reading
- Guessing the difficult words
- Omission of words and lines while reading
- Slow rate of reading
- Repeating the same sentence
- Reading without pause in between
- Confusing similar words while reading
- Sequencing errors: e.g. was for saw; no for on
- Inversions: e.g.,/u/for/n/
- Reversals: e.g.,/b/ for /d/

- Complains of pain in the eyes, itches or rubs eyes
- Turns head or paper at odd angles
- Frequently yawns while reading
- May complain of blurring of print while reading.

3) **Writing problems:** Children with learning disability show several writing deficits as follows:

- Poor and illegible handwriting, overly large or cramped handwriting
- Extra and unwanted pressure on the hand while writing
- Preference for manuscript rather than cursive
- Overuse of printed form of the uppercase
- Holds the pencil too tightly while writing and often breaks pencil points/crayons
- Uses erasers excessively which results in messy papers
- Interchanging of capital and small letters
- Improper spacing of letters/words/lines
- Overall incompetency in writing
- Mistakes while copying
- Inconsistency while drawing margins
- Phonetical spelling for words
- Slow writing skills under timed constraints
- Lack of fluency in writing
- Grammatical errors
- Lack of comprehensive writing
- Letters not on the line
- Mirror writing.

4) **Arithmetic problems:** Arithmetic problems form a part of learning disabilities and the following problems are exhibited by the children with learning disability:

- Confusion between similar numbers, inability to associate numbers with numerals
- Difficulty in solving problems
- Computational errors
- Incorrect problem solving strategies
- Difficulty in understanding basic mathematical concepts
- Lack of understanding of mathematical terms and principles
- Failure to recognize numerical symbols
- Difficulty in understanding which numbers are relevant to the arithmetical problems being considered
- Difficulty in carrying out standard mathematical manipulations
- Difficulty in properly aligning numbers or inserting decimal points or symbols during calculation
- Poor spatial organization or arithmetical calculations, inability to understand measurement principles
- Inability to learn multiplication tables satisfactorily
- Difficulty in telling time and learning the value of coins.

5) **Study problems:** The following are some of the few study problems faced by the children with learning disability:

- Time management problems
- Difficulty outlining and note taking
- Poor short term memory to recall material
- Difficulty initiating and sustaining consistent effort on a task
- Problems integrating information from various sources

- Trouble with test taking strategies
- Insufficient use of the dictionary and other self help handbooks
- Difficulty completing assignments independently
- Difficulty selecting relevant facts from irrelevant details
- Difficulty preparing for tests.

6) **Communication problems:** Children with learning disability may have communication problems, which may be verbal or nonverbal. The below mentioned ones are a few of them.

- Delay in language acquisition and development
- Articulation problems, inconsistencies in sound production
- Difficulty in understanding wh- questions, using pronouns and prepositions
- Difficulty in processing sentences with multiple word meanings and figurative language
- Spontaneous and or inappropriate verbalizations, which may be related to forced responsiveness to internal stimuli
- Less sophisticated and a narrower range of vocabulary and syntactic structures and a lesser number of transformational rules per sentence
- Less likely to request for additional needed information during a conversation than their normally achieving peers
- Information contained in the messages expressed is repetitive, contradictory or unrelated to the communication task
- Discourse errors characteristic of poor topic maintenance, need for repetition and failure to provide adequate information
- Difficulty remembering or understanding oral instructions

- Difficulty in sequencing ideas
- Word finding difficulty
- Difficulty learning to speak a foreign language.

7) **Perceptual problems:** The perceptual problems may either be exhibited in the auditory mode or in the visual mode.

   a) Visual perceptual deficits: The following are the visual perceptual deficits that are exhibited by the learning disabled child:

      - Reversal of geometric designs and figures, letters (mirror writing) e.g.,b for d, p for q
      - Inability to copy the letters correctly
      - Collision of letters with each other
      - No space between words
      - Strange way of formation of letters
      - Inability to perceive the difference between a hexagon and an octagon
      - Closure of one eye while working
      - Inability to recognize an object or word if only a part of it is shown
      - Slow to pick up on likeness-differences in words and changes in environment
      - Distortion in depth perception
      - Difficulty in carrying out activities involving cutting and pasting.

   b) Auditory perceptual deficits: The most commonly observed characteristics of children with learning disability primarily involving auditory perceptual skills are as follows:

      i) Auditory attention or attending behaviors: Children with learning disability have difficulty in attending to pertinent auditory stimuli, particularly when multiple background stimuli are present. They cannot filter out extraneous noise and cannot distinguish teacher's voice from others. Teachers report that they "don't listen" or "don't pay attention" in the classroom. In the testing situation, they might have difficulty attending to various test items. Some children might get very tensed in a noisy classroom.

ii) Auditory sequential memory and/or serial memory: There is general difficulty remembering and carrying out verbal instructions, particularly in a group setting. Tests that use a string of digits or words are often difficult as is recalling and sequencing auditory stimuli. Also, learning from rote memory (for e.g.,days of the week, months of the year, nursery rhymes and alphabets) seems to take longer for these children. Teachers and parents report that "he can't follow instructions" or "he forgets half of what I tell him to do".

iii) Auditory discrimination: They may not hear differences in sounds like plosives, b, p, d, t, k, g and hence may confuse rhyming words like mat/bat or cognate sound (p/b). They may not be able to perceive the difference between various consonant blends or may not be able to differentiate the front door bell and the first ring of the telephone. They may not hear the final consonants accurately.

iv) Auditory sound blending: Often there is a problem in learning to blend (or synthesize) the sounds of a word into a whole word (for e.g.,c-a-t is cat). This seems to be related to a child's difficulty with auditory sequential memory in that it involves similar processes of recall.

v) Spatial and temporal concepts and relationships: The children with learning disability not only experience difficulty in learning the sequencing of concepts, such as days of the week/months of the year, but also has problem with relationships of these concepts. For e.g., questions such as "what day comes after Tuesday"? or "what month is before April"? may pose a problem for this child. Concepts involving directions of left and right or even telling time or recalling events of time, such as his birth date, are usually more difficult for these children to learn,

vi) Auditory processing: These children cannot understand conversation delivered at a normal rate i.e. they may comprehend if information is presented very slowly and repeated several times,

vii) Auditory localization: These children have difficulty in indicating the direction of sound source.

viii) Auditory distortion: They hear some sounds better than the other which leads to spelling errors.

ix) Auditory selectivity: They may mishear frequencies in a drastic manner. They may hear a tone of 6 kHz as high as 8 kHz. This kind of hearing may disturb the speech perception and lead to spelling mistakes,

x) Response timing: Normal children take less than a second to indicate a perception of sound but the reaction time of children with learning disability is between 2 to 5 sec which leads to difficulty in gathering the information received.

8) **Conceptual deficits:** Below mentioned are a few conceptual deficits that are exhibited by the children with learning disability:

- Inability to read social situations and understand body language
- Inability to see the relationship between similar concepts and compare things that are alike/different
- Difficulty with the classification activities
- Inability to understand time relationships (yesterday, tomorrow, after, before, 15 minutes vs. 2 hours, etc.)
- Difficulty in associating an act with its logical sequence ("If I talk, I get detention)
- Has little imagination and no sense of humor

- Difficulty in thinking in an orderly, inferential or logical way
- Inability to understand emotions and concepts such as beauty, bravery etc.
- Difficulty in grasping concepts like more/less, greater/lesser
- Inability to create poetry or original stories
- Difficulty in making closure, e.g., cannot finish a sentence such as "I like it when......" i.e. has difficulty in filling the blanks
- Classroom answers and reasoning abilities are bizarre and "off track".

9) Metacognitive deficits: The children with learning disability exhibit several metacognitive problems as follows:

- Lack of awareness of skills needed for a task
- Lack of ability of time managing
- Inability to plan ones moves
- Inability to evaluate effectiveness
- Inability to check outcome of ones efforts
- Lack of ability to remediate difficulties.

10) Memory deficits: The memory skills of children with learning disability are similar to those of younger children i.e. they have immature memory functioning. Every individual has three memory systems - visual memory, auditory memory and physiomotor memory. All children with learning disability have problems with one of the three memory systems. They can only remember a single word or a few letters at a time. This makes them very slow at writing and leads to spelling errors and inversion of letters. Also, these children tend to concentrate so hard on the act of copying that they do not take in the sense of what they are writing. Children with learning disability exhibit the following memory deficits:

- More time to conduct a memory search
- Deficiency in the quality of rehearsal
- Rarely use organizational strategy while rehearsing several items
- Demonstrate a failure in performing elaborative processing of each word
- Exhibit a poor short term memory, working memory and recent memory
- Deficient in long term memory for tasks that require semantic processing
- Slow to memorize rhymes/poems, difficulty in retaining information and recalling sequential information
- Difficulty in remembering what was just seen or heard, a sequence of four numbers presented auditorily, spellings of common or frequently encountered words and the names of common objects
- Difficulty in copying maths problems accurately
- Poor sight vocabulary
- Makes the same error again and again and does not seem to benefit from experience.

11) Behavior problems

a) Hyperactivity: The children with learning disability may be hyperactive. This is particularly true among those with actual brain insult. These children exhibit the following problems:

- Restlessness,
- fidgeting movements (drumming fingers, tapping toes, rolling pencil, fooling with objects, making mouth noises or talking incessantly),
- inability to sit/stand still,
- blurting out answers before questions have been completed,
- frequently shifting from one activity to another, and

- difficulty in playing quietly.

It is not always that any one action is so much a problem, but rather that they are moving in triple time is a problem to others. Also, with so much movement, it is difficult for them to attend to anything long enough to achieve much academically.

b) Hypoactivity: Although not found as often as hyperactivity, it is found often enough worthy of mention.

c) Inattention: This may or may not be related to hyperactivity. It can simply be a matter of actual inability to focus on any particular activity for any length of time. These children have a short attention span and hence little work is produced. They daydream, may read something correctly, but may not concentrate as evidenced in poor comprehension. They may not follow rules and may claim that they didn't hear them.

d) Over attention: Also called as attention fixation, the children will focus on one particular object and seem unable to break the focus. This also can relate to figure-ground problems, or the inability to see the significant element or elements in a total setting, while focusing instead on the background.

e) Impulsivity: Children with learning disability are impulsive i.e. they will not consider the consequence before acting. They also have a low frustration tolerance and a short fuse.

f) Distractive behavior: These children may be auditorily distractible i.e. they respond by looking up to all sorts of noise. They also may be visually distractible by responding to all visual stimuli.

g) Erratic and uneven behavior: The overall academic production record of the children with learning disability is apt to be uneven. Their work in a given area often will fluctuate far beyond the variance expected of children of their age. Interest and attention span will also fluctuate, sometimes at a normal and high quality level, sometimes short and more typical of children with other than learning disability problems. The irregularity and erratic nature of the changes are more important clues than the absolute levels and quantity of the behaviors.

h) General behavior: Such children may have a negativistic or oppositional behavior. They might also overreact to stimuli. They may be cruel and mean to others and make fun of them. There may be mood swings which may be exhibited by good days and bad days. They are disorganized; misplace books, papers, lunch box, etc. They may not finish assignments in an allotted time.

12) **Neurological problems:** Most children with learning disability do not manifest classical signs of nervous system dysfunction, as assessed by standard methods of testing. Often the neurological findings are minimal and of debatable significance because they are sometimes found in children without learning or behavior problems. These include:

- slightly impaired motor coordination,
- hyperactive reflexes,
- hyperkinetic behavior, and
- clumsiness and perceptual difficulties.

In children with learning disabilities, the presence of these neurological signs assumes significance because they are thought to be indicative of an antecedent insult to the developing nervous system.

13) **Motor output deficits:** The motor output deficits can either be in the form of coordination problems or perseveration.

a) Coordination problems: Some of these problems are actually related to kinesthetic perceptual problems, an inability to assess position in space, balance or both. The following deficits may be exhibited by the children with learning disability:

- Slower development of the ability to throw or catch a ball, to skip, or to run
- Difficulty in writing and other fine motor skills
- Clumsiness, stumbling or falling frequently
- Difficulty in cutting, pasting, coloring and writing
- Difficulty in copying accurately
- Exhibit tics.

b) Perseveration: A child may perseverate or repeat persistently in almost any behavioral area, but this is more often seen in writing or copying. A child may copy a word over and over again involuntarily. He/she may also perseverate in oral response.

14) **Spatial relationships and body awareness deficits:** The following deficits may be exhibited by the children with learning disability:

- Getting lost even in familiar surroundings such as school or neighborhood
- Directionality problems
- Inability to read or write from left to right
- Poor spacing between the words
- Inability to keep columns straight in mathematics
- Bumping into things, clumsy and accident prone
- Inability to understand concepts such as over, under, through, first, last, front, back, up, down etc.

15) **Failure syndrome:** A repeated history of academic failure in educational pursuits will establish an expectation of failure and a drop in attempts to achieve. Thus, the anticipation of forthcoming failure of a still undefined specificity may produce restlessness, uneasiness and some types of shallow withdrawal such as daydreaming or inattentiveness. These children may become frustrated and fail to develop a sense of accomplishment. Many a times behaviors such as "crying more easily" or demonstrating frustration over even "simple failures" or being "too sensitive" are noted by parents and teachers. This will also lead to lowering of behavior rate, diverting interest from normal educational pursuits and generally lower or shift motivation. They may describe themselves as "dumb", may also try to avoid group activity. They may be the clowns in the class by displaying their immature, babyish behavior because of which they seem younger and dependent on others.

16) **Emotional problems:** The following emotional problems may be exhibited by the children with learning disability:

- Explosive, unpredictable and dangerous behavior
- Preoccupation with death and destruction
- Preferring dark colors like red, purple and yellow
- Shallow feeling for others
- Fearful, anxious, insecure and tense
- Telling bizarre stories and purports that they really happened
- Inability to distinguish reality from fantasy
- Withdrawing from the environment and rarely involving themselves in communication
- Feels "picked on"

- Using projection and denial
- Never assuming responsibility for actions.

17) **Social problems:** The following social problems may be exhibited by the children with learning disability:

- Inability in keeping up with social norms, social distress
- Lack of social comprehensive skills
- Poor role taking skills
- Listening and speaking difficulties
- Lack of proper eye contact
- Inability in reading social situations
- Loneliness and rejection by peers
- Lower academic self concept
- Inability to understand body language (Johnson & Morasky, 1977; Beasly, Cole, Covington & Orchik, 1979; Gearheart, 1981; Valenti & Vogel, 1990; Berard, 1993).

CLASSIFICATION OF LEARNING DISABILITY

Bateman (1964) delineated three major categories of learning disabilities:

1. Dyslexia
2. Verbal communication disorder
3. Visual-motor integration problem

Myers & Hammill (1969) categorized children with learning disability in terms of six major categories:

1. Disorders of motor activity
2. Disorders of emotionality
3. Disorders of perception
4. Disorders of symbolization
5. Disorders of attention
6. Disorders of memory

Ingram, Mann & Blackburn (1970) found three subgroups of learning disability based on academic performance (reading patterns).

1. Auditory dyslexia
2. Visuo-spatial dyslexia
3. Mixed group

Hallahan & Cruickshank (1973) classified learning disability into seven "psychological behavior characteristics".

1. Cognition-language
2. Perceptual-motor behavior
3. Socioemotional behavior and adjustment
4. Hyperactivity-distraction
5. Figure ground confusion
6. Perseveration
7. Memory

McKinney (1984, 1990) grouped children with learning disability in terms of their overt behavior in classroom settings into six groups.

1. Attention deficit
2. Conduct problems
3. Withdrawn behavior
4. Low positive behavior
5. Global behavior problems
6. Normal behavior patterns

Feagans & McKinney (1991) classified learning disability using multivariate empirical classification approach (cluster analysis). These include

1. Visuoperceptual (visuo motor) subtype
2. Auditory linguistic deficit subtype
3. Mixed deficit subtype

Rourke & Del Dotto (1994) proposed the following classification of learning disability subtypes based on the neuropsychological functioning:

1) Learning disabilities characterized primarily by disorders of linguistic function which is classified into the following:

   a) Basic Phonological Processing Disorder (BPPD): Reading, spelling and those aspects of arithmetic performance that require reading and writing are affected. The nonverbal aspects of arithmetic and math are unaffected. Difficulty in remembering multiplication tables, deficits in phonemic hearing, segmenting and blending, impaired attention and memory for auditory-verbal material, poor verbal reception, repetition and storage are some of the other problems found in these children.

b) Word-finding disorder (WFD): This is characterized by outstanding problems in word finding and verbal expressive skills within a context of a wide range of intact neuropsychological skills and abilities. The phoneme grapheme matching is intact. They have an outstanding neuropsychological deficit in accessing a normal store of verbal associations. Reading and spelling are very poor during early school years, with near average or average performances in the areas towards the end of sixth to eighth grade. Arithmetic and math are early strengths. Writing of words that can be expressed and writing from a model are average to good.

c) Phoneme-grapheme matching disorders (PGMD): Written spelling of words not known by sight is as poor as in BPPD subtype. Word recognition is better than that in BPPD subtype. Arithmetic and math performance may rise to average or above average levels when the words involved in performance on problems in this domain are minimized or learned by sight. The neuropsychological deficit is seen in the area of phoneme grapheme matching (most often G>P). They exhibit normal phonemic hearing, segmenting and blending.

2) Learnings disabilities characterized by disorders of nonverbal functioning (NLD): It is characterized by good word decoding and spelling abilities and well developed verbatim memory. But these children are poor in reading comprehension, mechanical arithmetic, mathematics and science. They have the maths facts in memory but just fail to retrieve it when needed. The neuropsychological deficits seen include deficit in tactile and visual perception, problems in concept formation and problem solving, deficit in the pragmatic dimension of language and poor visual spatial organization.

3) Learning disabilities characterized by output disorders in all modalities: It is characterized by severe problems in oral and written output including written arithmetic. This is similar to the WFD subtype with respect to the neuropsychological deficits.

The Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV), published by American Psychiatric Association (APA, 1994), recognizes subtypes within learning disorders (formerly called as academic skill disorders). The diagnostic criteria for each of these learning disorders specify that, as measured, 'on individually administered, standardized tests', achievement is 'substantially below that expected for age, schooling and level of intelligence', and 'if a sensory deficit is present, the learning difficulties must be in excess of those associated with it'. The subtypes include the following:

1) Reading disorder (dyslexia): Padget, Knight & Sawyer (1996) defined dyslexia as a language based learning disorder that is biological in origin and primarily interferes with the acquisition of print literacy (reading, writing and spelling). Poor decoding and spelling abilities as well as deficit in phonological awareness and/or phonological manipulation characterize dyslexia. These primary characteristics may co-occur with spoken language difficulties and deficits in short term memory. Secondary characteristics may include poor reading comprehension (due to the decoding and memory difficulties) and poor written expression, as well as difficulty organizing information for study and retrieval. Difficulty is experienced in word recognition and reading comprehension. 2-8% of school age children have this problem.

2) Mathematics disorder: Difficulties in the following skills are noticed:
    a) Linguistic skills: Difficulty in coding written problems into mathematical symbols.
    b) Perceptual skills: Difficulty in recognizing numerical symbols: missing/adding a step to specific procedure.

c) Attention skills: Difficulty in remembering the rules.

d) Mathematical skills: Difficulty in operations.

Other difficulties include deficiency in short term and long-term memory, spelling, fine motor coordination, visual-spatial processing.

3) Disorders of written expression: It is an impairment characterized by difficulty in the ability to compose the written word, spelling errors, grammatical or punctuation errors or poor paragraph organization. They also have difficulty in reading comprehension, spelling, auditory verbal, memory, auditory analysis of common words and verbal and auditory perceptual areas.

4) Learning disorders not otherwise specified

Shafrir & Siegel (1994) classified the learning disabilities into three subtypes:

1) Reading disabled (RD) which is defined as a child reading on the wide range achievement test (WRAT-R) (Jastak & Wilkinson, 1984) at or below 25th percentile and on the arithmetic subtest, to be performing at or more than 30th percentile.

2) Arithmetic-disabled (AD): The child performs at or below 25th percentile in the arithmetic subtest in the WRAT, and at or above 30th percentile in reading (word recognition) in the WRAT.

3) Both reading disabled and arithmetic disabled (RAD): The child reads at or below 25th percentile in the WRAT word-recognition subtest and is also at or below 25th percentile in the arithmetic subtest on the WRAT.

CRITERIA FOR IDENTIFICATION OF LEARNING DISABILITY

For purposes like diagnosis and classification, U.S office of Education (USOE, 1976) issued the following operational definition of learning disability. "A specific learning disability may be found if a child has a severe discrepancy between achievement and intellectual ability in one or more of several areas: oral expression, written expression, listening comprehension or reading comprehension, basic reading skills, mathematics calculation, mathematics reasoning, or spelling. A "severe discrepancy" is defined to exist when achievement in one or more of the areas falls at or below 50% of the child's expected achievement level, when age and previous educational experiences are taken into consideration. The criteria to be used in identifying students with learning disability were provided in the Federal Register which was published in 1977. They include the following:

1) A team may determine that a child has a specific learning disability if:
   a) The child does not achieve commensurate with his/her age and ability levels in one or more of the following areas when provided with learning experience appropriate for the child's age and ability levels:
      i) oral expression,
      ii) listening comprehension,
      iii) written expression,
      iv) basic reading skill,
      v) reading comprehension,
      vi) mathematical calculation, and
      vii) mathematical reasoning.
   b) The team finds that a child has a severe discrepancy between achievement and intellectual ability in one or more of the same areas listed in the preceding statement.

2) The team may not identify a child as having a specific learning disability if the severe discrepancy between ability and achievement is primarily the result of:

   i) a visual, hearing or motor handicap,

   ii) mental retardation,

   iii) emotional disturbance, and

   iv) environmental, cultural or economic disadvantage.

DIFFERENTIAL DIAGNOSIS OF LEARNING DISABILITY

Learning disabilities can be also be found in those with mental retardation, emotional disturbance, behavior disorders or low achievers, primary sensory impairments like deafness or blindness etc. Hence it is important to differentially diagnose these children from the children with specific learning disability.

1. Differential diagnosis between learning disabled and mentally retarded: Children with learning disability have adequate intelligence as measured with traditional intelligence tests such as weschler intelligence scale for children-revised (WISC-R, 1976). Typically they show an erratic pattern or scatter in the subtest performance i.e. they do poorly in some items (e.g., digit span subtest) and do much better in the others and hence they tend to show peaks and troughs in the performance profile. In contrast, children with mental retardation tend to show a very flat performance profile on a given test and on each subtest they perform below average. Such children do not have adequate intelligence as measured by traditional IQ tests.

   Another important criteria for differentiating is "adaptive skills", that is an individual's capacity to cope with his or her environment (e.g., self help skills). Only children with mental retardation have limitations in two or more of the following adaptive skill areas viz., self-care, home living, community use, health and safety and leisure work.

2. Differential diagnosis between learning disabled and emotionally disturbed: Individuals with learning disabilities have emotional problems that are associated with their histories of academic failure. But these emotional problems can be ameliorated and appear to subside as they achieve academic success or improvement. Children with emotional and behavioral disorders have impaired learning performance. However, it is possible to differentiate between them and those with learning disabilities by the extremeness of their behavioral problems and their persistent inability to make or sustain satisfactory relationships with others. Their difficulties in relating to peers or adults mainly lie in their reactions to friendly approaches. Either they react aggressively or with hostility or they with draw out of fear, nonchalance or disinterest (Hallahan & Kauffmann, 1994). Children with learning disabilities progress in academic learning, but such progress is not evident in those who are emotionally disturbed. Given a moderately learning disabled child who is bright, when matched with an appropriate educational program and effective learning strategies, he or she may make rapid progress in learning. However, appropriate educational programming and strategies may not suffice to induce learning progress in an emotionally disturbed child because he/she must first receive successful therapy to eliminate the emotional disturbance.

3. Differential diagnosis between learning disabled and low achievers: Low achievers are students who hover above the failing grade, e.g., their best grade being C- or just pass. They tend to share many attributes with the learning disabled. Specifically they are unmotivated in academic learning. They are passive in class in their learning style, they do not persist in difficult tasks and they lack efficient leaning strategies. Unlike the

children with learning disabilities, whose efforts at learning have been crushed by continual failure, low achievers rarely apply themselves. They differ from the latter in at least two important ways:

1. They would not have the discrepancy between ability and performance as found in those with learning disability.
2. They do not have processing problems such as memory problems as found in those with learning disabilities.

AUDITORY DISCRIMINATION IN SUBJECTS WITH LEARNING DISABILITY

Auditory discrimination refers to the ability of an individual to contrast sounds. Wood (1971) has defined auditory discrimination as the "ability to discriminate between sounds of different frequency, intensity and pressure patterns; the ability to distinguish one speech sound from another". The term has been used for tasks such as detecting small acoustic differences between stimuli like differential intensity thresholds (Jesteadt, Wier & Green, 1977), determining which of two simultaneous stimuli begins first (Hirsh, 1959), selecting between stimuli that differ in the frequency ratios of the simultaneously presented set of tones that constitute each signal (Viemiester & Fantini, 1987) and reproducing sequences of stimuli (Tallal, Stark, Kallman & Mellits, 1981). Both researchers and clinicians have used the term auditory discrimination to refer to different (phonological, phonetic and phonemic), but still overlapping, discrimination skills.

'Phoneme' is a minimal unit in the sound system of a language. A sound is considered to be 'phonemic', if its substitution in a word does cause a change in meaning. Sounds are considered to be the members of the same 'phoneme' if they are 'phonetically' similar, and do not occur in the same 'environment', or if they do, the substitution of one sound for the other does not cause a change in meaning (i.e. they are in free variation). Out of the very wide range of sounds produced by the human vocal apparatus, only a small number are used 'distinctively' in any language. The sounds are recognized into a 'system of contrasts' that are analyzed in terms of 'phonemes' or 'phonological units'.

Discrimination performances are ultimately based upon the individual's ability to distinguish fine acoustic differences between or among stimuli with the critical distinction being whether or not these acoustic differences signal semantic distinctiveness to the listener (Seymour, Baran & Peaper, 1981).

Several studies have been carried out *to investigate the relationship of auditory skills* ***and*** *reading* ***abilities and the role*** *of* ***auditory*** *discrimination in its acquisition.* Gates, Bond & Russell (1939) administered tests involving almost every suggested means of appraising reading readiness, including a number of auditory discrimination tasks to first grade children of four New York City public schools. Correlations between each of the auditory discrimination tests and each of the reading achievement measures were computed midway through the first grade, at the end of the first grade, and midway through the second grade. Mean correlation coefficients were computed to give some idea of the relationship between each auditory instrument and general reading ability. The average correlations with reading achievement ranked according to size were (1) giving words with the same or rhyming final sounds, (0.43); (2) giving words with the stated initial sounds, (-0.41) (score in this test was the number of errors); (3) blending, (0.38); (4) reproduction of nonsense words, (0.23); (5) giving letters for sounds, (0.21); and (6) discriminating word-pairs, (0.20).

Gates (1939 a) reported the results of a study which related readiness to reading achievement of pupils in a number of classrooms in which reading instruction varied from giving very little emphasis to phonics to giving a great deal of emphasis to "sounding" techniques. Correlations between skills in rhyming and reading achievement ranged from -0.07 to 0.67 for the various classes studied, while similar correlations involving blending ability and reading varied from 0.10 to 0.54. In general, the highest correlations were given by tests which measured abilities similar to those which children were going to be taught. The results suggested that tests of auditory discrimination are more closely related to later reading success in classrooms in which the teacher utilized phonics as an aid to recognition of words.

Steinbach (1940) used as a sample 300 children entering first grade, who were administered a large number of readiness tests, including a word-pair discrimination test, the only measure of auditory discrimination. Results showed this test to rank second of all the readiness measures employed in terms of its relationship with reading achievement at the end of the school year (r=0.51). Furthermore, the word-pair test ranked first with respect to its contribution to a multiple regression equation for the prediction of midyear and end of year reading achievement. Reynolds (1953) surveyed extensively the auditory characteristics of 188 fourth grade children and found that auditory blending was unrelated to general reading ability and was only slightly related to word recognition skills. Auditory discrimination which involved differentiating between word pairs, however, demonstrated somewhat higher relationships with all aspects of reading achievement.

Wheeler & Wheeler (1954) measured auditory discrimination in 629 children in the fourth, fifth, and sixth grade in a number of ways. The various tests required each subject to (1) discriminate typical word-pairs, (2) discriminate between paired sounded elements and determine whether each pair was the same or different (er-or, er-er...etc) (3) select one word from four which did not rhyme and (4) select one sound from a list of three sounds which he had heard in a stimulus word previously pronounced by the examiner. Results indicated that each of the measures of auditory discrimination was significantly related to reading achievement. However, the correlation coefficients were in 0.30 to 0.40 range.

Harrington, Sister Mary James & Durrell (1955) used somewhat different techniques in surveying approximately 100 parochial school second grade pupils in Boston. The auditory discrimination test that was administered in this study tested the child's ability to notice initial consonant sounds, rhyming at the ends of words, final consonants, and a combination of initial and final consonants in words spoken by the examiner. The design of this study made use of a variation of the pairing technique in that pupils were paired on the basis of their being similar on each of three experimental variables, but marked different on the variable being studied. Therefore pupils were matched with respect to mental age, visual discrimination and phonics ability. At the same time, each pair differed widely in auditory discrimination skill, which made possible the comparison of reading ability among pupils of "high" and "low" auditory discrimination. Highly significant differences were found, indicating that pupils with superior auditory discrimination were likewise superior in reading ability. The study was later replicated with a group of 1000 second grade pupils in Oklahoma and Kansas. Again, significant differences in reading ability were noted between the groups of "high" and "low" auditory discrimination pupils.

Wepman (1960) administered Auditory discrimination Test (New forms I & II), the Speech and Language Clinicians Articulation test, the Chicago Reading tests and the Kulmann-Anderson Intelligence test to first and second grade children. The children in each grade were divided into three groups based on their scores on the tests of auditory discrimination and articulation. Group I consisted of pupils whose scores indicated that their auditory discrimination and articulation were adequate for their age. Group II included children whose scores showed that while their articulation was adequate for their age, but their auditory discrimination was not. Group III consisted of pupils whose scores showed that neither their auditory discrimination nor their articulation was adequate for their age. Results revealed that children with poor discrimination, whether or not they have speech difficulty, were more likely to be poor readers than the total group. While there was a positive relation between IQ and lower speech and reading scores, the differences between the groups were not statistically significant. A comparison of data for first and second graders showed a decreasing number of children with poor auditory discrimination - 27% in grade I and 19% in grade II. The data also showed significantly lower attainment of the children with poor discrimination. The author concluded that there exists a close relationship between auditory discrimination and speech accuracy of articulation and a relationship of importance between poor reading achievement and auditory discrimination ability.

Durrell & Murphy (1963) investigated the relationship of the ability to identify sounds in spoken words to reading achievement in grades one, two and three. Correlations between the auditory analysis ability and reading achievement were reported to be 0.56, 0.52 and 0.52 in grades one, two and three respectively. On the basis of this study in conjunction with a number of related studies, they concluded that the ability to notice the separate sounds in spoken words is a highly important factor in determining a child's success in learning to read.

Auditory discrimination measures correlate with reading achievement. Further, studies in this direction report better performance in girls compared to *boys.* Dykstra (1966) tested 331 boys and 301 girls of first grade on seven measures of auditory discrimination and intelligence test at the beginning of the first grade. The auditory discrimination tests were as follows:

1) Rhyming test: Assesses the child's ability to detect rhyming elements at the ends of words.

2) Auditory discrimination: Assesses the ability to discriminate between spoken words, which do or do not begin with identical sounds.
3) Context and auditory clues: Assesses the ability to use auditory cues with context clues in the identification of strange words.
4) Auditory discrimination of ending sounds: Assesses the ability to recognize similarities and differences in final consonants and rhymes.
5) Discrimination of correct pronunciation: Assesses the ability to identify correct pronunciation of words.
6) Auditory blending: Assesses the ability to discriminate sounds accurately and to blend the words in word building.

Children were also administered two measures of reading achievement (word recognition and paragraph reading subtests from Gates primary reading test) at the end of the first grade. Relationship between pre-reading measures of auditory discrimination and reading achievement were assessed by means of correlation analysis and multiple regressions. Results showed inter-correlations among auditory discrimination measures and between each measure and subsequent reading achievement. In addition, intelligence was significantly related to reading achievement. Nevertheless, variation in performance on the auditory discrimination and intelligence measures accounted for less than half of the variation in performance on the reading measures. Moreover, the older first grade children exhibited no greater skill at making auditory discrimination than did their younger counterparts. Other findings included significant sex differences in performance on three of the auditory discrimination tests (rhyming, making auditory discriminations & using context and auditory clues) and on both reading tests. All such differences favored girls.

Wepman & Morency (1971) conducted one of the few longitudinal investigations of visual and auditory processing ability to school achievement. In addition, they studied articulatory accuracy and verbal intelligence. The two hundred and fifty nine subjects entering first grade were reduced to one hundred and twenty completing sixth grade due to attrition. Each year a battery of tests were administered, along with the end of year achievement tests. This procedure permitted a study of the annual change in perceptual scores, a comparison in school program between children with and without early perceptual deficits, and the relationship between first year perceptual scores and achievement at the end of each of six grades. They found that perceptual abilities reached their crest by the end of the third grade and remained asymptotic thereafter. Furthermore, lags in perceptual development were seen to have a continuing relationship to school achievement through out the elementary grades.

While all these studies indicate a relationship between auditory discrimination and reading skills, it has also been identified that auditory discrimination skills are poor in children with learning disabilities. In the early studies (1940-1970), the auditory perceptual functioning of these children had been judged primarily from their performance on ***behavioral tests of auditory discrimination, auditory memory span and auditory*** *sequencing.* These tests employed naturally spoken sounds or nonsense syllables as stimuli. The task involved was to discriminate two words in a pair. The results of the studies by Wolfe (1941), Robinson (1946), and Schonell (1948) indicate poor auditory discrimination in reading disabled children compared to normal children. Wolfe (1941) reported that her group of retarded readers, all of whom were 8 and 9 years old, was significantly inferior to a group 6f average readers in an ability to discriminate between word pairs. Robinson (1946) studied 30 disabled readers in the age range of 6.9 years to 15.3 years. All of them achieved Intelligence Quotients (IQ) of above 85 on the Stanford Binet Test. Administration of an auditory discrimination test designed to test discrimination of vowels and consonants separately indicated that five cases had insufficient auditory discrimination of vowels and four cases had a similar deficiency with respect to consonants. Only 24 of the 30 cases received the auditory discrimination test and as a result the corresponding percentages of deficiency in auditory discrimination were 22 and 17 for vowels and consonants, respectively. Schonell (1948) reported that 38% of the backward readers studied over a period of eight years demonstrated some degree of deficiency of auditory discrimination. Moreover, weakness in auditory discrimination of speech sounds was stated as one of the most important and most frequently occurring causal factors in reading disability.

Some attempts have been made to identify 'good' readers and 'poor' readers in general population and in population of children with learning disability. Poling (1953) studied a group of reading disabled cases, which consisted of 58 boys and 20 girls between the ages of 8 and 13 years with IQ's ranging from 100 to 120. The data were treated by dividing the group of disabled readers into levels on the basis of performance on an auditory discrimination test. The "high" group included 30 cases who achieved a percentile rank of 70 or above on the test; the "low" group was composed of 10 students who ranked below the 30^{th} percentile on the same test. Following this sectioning of pupils on the basis of skill in auditory discrimination, comparisons were made between groups with respect to the number and type of errors made by each. Results indicated no significant differences on any of the tests; the pupils with weak auditory discrimination were no more likely to make vowel, consonant or reversal errors, or to add or omit sounds in words than were their counterparts who possessed a greater degree of auditory discrimination skill. Poling concluded that auditory discrimination is not a wide spread cause of inefficient word recognition.

In contrast, a positive correlation between reading and recognizing a word containing a given sound has been observed to discriminate a group of 'good' and 'poor' readers (Templin, 1954). Templin studied 318 fourth grade children from the Minneapolis public schools and administered various tests of auditory discrimination as well as a test of general reading ability. Correlation coefficients between reading ability and the various auditory discrimination tasks were found to fall in the range, 0.22 to 0.47. The correlation of reading with word-pairs discrimination was 0.22; with writing consonant sounds, 0.25; with recognizing a sound in a specific position within a word, 0.40; with recognizing a sound in a specific position within a nonsense word, 0.44; and with recognizing a word containing a given sound, 0.47.

Auditory discrimination and syllable identification skills have been reported to differentiate normals from poor readers. Goetzinger, Dirks & Baer (1960) investigated 15 matched pairs equated in terms of sex, chronological age, intelligence and visual acuity. The subjects ranging in age from 10 years 7 months to 12 years 9 months included 15 male normal readers from the Kansas City, Missouri, public schools and 15 boys of the same age who were attending a reading clinic class. All the subjects were administered a word-pair discrimination test as well as two measures of auditory perception which required each subject to identify 50 monosyllabic words after hearing them spoken. The analysis of the comparison between good and poor readers demonstrated highly reliable differences between the groups in performance on the word-pair tests and on one of the perception instruments. This relationship was further accentuated by the obtained correlation coefficients of 0.56 and 0.58 between reading achievement and the word-pair and perception tests, respectively. Performance on the other perception test, however, did not discriminate between the two groups. One additional finding of interest was that word-pair test was not significantly related to either of the perception techniques. This indicated that the two measures of auditory discrimination were testing somewhat different skills. The authors suggested that poor readers have reduced function at the primary auditory-cortical level.

The notion that auditory discrimination skills can differentiate 'poor' and 'good' readers was also supported by the study of Thompson (1963) who found that, out of the best 24 readers from a sample of second grade pupils, 16 had possessed adequate auditory discrimination upon entering the first grade the previous year. However, examination of the poorest twenty-four readers from the sample indicated that only one had demonstrated adequate skill in making auditory discriminations at the beginning of the first grade.

Blank (1968) carried out a three-part study on cognitive process in auditory discrimination. She stated that while reading might seem to be a visual task it is more highly correlated with auditory performance. Perhaps the failure to learn written language is related to failure in learning spoken language, which is also an auditory function because in context the initial part of the word contains the most information. She hypothesized that retarded readers are less proficient in discrimination because they do not attend to word endings. However, this approach would place a much greater emphasis on the context to determine meaning. Using only the initial part of a word is a greater disadvantage in written language because spoken language contains many contextual and other clues. Blank theorized that retarded readers would be more inclined to attend to initial parts of words in the English language whereas in highly inflected languages they might pay more attention to word endings. In these languages it would be necessary to pay attention to the latter parts of the word in order to get full meaning. Support for this theory came from three experiments conducted by Blank (1968). All the experiments were carried out in Israel because Hebrew is a highly inflected language. In experiment I, 23 retarded and 23 normal readers between 6.5-7.5 years were evaluated. The Wepman Auditory Discrimination test and a similar test constructed using Hebrew words were used. The English portion was essentially a nonsense syllable test for these Israeli children. A same-different task was used. Some children had to be eliminated from the study, as they could not understand the instructions. The normal readers were highly favored on both tests but particularly the Hebrew version. The percentage of errors for the final parts of words was almost twice as great as the initial parts for the retarded readers in both languages. Experiment II was designed to eliminate the need for understanding the 'same-different' concept. Twelve retarded and 12 normal readers were asked to repeat the word pairs from the Hebrew test alone. It should be noted that unlike the first experiment no children had to be excluded from this study for an inability to carry out the instructions. This suggests that the same-different concept may be a rather complex one for some first grade children. If the child repeated two words which were the same whether or not they were the exact words presented, the experimenter indicated his response as being 'same'. If the child gave words which were different whether they were the words presented or not, the experimenter indicated this response as being 'different'. Again normal readers were superior to retarded readers. This was much more obvious in the percentage of pairs correct (same-different) than in the number of individual words actually repeated correctly. Retarded readers tended to perseverate a greater percentage of their errors than did the normal readers. When given the item 'bass-bath' they tended to repeat 'bass-bass', while normal readers tended to say 'bass-bat' when they made an error. Experiment III was carried out with 12 retarded and 12 normal readers. The purpose was to find out whether words given singly would lead to perseveration. This experiment showed that retarded readers were not inferior to normal readers on the simple word repetition task.

Different stimuli, including tones and speech sounds have been used in an auditory discrimination task and better scores have been reported in normal learning children by Doehring & Rabinovitch (1969) who compared the auditory discrimination abilities of pitch, loudness, simultaneous tones, successive tones and speech sounds in 20 children (5 girls and 15 boys) with learning disabilities with 35 (17 girls and 18 boys) normal learning children. An oddity response procedure was used. On each trial the child heard three successive sounds, two of which were the same. The child had to judge the odd sound. An audio oscillator generated stimuli for pitch and loudness tests. Stimuli for simultaneous tone test were 2-5 notes played together on a baby grand piano with the odd stimulus varying from a difference of one semitone in one note of a two note stimulus on the first trial to a difference of one semitone in a middle note of a 5-note stimulus on the 36th trial. The successive tone test made use of tonal sequences from the Seashore Tonal Memory Test, with one tone of the odd stimulus differing in pitch. Vowel-consonant combinations taken from a sound discrimination test for 6-8 year old children (Templin, 1957) were used for the speech sound discrimination test, with the odd stimulus differing by one consonant sound. The children with learning problems were within normal limits in thresholds for pure tones and speech, and in speech discrimination in both quiet and noise i.e. they performed equal to normal children. On a series of auditory oddity tasks, the groups did not differ significantly in loudness discrimination or on the first of two pitch discrimination tests, but the normal-learning group obtained significantly better scores on a second pitch discrimination test and on tests involving the discrimination of simultaneous tones, successive tones, and speech sounds.

Zigmond (1969) carried out six tests, five measures of auditory memory and one measure of auditory discrimination to evaluate the auditory functioning of children with learning disabilities. In each test, an auditory stimulus was presented which required a spoken response. Tests for auditory discrimination, memory for nonsense words, digits, words, sentences and rhythmic sequences were administered. All six of the auditory tests showed the dyslexic subjects to be inferior to the controls. It was evident that the dyslexic group was deficient in both discrimination and memory aspects of auditory functioning.

Flynn & Byrne (1970) hypothesized that advanced and retarded readers perform differently on auditory tasks and socioeconomic environment affects auditory ability. They studied the auditory abilities of a selected group of advanced and retarded readers from high and low socioeconomic environments. A one hour battery of auditory tests were administered to 39 third grade children in the age range of 8.2 to 9.7 years, all of whom were at least one year ahead or one year behind grade level in reading achievement. During the first half hour session, the Pitch Subtest of the Seashore Test of Musical Talents (listening to two tones and saying which tone is higher in pitch), Schiefelbusch-Lindsey Test of Auditory Discrimination (discrimination of sounds in initial and final position of words by two different methods, subject monitored and unmonitored) and the Templin-Darley Screening Test of Articulation (saying the name of the picture seen aloud) was administered. During the second half hour session, the other six tests i.e. Kindergarten PB-K-50 Word List 3 (repetition of words after listening), Wepman Auditory Discrimination Form I (hearing a pair of words and saying whether they are same/different), Examiner-Designed Blending Test (synthesizing of words), Auditory-Vocal Sequencing Subtest of the ITPA (repeating of numbers after listening), Templin Test of Auditory Discrimination (hearing a pair of syllables and saying whether they are same/different) and Sound Blending Subtest of the Monroe Diagnostic Reading Examination (synthesizing sounds to form a word) were administered. The scores of subjects were compared using the Mann-Whitney U test (Seigel, 1956). Results indicated a significant difference between the advanced and retarded readers on auditory tasks. Advanced readers scored significantly higher on the Wepman, Templin, Schiefelbusch, Pitch and both blending tests. The test that yielded highly significant differences between the advanced and retarded readers required blending of phonemes and syllables and discriminating between pairs of words, nonsense syllables and musical pitches. In short, the tests which called for the additions of acoustical transitions between phonemes or for discriminatory judgements differentiated these groups. The advanced and retarded readers did not differ on the PB-K-50, the Auditory Vocal Sequencing, or the articulation tests. The performance of advanced and retarded readers within the same economic level was also evaluated. Results showed that advanced readers in the high economic sub sample scored significantly higher than their retarded readers counterparts on the Templin, Pitch, Schiefelbusch and the Examiner Designed Blending Tests. Advanced readers from the low economic group scored significantly higher than their retarded reader counterparts on the Wepman, Templin, Schiefelbusch and both blending tests. Socioeconomic environment, alone, did not affect auditory ability. The advanced readers from both levels performed similarly and so did the retarded readers. Significant differences were more frequently found when the groups had more widely divergent mean IQ scores.

A relationship between auditory perception and reading was strengthened by the results of an investigation by Carpenter & Willis (1972). They reported normal intellectual and visual factors and very poor achievement on a variety of auditory tasks like auditory analysis, auditory blending of nonsense words, auditory discrimination (difficulty in discriminating which parts of a word pair created the similarities or differences), auditory learning and recall of the sounds of letters in a 9-year old male child with a severe reading disorder of an auditory nature.

Some authors opine that auditory discrimination is not likely to differentiate learning disabled children and nondisabled children unless both groups had articulation problems (Matthews & Seymour, 1981). They studied four groups of 87 children; (1) articulatory defective (AD) only consisting of 17 children (6 girls and 11 boys), (2) learning disabled articulatory defective (ADLD) consisting of 22 children (9 girls and 13 boys), (3) learning disabled (LD) consisting of 25 children (5 girls and 20 boys) and (4) normals consisting of 23 children (12 girls and 11 boys). The main aim of the study was to compare the performance of articulatory defective learning disabled children with articulatory defective children on interpersonal and intrapersonal auditory discrimination tasks. They were administered the four subtests out of the'eight of the Ohio Test of Articulation and perception of sounds by Irwin & Abbate (1973) to assess auditory discrimination abilities under four conditions:- interpersonal identification of sounds (to judge whether an external auditory stimuli was phonetically correct or incorrect according to his own auditory image), interpersonal perception of sounds (to auditorily discriminate between two similar sounds when presented by an external source on a same different judgement task), intrapersonal identification of sounds (to compare the child's verbal response with that of an externally produced model and judge his own production) and intrapersonal comparator perception of sounds (to compare the examiner's production of the stimulus words with his own production and then to make a same different judgement for that comparison). The mean error scores for each were determined and statistical analysis was undertaken. The results revealed that all the four groups of children performed significantly different under each of the various auditory conditions. A subsequent analysis (Duncan's Multiple range test, Bruning & Kintz, 1968) showed that the groups ADLD and AD differed significantly on intrapersonal identification auditory discrimination task. The test also revealed that there was a significant difference in performance between ADLD and LD children and AD and normal children. The mean error scores were higher for ADLD group followed by AD and then by the LD group. But there was no significant difference between LD and normal children on any of the four tests. The LD and normal children made most errors on the interpersonal identification task whereas the

AD group made the most errors on the intrapersonal comparator task. The ADLD group made errors on the interpersonal identification task.

Residual auditory discrimination problems reportedly interfere significantly in several areas of learning new vocabulary in school or on the job, taking telephone messages, especially names, accuracy, spelling, and pronouncing multisyllabic words in conversation. In a study by Blalock (1982), of the 80 (57 males and 23 females) congenital learning disabled adults in the age range of 17 to 48 years, 63 were found to have oral language and/or auditory processing deficits. These problems included deficits in auditory discrimination, comprehension, memory, auditory recall, oral formulation and pronunciation of multisyllabic words. Problems in metalinguistic abilities were seen most frequently. Twenty-six people were diagnosed as having auditory discrimination problems. Of these, eight scored one or more standard deviation below the mean for 8-year olds on the auditory discrimination test (Wepman, 1958); some had difficulty when presented with isolated words on tests like the PPVT (peabody picture vocabulary test; Dunn, 1965) and asked for numerous repetitions. Others mispronounced multisyllabic words and when tested could not differentiate correct and incorrect pronunciations by the examiner (e.g., pacific/specific, wash/watch, curricular/curriculum). Several had the most difficulty with the repetition of nonsense words.

Perceptual and memory characteristic of gifted children with learning disabilities as well as their abilities in specific academic sub areas of reading, mathematics and spelling have been explored by Waldron & Saphire (1992). They studied the ways in which these children perceive and recall auditory and visual input and apply this information to reading, mathematics and spelling. Twenty-four learning disabled/gifted children and a matched control group of normally achieving gifted students were tested for oral reading, word recognition and analysis, listening comprehension and spelling. In mathematics, they were tested for numeration, mental and written computation, word problems and numerical reasoning. To explore perception and memory skills, students were administered formal tests of visual and auditory memory as well as auditory discrimination of sounds. The auditory discrimination was assessed with the help of Wepman Auditory Discrimination test (Wepman, 1958) and the auditory sequencing and memory was assessed with the help of WISC-R Digit Span subtest. Their responses to reading and to mathematical computations were further considered for evidence of problems in visual discrimination, visual sequencing and visual spatial areas. Analysis was done using t-test and Standard paired comparison t-test. The results indicated that these learning disabled/gifted students were significantly weaker than controls in their decoding skills, in spelling and in most areas of mathematics. They were also significantly weaker in auditory discrimination and memory and in visual discrimination, sequencing and spatial abilities. The authors concluded that these underlying perceptual and memory deficits might be related to student's academic problems.

While the above studies used word-pairs, and tones, for a discrimination task, the neurophysiological and psychoacoustical research suggests that an auditory deficit might be better explored by means of non meaningful *synthetically produced speech stimuli,* in which specific acoustic characteristics (such as voice onset time) could be systematically altered and tasks that do not require a verbal response can be used. The computer produced, synthetic speech syllables represent "good" tokens of natural speech (Tallal & Piercy, 1974), while at other times, the synthesized syllables have represented intermediate steps along a continuum between two end point syllables (Brandt & Rosen, 1980; Godfrey, Syrdal-Laskey, Millay & Knox, 1981). In this task, subjects are presented with a series of stimuli that represent points along an acoustic continuum. In the traditional categorical perception paradigm, both identification and discrimination functions along synthetic speech continua are measured in order to determine the 'sharpness' of category boundaries. Using this paradigm, several authors found that, when compared to normal children, children with learning disability were less consistent in identifying and less accurate at discriminating stimuli close to category boundaries indicating less sharply defined phonetic categories than normal children.

Brandt & Rosen (1980) were the first to use synthetic stimuli to investigate identification and discrimination in dyslexics. Twelve dyslexics and four normal children participated in the study. They divided the dyslexics in to three groups. Group I consisted of four dyslexics whose verbal IQ was greater than performance IQ by 15 points. Group II consisted of four dyslexics whose verbal IQ was less than performance IQ. Group III consisted of four dyslexics in whom there was a discrepancy between verbal and performance IQ by 10 points or less. They used a /ba-da-ga/ continuum that varied in VOT or direction of formant transition. Subjects used a same-different task. The results indicated that the identification and discrimination functions of dyslexics were not markedly impaired compared to normals and no significant differences were observed between groups. Godfrey, Syrdal-Laskey, Millay & Knox (1981) re-examined the data of Brandt & Rosen (1980) and concluded that in dyslexic children discrimination peaks were lower. Further, dyslexics did not show any peak at the category boundary of /ga/. Thus, dyslexics are not as accurate as normals. The varying data among dyslexics suggested that they couldn't be treated as a uniform group.

The notion that categorical perception in dyslexics is not consistent as a group or as accurate as normal readers is supported by the study of Lieberman, Meskill, Chatillon & Schupak (1985). They investigated steady-state consonant and vowel perception in syllable initial position that differed with respect to place of articulation in 18 adult developmental dyslexic subjects (13 males and 5 females) and normal subjects. They also employed a synthetic /ba/-/da/-/ga/ continuum as well as natural and synthetic vowel stimuli. A dictation procedure was used in which the subjects were asked to repeat orally what they heard which were later transcribed by phonetically trained listeners. The error rates and the standard deviation were calculated. The developmental dyslexic subjects showed deficit in the identification of the vowels of English when the sole acoustic cues were steady state formant frequency patterns. Deficit in the identification of place of articulation of the English stop consonants /b/, */d/,* and /g/ in syllable initial position were also observed. The average vowel error rate was 29% and the consonantal error rate was 22% for the dyslexic group, which was significantly different from those of the control group. Their results exemplified the heterogeneity found among dyslexic individuals. In a subgroup of four dyslexic subjects, average errors on the consonant task differed significantly from those of nondyslexic controls, but another subgroup of four dyslexic subjects did not differ from the controls. Similar results were reported for the vowel portion of the study; however, it was not the same subgroup of dyslexic subjects who differed from nondyslexic controls on the consonant task. Thus the results revealed that no single deficit characterized the entire group of dyslexic subjects. The pattern with respect to place of articulation also varied for different group of subjects. Three dyslexics had high vowel error rates and low consonantal error rates. They also concluded that the dyslexics have different perceptual deficits than a general auditory deficit involving the rate at which they can process perceptual information.

It has also been found that dyslexics have more auditory discrimination problems when the stimuli have rapid acoustic changes as in stop consonants. Reed (1986) comparing the performance of reading-disabled and normal controls on three auditory discrimination tasks of complex tones, two vowels (/e/ and /as/) and two syllables (/ba/ and /da/) found that the performance of the reading-disabled subjects did not differ from the normals on the vowel task even when the inter-stimulus interval was less than 300 msec. Reed attributed this to the relatively long duration of the steady state vowels (250 msec). In contrast, the performance of the reading-disabled subjects differed from the normal controls when consonants and tones were presented for relatively short intervals.

Werker & Tees (1987), De Weirdt (1988), and Reed (1989) also found that dyslexics were poorer than normals on a temporal order judgement task for tones and stop consonants but not for vowels. They compared dyslexics and normals on three tasks including complex tones, /ba-da/ continuum (De Weirdt - /pa/-/ba/), and two vowel continuum.

Mody, Studdert-Kennedy & Brady (1994-95) proposed two hypotheses to account for the speech perception deficits in poor readers - a speech specific failure in phonological representation, and a general deficit in auditory temporal processing, such that they can't easily perceive the rapid spectral changes of transitions at the onset of stop-vowel syllables. Temporal order judgment (TOJ) on /ba-da/, /ba-sa/, and /da-sa/ continuum was tested. The second and third pairs were used to determine whether the apparent TOJ deficit of the poor readers arose from difficulties in identifying /ba/ and /da/ at rapid rates of presentation due to their close similarity rather than from a deficit in judgments of temporal order itself. If this were so, it would be expected that their difficulties would disappear when the syllables are presented in more easily discriminable pairs, such as /ba-sa/ and /da-sa/. Two groups of second grade children (20 'good' readers and 20 'poor' readers) matched for age and intelligence were selected. The results indicated that the groups did not differ in (1) TOJ when /ba/ and /da/ were paired with more easily discriminated syllables /ba-sa/, and /da-sa/, (2) discriminating non-speech sine wave analog of the second and third formants of /ba/ and /*ga/,* and (3) sensitivity to brief transitional cues varying along a synthetic speech continuum. Thus, poor readers' difficulties with /ba-da/ reflected phonological confusion between phonetically similar, though phonologically contrastive, syllables rather than difficulty in perceiving rapid spectral changes. The results are consistent with a speech-specific failure in phonological representation and not a general deficit in auditory temporal processing.

Manis, McBride-Chang, Seidenberg, Keating, Doi, Munson & Petersen (1997) administered phonological awareness and phoneme identification tasks to dyslexic children, and both chronological age (CA) and reading-level (RL) comparison groups. Dyslexic children showed less sharply defined categorical perception of a 'bath-path' continuum varying in voice onset time when compared to the CA but not the RL group. The dyslexic children were divided into two subgroups based on phoneme awareness. Dyslexics with low phonemic awareness made poorer /b/-/p/ distinctions than both CA and RL groups, but dyslexics with normal phonemic awareness did not. Examination of individual profiles revealed that the majority of subjects in each group exhibited normal categorical perception. However, seven of the 25 dyslexics had abnormal identification functions, compared to one subject in the CA group and three in the RL group. The results suggested that some dyslexic children have a perceptual deficit that may interfere with processing of phonological information. Speech perception difficulties may also be partially related to reading experience.

Using a continuum of synthesized CV syllables, Elliott, Longinotti, Meyer, Raz & Zucker (1981) developed *a.* ***fine-grained measure*** *of* ***auditory discrimination*** that provided scores of individual listeners. For this measurement of fine-grained discrimination, subjects are presented with stimuli that become increasingly similar along a particular acoustic dimension according to an adaptive procedure. The discrimination threshold, or just noticeable difference score (JND), is determined as the point at which the subject's ability to discriminate two stimuli reaches a preset criterion, such as 70% correct. Elliott et al.,(1981) used an auditory discrimination procedure that assesses the "smallest difference" associated with speech-like consonant (C) sounds that may be discriminated (just noticeable differences - JNDs). Because JNDs were measured the task was considered as assessing *"fine-grained auditory* ***discrimination*** *"*. The results of the study demonstrated that ***normal children*** require larger acoustic differences in both frequency and time to discriminate consonant sounds than the ***normal adults.*** Further more, Elliott & Busse (1987) found the performance of many high-achieving ***young adults with*** relatively severe ***language-learning disabilities*** to be as poor, or even poorer than that of normal six-year old children and poorer than that of their normally developing age-mates for this fine-grained auditory discrimination task of frequency differences associated with CV stimuli. This finding was particularly interesting because performance of these same young adults on the speech perception in noise (SPIN) Test (Kalikow, Stevens & Elliott, 1977; Bilger, Neutzel, Rabinowitz & Rzeczkowski, 1984) equaled that of their normally developing peers for high-predictability sentences, where contextual information may facilitate speech perception. However, their SPIN Test performance was remarkably poorer than that of their peers for low-predictability sentences, which require precise perception of acoustic information. High- and low-predictability sentences are intermixed on the SPIN Test. Thus, cognitive processes such as attention to the task, motivation and memory components would be expected to be equivalent for both types of sentence items and should not differentially influence performance for only one type of sentence. These subjects' poor performance on low-predictability sentences, where cognitive contributions are minimal, suggested that poorer-than-normal auditory perception of the acoustic waveform might characterize some who experience language-learning problems.

Elliott & Hammer (1988) studied two groups of children-one progressing normally in school and the other exhibiting language-learning problems. They were tested in each of three years on a set of fine-grained auditory discrimination that required listening for small acoustic differences (JNDs) among the CV syllables on a same-different task. Children's ages ranged from 6-9 years; there were twenty-one children per group (42 children in total). Two continua of CV stimuli were synthesized using Klatt's parallel/cascade synthesizer program. A five formant, 8-item continuum that varied in VOT from 0-35 msec in 5 msec steps (ba-pa) was created. The second continuum represented the place of articulation features of speech production (ba-da-ga) and consisted of 13 items, each having five formants. The major acoustic differences along this continuum were the starting frequencies of the second and third formants and frequencies of the onset bursts. JNDs were measured with regard to both the /ba/ & /pa/ ends of the VOT continuum. For the place of articulation continuum, JNDs were measured relative to /da/ separately in the directions of /ba/ & /ga/. A computer controlled, up down adaptive procedure was used to track the 50% level of correct response. Means and standard deviations were calculated. ANOVA and MANOVA were used for the statistical analysis. The results indicated that the mean JNDs for children with language-learning problems were nearly always larger than those for .normal children in each year of testing. These were statistically significant only for the VOT continuum. In the year 3, the JNDs measured in the direction of /ba/ were identical for both groups. Age related improvements in JNDs were observed i.e. the mean JNDs improved over a three-year period. They concluded that the children with language-learning problems, despite having normal IQ / and normal pure tone sensitivity, showed poorer auditory discrimination than normal children for temporally based acoustic differences. This effect continued across three years. Children with language-learning problems also exhibited poorer receptive vocabulary and language performance as well as more deviations from standard Mid West Articulation than children making normal progress in school.

Elliott, Hammer & Scholl (1989) studied 295 children in the age range of 6-11 years who were divided into two large groups of children - one progressing normally in school and the other exhibiting language-learning problems and based on the age. Two continua of consonant-vowel stimuli were synthesized using Klatt's parallel/cascade synthesizer program. A five-formant, eight-item continuum that varied in VOT from 0-35 msec; in 5 msec steps (ba-pa) was created. The second continuum represented the place of articulation feature of speech production (ba-da-ga) and consisted of thirteen items, each having five formants. The major acoustic differences along this continuum were the onset frequencies of the second and third formants. These children were tested on a set of fine-grained discrimination tasks that required responding to small acoustic differences among the CV syllables (JNDs). JNDs were measured with regard to the /ba/ and /pa/ ends of the VOT continuum. For the place of articulation continuum, JNDs were measured relative to /da/, separately in the direction of/ba/ and /ga/. The listener's task was to judge them as 'same' or 'different' by pushing one of the response buttons. A computer controlled, up-down adaptive procedure was used to track the 50% correct response level. Means and standard deviations as well as intercorrelation coefficients for the variables of interest were also obtained separately for the younger and older children and two way ANOVA were run for these measures. In all the age groups, the children with language-learning problems exhibited poorer JNDs than the normal children. Among the younger group, more numbers of children with language-learning problems were unable to make one discrimination each. Discriminant analysis procedures, using only results for the auditory tasks, correctly classified nearly 80% of the 6 and 7 year olds and near 65% of the 8 to 11 year olds according to their school placements. Percentages of correct classifications increased to 87% and 75% when measures of receptive vocabulary (PPVT-R), receptive language (The Token Test for Children), and the digit span, coding and block design subtests of the WISC-R were also included in the discrimination functions. Results suggested that the children with language-learning problems experience delayed maturation of fine-grained auditory discrimination relative to normal

' children. They concluded that fine-grained auditory discrimination makes a major contribution to language learning, particularly in the early elementary school years.

Steffens, Eilers, Gross-Glenn & Jallad (1992) investigated speech perception (phonetic perceptual processing capabilities) in a carefully selected group of 36 adult subjects [18 (9 males and 9 females) with familial dyslexia and 18 normal readers]. Perception of three synthetic speech continua was studied: (1) /a/-*/a/,* in which steady state spectral cues of the first three formants Fl, F2 and F3 distinguished the vowel stimuli. Fl decreased and F2 and F3 increased in frequency as the continuum stepped from /a/ to/a/*;* (2) /ba/-/da/ in which rapidly changing spectral cues (F2 and F3) were varied; (3) /sta/-/sa/, in which a temporal cue, silence duration was systematically varied. The perception of the consonant cluster /sta/ in step 1 resulted from 130 msec of silence inserted between the offset of/s/ and the onset of /a/. The silent interval was decreased in 10 equal steps so that no silence occurred between the / *s/* and /a/. These were generated on an IBM PC AT using Klatt's synthesis routines. These three continua, which differed with respect to the nature of the acoustic cues discriminating between pairs, were used to assess subjects' abilities to use steady state, dynamic and temporal cues. The subjects participated in one identification task and two discrimination tasks for each continuum. The identification task required the subjects to categorize the experimental stimuli (two repetitions of each stimulus separated by a 500 msec interval in reference to an end point stimulus. The first discrimination task (a same-different paradigm) required subjects to discriminate between all pairs of stimuli separated by three continuum steps (e.g.,stimuli 1 & 4, 2 & 5, etc). The second discrimination task (an ABX paradigm) required the subjects to match the X (or the third stimulus) with either the first (A) or the second stimuli (B) differing by three continua steps. ANOVA was used for the statistical analysis to study the three and two-way interaction. Results revealed systematic small differences in phonetic perception in the dyslexic subjects. The normal reading women and the dyslexic men identified more stimuli at continuum steps closer to the/a/ end point as /a/ than did the other two groups (normal reading males and dyslexic females). The dyslexic men were less accurate in labeling of the vowel stimuli. The dyslexic subjects identified more exemplars as /ba/ at the /da/ end of the continuum. The dyslexic readers required greater silence duration than normal readers to shift their perception from /sa/ to /sta/. For all the groups the /ba/-/da/ continuum was the most difficult and the /a/-*/A/* continuum was the least difficult. They concluded that although the dyslexic subjects were able to label and discriminate the synthetic speech continua, they did not necessarily use the acoustic cues in the same manner as normal readers i.e. they lack the precision demonstrated by normal readers in tests of identification and discrimination and their overall performance was generally less accurate.

Elliott & Hammer (1993) tested the hypothesis that as children's language development matures, factor-analytic structural changes occur that are associated with measurements of fine-grained auditory discrimination, receptive vocabulary, receptive language, speech production and three performance subtests of the weschler intelligence scale for the children - revised (WISC-R). Three hundred and eighty four children (187 normals and 197 children with language-learning problems) and a small group of retarded children in the age range of 6-11 years were considered for the study. Two continua of five-formant CV stimuli were synthesized using Klatt's parallel/cascade synthesizer program. The first continuum represented the place of articulation features of speech production (ba-da-ga) and consisted of 13 items. The major acoustic differences along this continuum were the starting frequencies of the second and third formants and frequencies of the onset bursts. A second, 8-item continuum that varied in VOT from 0-35 msec in 5 msec steps (ba-pa) was created. An auditory discrimination task (same-different) was used to determine the smallest acoustic differences among the CV syllables i.e (JNDs). JNDs were measured with regard to both the /ba/ and /pa/ ends of the VOT continuum. For the place of articulation continuum, JNDs were measured relative to /da/ separately in the directions of /ba/ and /ga/. A computer controlled, up down adaptive procedure was used to track the 50% level of correct response, peabody picture vocabulary test - revised (PPVT-R) (Dunn & Dunn, 1981) and The Token Test for Children (Disimoni, 1978) were administered to obtain measures of receptive vocabulary and language. Templin-Darley Screening Test of Speech Articulation (Templin & Darley, 1969) and three performance subtests of WISC-R (Weschler, 1974 - digit span, block design and coding) were also administered. Means, standard deviations and t-test outcomes were calculated. The results revealed that the younger children with language-learning problems performed significantly poorer than younger normal children on every test measure i.e. the younger children with language-learning problems required 23 msec for VOT discrimination relative to /ba/ (JBP) - JND measured relative to the /ba/ end of the VOT continuum-, while normal children required only 17 msec VOT to make the same discrimination. This difference of approximately 6 msec VOT indicated that children with language-learning problems required a 35% longer VOT than normal children to make the JBP discrimination. Also the performance of older children with language-learning problems was better than the younger children with language problems. The factor analytic results

/ revealed that the factor structure that resulted for the younger normal children resembled the one for the younger children with language problems but was not as well defined. Among the 6-7 year old children, the percentage of total variance attributed to the factor defined by fine-grained auditory discrimination measures were approximately 43% for children who were intellectually impaired, 27% for the youngsters who had language-learning problems, and 16% for the regularly progressing children. The WISC-R subtest scores did not load on the auditory discrimination factor. The difference in variance explained by the auditory discrimination factor was interpreted as representing greater relative importance of auditory discrimination among children with less well developed language competencies than among children with more mature language skills. This interpretation was strengthened by the finding of no distinct auditory discrimination factor for 8-11 year old children who were either regularly progressing or language-disabled even though the language/speech factor at this age closely resembled that found among younger children. They also carried out the same experiment on children with moderate retardation. The results showed that the mean performance of these children were poorer than that of the children with language-learning problems. They also had poorer receptive vocabulary and language scores. The factor analytic results revealed that the factor structures for children with moderate retardation more closely resembled the structure of children with language problems than that for young normal subjects. They concluded that the performance of young children who are learning basic language skills may be described, in part, by a fine-grained auditory discrimination dimension or factor and that the poorer the children's language/speech competencies, the greater this dimension's salience. Among the older children, with better speech and language skills, fine-grained auditory discrimination seemed less a unitary dimension. Thus, the fine-grained auditory discrimination was particularly well defined for children with moderate retardation, quite well defined for younger children with language-learning problems, fairly well defined for younger normal children and not as well defined for older children with language problems and regularly progressing children who had greater vocabulary, language and speech competencies.

Bradlow, Kraus, Nicol, McGee, Cunningham, Zecker & Carrell (1999) investigated the precise acoustic feature of stop consonants that pose perceptual difficulties for some children with learning problems. The discrimination thresholds (JND) along two separate synthetic /da-ga/ continua were compared on a fine-grained auditory discrimination task in a group of children with learning problems (11 children with learning disability, 41 with attention deficit disorder and 7 with both) and a group of normal children aged 6-16 years. Two /da-ga/ place of articulation continua were created using the Klatt cascade-parallel formant synthesizer (Klatt, 1980). In the first continua, the length of the formant transition duration duration was 40 msec and in the second continua, it was increased to 80 msec. A control condition /ba-wa/ (a stop-glide continuum) was also created. Results indicated that the discrimination thresholds were elevated in the children with learning problems in the /da-ga/ continua at both 40 and 80 msec transition duration. There was no significant difference between both the groups in the /ba-wa/ continua. Thus lengthening the formant transition duration from 40 to 80 msec did not result in improved discrimination thresholds for the group of children with learning problems. An electrophysiological response that is known to reflect the brains representation of a change from one auditory stimulus to another - the Mismatch Negativity (MMN) was recorded which indicated diminished responses in the group of children with learning problems to /da/ vs. /ga/ when the transition duration was 40 msec. In the lengthened transition duration condition, the MMN responses from both the groups were similar and were enhanced relative to the short transition duration condition. These data suggest that extending the duration of the critical portion of the acoustic stimulus can result in enhanced encoding at a pre attentive neural level; however, this stimulus manipulation on its own is not a sufficient acoustic enhancement to facilitate increased perceptual discrimination of this place-of-articulation contrast. Taken together, these behavioral and neurophysiologic data suggest that the source of the underlying perceptual deficit may be a combination of faulty stimulus representation at the neural level as well as deficient perception at an acoustic-phonetic level, which suggest a 'biological basis' for the impaired behavioral perception.

The review of literature indicates that a variety of task-related variables have been employed in studies of auditory discrimination abilities in impaired children; however, most tasks fall into one of the three basic types. The first type of task requires subjects to respond to stimulus pairs, or longer strings of stimuli, in which each member represents a good exemplar of a particular speech sound category. In these tasks, subjects are typically required to identify a given stimulus as a member of one of two categories, to discriminate between the two stimuli. Since subjects hear only good category exemplars, these tasks tap into the subjects' abilities to make judgements that rely on perception of cross-category differences. This type of task using stimulus pairs that are minimally different has revealed identification, discrimination and temporal order judgement impairments in clinical population relative to normal population. In the second type of task, subjects are presented with series of stimuli that represent points along an acoustic continuum. In the traditional categorical perception paradigm, both identification and discrimination functions along synthetic speech continua are measured in order to determine the 'sharpness' of category boundaries. Using this paradigm, several studies found that, when compared to normal children, children with learning disability were less consistent in identifying and less accurate at discriminating, stimuli close to category boundaries, indicating less sharply defined phonetic categories than normal children. Synthetic speech continua have also been used to determine discrimination thresholds. For this measurement of fine-grained discrimination, subjects are presented with stimuli that become increasingly similar along a particular acoustic dimension according to an adaptive procedure. The discrimination threshold, or just noticeable difference score (JND), is determined as the point at which the subject's ability to discriminate two stimuli reaches a preset criterion, such as 70% correct. Using this kind of task, several studies have shown that children with language-learning disability require greater acoustic distance between stimuli along certain speech continua in order to discriminate them.

There are seven studies that have used fine-grained auditory discrimination. Of these studies, Elliott et al., (1981) compared fine-grained auditory discrimination abilities of normal children and adults. Steffens et al., (1992), and Bradlow et al., (1999) have investigated fine-grained auditory discrimination in adults with familial dyslexia and children with learning problems, respectively. The other authors (Elliott & Hammer, 1988, 1993; Elliott, Hammer & Scholl, 1989) have investigated fine-grained auditory discrimination in children with language-learning problems and Elliott & Busse (1987) have investigated in young adults with language-learning disabilities. Spectral parameters (Elliott et al. 1981; Elliott & Busse, 1987; Bradlow et al. 1999), and various spectral and temporal parameters (voce onset time, and place of articulation represented by varying F2 and F3 - Elliott & Hammer, 1988; Elliott, Hammer & Scholl, 1989; Elliott & Hammer, 1993; vowel and consonant, and silence in /sta-sa/ pair- Steffens et al. 1992) have been used to measure JNDs. Also, the only VOT continuum used is /ba-pa/ and the only continuum used for silence is (sta-sa). All the studies are conducted on English speaking children or adults. The results of these studies indicate that children with language-learning problems are poor in fine-grained auditory discrimination abilities. There is no information on fine-grained auditory discrimination in children with learning disabilities. Neither is there information about the prevalence of auditory discrimination problems in children with learning disabilities nor is it known whether performance on the fine-grained auditory discrimination task can definitely separate children with learning disabilities from normal children. Also, there is no information about the performance of children with learning disabilities on the fine-grained auditory discrimination for VOT continuum other than /ba-pa/, for closure duration continuum and on other languages. As stop consonants differ from one language to another, VOT and closure duration of these consonants also differ. To address these issues the present study was undertaken in Malayalam language. Malayalam is a language spoken by the native people of the state of Kerala, in South India. It is also classified as a Dravidian language (Ladefoged & Maddieson, 1996). It has five places of articulation for stop consonants. It is a language having the maximum number of articulatory places. The unvoiced consonants have four aspirated ($p^{h,}$ th th k^h) and five unaspirated consonants (p, t^ t, t, k). The voiced consonants have three weakly voiced (P, T, K) and four unaspirated (b, d^ d.; g) consonants. Unlike English, stop consonants do not occur in word-final position in Malayalam. The aim of this study was to investigate the auditory discrimination abilities in 7-12 year old Malayalam speaking children with learning disability. The next three chapters that follows deals with experiments that involves assessing the fine-grained auditory discrimination abilities in children with learning disabilities and normal children altering three different temporal cues: voice onset time, closure duration and closure duration, and transition duration.

CHAPTER III

Fine-grained auditory discrimination for Voice Onset Time

Syllables govern the world

John Selden

Experiment I: Fine-grained auditory discrimination for voice onset time

Introduction

In general, plosives may be categorized as phonologically 'voiced' or 'unvoiced'. A number of consonants are produced with the same manner and place of articulation but differ only among the dimension of voicing. Here, voicing is the primary dimension used to distinguish these minimal pairs, for e.g., in the minimal pairs /p b/, A d/, /k g/, /p t k/ are 'unvoiced' and /b d g/ are 'voiced'. A range of physiological and acoustic differences have been identified between the two voicing categories. Acoustic cues which have been noted to differentiate the two voicing categories include voice onset time (VOT) (Lisker & Abramson, 1964, 1967; Abramson & Lisker, 1973), amplitude of the burst (Repp, 1979; Jongman & Blumstein, 1985), fundamental frequency (FO) characteristics (Haggard, Ambler & Callow, 1970), closure duration (or stop gap) preceding the release of plosive (Lisker, 1957) and preceding vowel duration in the case of non-initial plosives (Chen, 1970).

There is, therefore, a 'many-to-one mapping' of acoustic cues to voicing (Lisker, Liberman, Erickson, Dechovitz & Mandler, 1977). However, of these cues, VOT is considered to be the primary cue for the voicing distinction as it has been identified as 'the single most effective measure' (Lisker & Abramson, 1971) in the perception and production of word-initial prevocalic plosives (Lisker & Abramson, 1964, 1967).

VOT is defined as the difference in time between the release of a complete articulatory constriction and the onset of quasiperiodic vocal fold vibration (Lisker & Abramson, 1964; Abramson & Lisker, 1965). In the procedures for specification of VOT, the instant of burst release is denoted as zero. Thus measurement of VOT before the release is stated as negative values, expressed in msec and is called as voicing lead or prevoicing, while measurements of VOT after the release are stated as positive values and are called voicing lag (Lisker & Abramson, 1967 a). Voicing lag are of two types: coincident or short lag VOT (with zero or low positive VOT values) in which voicing onset is simultaneous or briefly lags behind the release burst and long lag VOT (with high positive VOT values) in which the voicing onset lags behind the release burst: While lead VOT and short lag VOT characterize the voiced stops (less than 20-30 msec), long lag VOT characterize the unvoiced stops (more than 50 msec) (Lisker, 1975). Fig. 3.1 shows lead, short lag and long lag VOT.

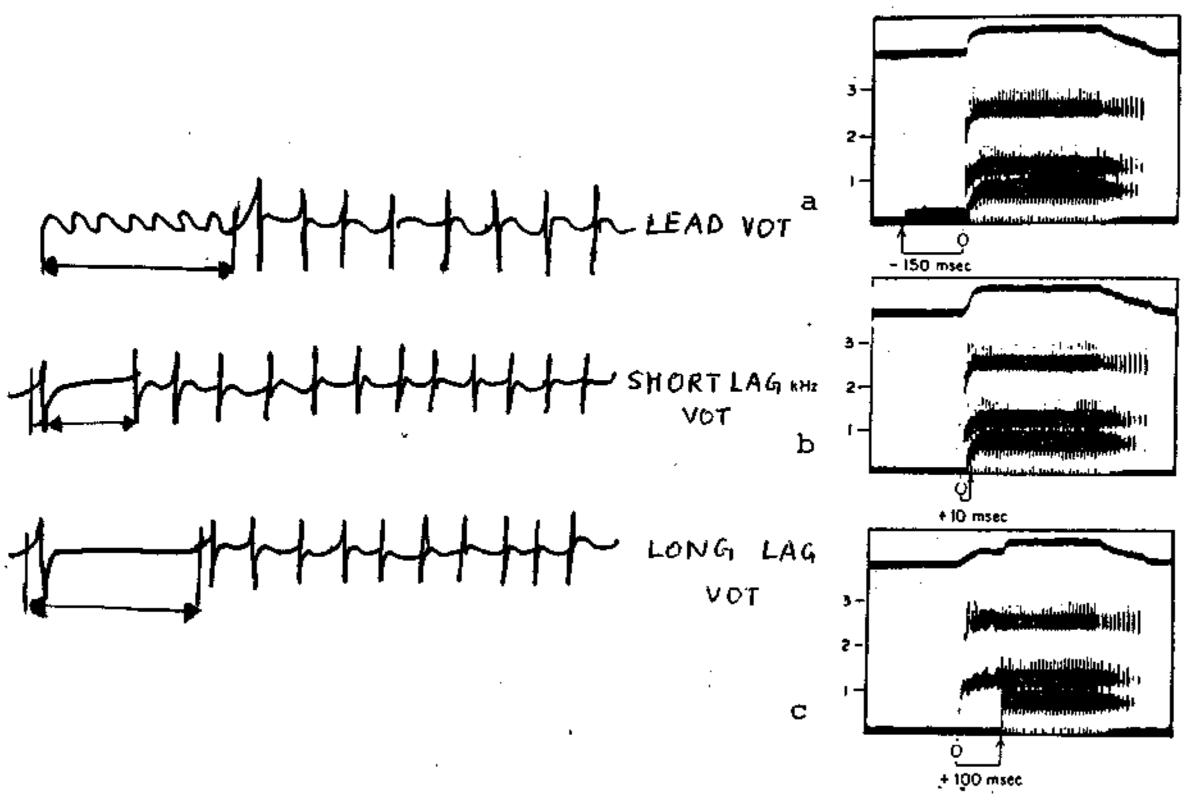

Fig. 3.1: Waveform depicting three conditions of VOT in synthetic labial stop consonants. From top to bottom spectrograms of (a) voicing lead (b) slight lag, and (c) long lag after (Abramson & Lisker, 1973).

When languages have a "traditional" voiced vs. unvoiced stop contrast in initial position (e.g., Arabic, Bulgarian, Efik, Japanese) with no aspiration involved, then VOT has been used in particular to differentiate the two. The differences in VOT have been termed lead vs. short lag for voiced and unvoiced, respectively (Lisker & Abramson, 1964; Keating, Mikos & Ganong, 1981). Lisker & Abramson (1964) reported modes of 0-20 msec VOT for voiced and 50-70 msec VOT for unvoiced stops in English. Across languages, Lisker and Abramson (1964, 1967) indicated a fairly consistent 60 msec minimum difference in VOT between voiced and unvoiced stops. Keating (1984) persists that these differences may be quantal and anchored to the region of the burst. Lisker and Abramson's (1970) classic study of voicing, in eleven different languages demonstrated that VOT is a useful concept in understanding the voicing contrast of languages with different phonetic categories of voicing. The data from speech perception studies using synthetic speech have suggested that the acoustic characteristics providing the simplest and the most direct indication of whether a stop consonant is voiced or unvoiced is VOT. Although there are considerable differences in its production and perception across different languages, one aspect of VOT perception appears universal: the perception of a difference in VOT between two stimuli generally occurs only when the stimuli belong to different phonetic categories. Listeners can only discriminate between the sounds on VOT continuum to which they can assign unique labels. For this reason, the perception of a difference in VOT is said to be categorical (Liberman, Cooper, Shankweiler & Studdert-Kennedy, 1967).

Thus, VOT as a perceptual cue seems to be a universal linguistic phenomenon. Furthermore, this cue is robust and maintained in the spontaneous speech of adult speakers (Krull, 1991; Abramson & Lisker, 1995).

VOT values exhibit intrinsic variations, relating to both their place of articulation and voicing category. VOT values increase as the place of articulation moves from anterior to more posterior, that is, alveolar plosives will be produced with a longer VOT value than the corresponding labial plosive (Lisker & Abramson, 1964, 1967). 'Unvoiced' plosives in English are produced with a wider distribution of VOT values than the voiced plosive as the 'unvoiced' plosive is the less stable member of the minimal pair. Also, the more extended the contact area, the longer the VOT (Stevens, Keyser & Kawasaki, 1986) and the faster the movement of the articulator, the shorter the VOT (Hardcastle, 1973).

Fine-grained auditory discrimination for VOT

Series of studies conducted by Tallal & Stark (1980), Elliott, Longinotti, Meyer, Raz & Zucker (1981), Elliott, Busse, Partridge, Rupert & DeGraff, (1986), and Sussman & Carney (1989) have added a new dimension to developmental research in terms of experimental paradigm and measurement of perception of Just Noticeable Differences and Fine-grained Auditory Discrimination.

Elliott, Longinotti, Meyer, Raz & Zucker (1981) conducted an experiment to determine whether age related differences would be observed for identification and discrimination of synthesized, five formant CV syllables among listeners who showed equal performance scores on a standard clinical test of speech understanding. Two 13-item continua that varied in the place of articulation feature.(ba, da, ga) were used; they differed primarily in the presence or absence of a 5 msec noise burst at the consonant onset. Results revealed strong age effects on all the three tasks - identification of syllables, adaptive estimation of 'ba-da' and 'da-ga' boundaries and discrimination (same-different task). With the exception of one condition for six year olds, only adults showed significant differences between boundaries and just noticeable differences (JNDs). More adults than children achieved the

81% correct criterion for labeling task which could be because of the greater number of years of practice that adults have in associating speech units for phonemes with sets of acoustic characteristics. Minimal differences were obtained in responses to stimuli with and without initial bursts. Across ages, there were no significant differences in the subject's ability to label the synthesized syllables as compared to the natural speech stimuli. Normal 10 year olds performance was more like adults than was performance of normal 6 year olds, which indicates that these effects are developmental in character.

Elliott (1986) further developed the study (the above study had discrimination when an adaptive procedure was used and trials were concentrated among pairs of stimuli that were discriminated 50% of the time), the major purpose of which was to determine whether the same types of age effects would be replicated for new groups of subjects and a different task in which all stimuli were presented equal number of times. An eight item, 5 formant CV continuum in which VOT ranged from 0-35 msec was used. The same different task presented all possible pairs of CV syllables in which VOT differed by 10 and 20 msec and an equal number of catch trials that contained identical CVs. Fifteen normal subjects each in the age range of 6.2 to 7.9 years, 8.3 to 11 years and 18.1 to 28.6 years participated in the perceptual experiment. Results showed that children displayed poorer discrimination than adults for CV pairs differing by both time intervals. Adults displayed a somewhat greater tendency to respond "same" than the children. The outcomes supported the results of the previous study and were interpreted as representing the true age related differences in VOT discrimination.

Elliott, Busse, Partridge, Rupert & DeGraff (1986) demonstrated age related differences in VOT discrimination using a same/different simple adaptive procedure (Levitt, 1971) with trial by trial visual feedback/reinforcement and "catch" trials. The experimental paradigm used in that study measured JNDs or the smallest VOT differences that could be discriminated 50% of the time relative to the end points of the VOT continuum. The adaptive procedure focuses test trials on those stimuli for which responses provide the greatest amount of information for each particular subject. This renders adaptive procedure particularly attractive for testing children, since the test session may then be as short as possible.

Within the history of learning disabilities as a categorization of learning problems, learning processes as contributors to the disability frequently have been studied. The process area of perception has received primary attention. Although the literature shows correlations between perceptual skills and academic achievement, there is a considerable controversy concerning perceptual testing and training.

Elliott & Hammer (1988) studied two groups of children-one progressing normally in school and the other exhibiting language-learning problems. They were tested in each of three years on a set of fine-grained auditory discrimination that required listening for small acoustic differences (JNDs) among the CV syllables on a same-different task. Children's ages ranged from 6-9 years; there were twenty-one children per group (42 children in total). Two continua of CV stimuli were synthesized using Klatt's parallel/cascade synthesizer program. A five formant, 8-item continuum that varied in VOT from 0-35 msec in 5 msec steps (ba-pa) was created. The second continuum represented the place of articulation features of speech production (ba-da-ga) and consisted of 13 items, each having five formants. The major acoustic differences along this continuum were the starting frequencies of the second and third formants and frequencies of the onset bursts. JNDs were measured with regard to both the /ba/ & /pa/ ends of the VOT continuum. For the place of articulation continuum, JNDs were measured relative to /da/ separately in the directions of /ba/ & /ga/. A computer controlled, up down adaptive procedure was used to track the 50% level of correct response.

Means and standard deviations were calculated. ANOVA and MANOVA were used for the statistical analysis. The results indicated that the mean JNDs for children with language-learning problems were nearly always larger than those for normal children in each year of testing. These were statistically significant only for the VOT continuum. In the year 3, the JNDs measured in the direction of /ba/ were identical for both groups. Age related improvements in JNDs were observed i.e. the mean JNDs improved over a three-year period. They concluded that the children with language-learning problems, despite having normal IQ and normal pure tone sensitivity, showed poorer auditory discrimination than normal children for temporally based acoustic differences. This effect continued across three years. Children with language-learning problems also exhibited poorer receptive vocabulary and language performance as well as more deviations from standard Mid West Articulation than children making normal progress in school.

Elliott, Hammer & Scholl (1989) studied 295 children in the age range of 6-11 years who were divided into two large groups of children - one progressing normally in school and the other exhibiting language-learning problems and based on the age. Two continua of consonant-vowel stimuli were synthesized using Klatt's parallel/cascade synthesizer program. A five-formant, eight-item continuum that varied in VOT from 0-35 msec; in 5 msec steps (ba-pa) was created. The second continuum represented the place of articulation feature of speech production (ba-da-ga) and consisted of thirteen items, each having five formants. The major acoustic differences along this continuum were the onset frequencies of the second and third formants. These children were tested on a set of fine-grained discrimination tasks that required responding to small acoustic differences among the CV syllables (JNDs). JNDs were measured with regard to the /ba/ and /pa/ ends of the VOT continuum. For the place of articulation continuum, JNDs were measured relative to /da/, separately in the direction of/ba/ and /*gal.* The listener's task was to judge them as 'same' or 'different' by pushing one of the response buttons. A computer controlled, up-down adaptive procedure was used to track the 50% correct response level. Means and standard deviations as well as intercorrelation coefficients for the variables of interest were also obtained separately for the younger and older children and two way ANOVA were run for these measures. In all the age groups, the children with language-learning problems exhibited poorer JNDs than the normal children. Among the younger group, more numbers of children with language-learning problems were unable to make one discrimination each. Discriminant analysis procedures, using only results for the auditory tasks, correctly classified nearly 80% of the 6 and 7 year olds and near 65% of the 8 to 11 year olds according to their school placements. Percentages of correct classifications increased to 87% and 75% when measures of receptive vocabulary (PPVT-R), receptive language (The Token Test for Children), and the digit span, coding and block design subtests of the WISC-R were also included in the discrimination functions. Results suggested that the children with language-learning problems experience delayed maturation of fine-grained auditory discrimination relative to normal children. They concluded that fine-grained auditory discrimination makes a major contribution to language learning, particularly in the early elementary school years.

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This interpretation was strengthened by the finding of no distinct auditory discrimination factor for 8-11 year old children who were either regularly progressing or language-disabled even though the language/speech factor at this age closely resembled that found among younger children. They also carried out the same experiment on children with moderate retardation. The results showed that the mean performance of these children were poorer than that of the children with language-learning problems. They also had poorer receptive vocabulary and language scores. The factor analytic results revealed that the factor structures for children with moderate retardation more closely resembled the structure of children with language problems than that for young normal subjects. They concluded that the performance of young children who are learning basic language skills may be described, in part, by a fine-grained auditory discrimination dimension or factor and that the poorer the children's language/speech competencies, the greater this dimension's salience. Among the older children, with better speech and language skills, fine-grained auditory discrimination seemed less a unitary dimension. Thus, the fine-grained auditory discrimination was particularly well defined for children with moderate retardation, quite well defined for younger children with language-learning problems, fairly well defined for younger normal children and not as well defined for older children with language problems and regularly progressing children who had greater vocabulary, language and speech competencies.

As a whole this review indicates a developmental trend and deficits in auditory discrimination in children with language-learning problems. The present experiment aims to investigate fine-grained auditory discrimination for VOT in Malayalam speaking children with learning disability.

Method

Stimuli: Six CV syllables with voiced stop consonants (velar /g/, dental /d/, and bilabial /b/) and their cognate unvoiced stop consonants (velar /k/, dental /t/, and bilabial /p/) as uttered three times by a 32 year old normal female Malayalam speaker was recorded on to a DX 486 computer with a sampling frequency of 16000 Hz at 12 bit resolution using the VSS (Voice and Speech Systems, Bangalore) data acquisition system. This digitized data was stored in to the computer memory and using the 'waveform display', the VOTs and vowel durations were measured. VOT was measured as the time difference between the burst and the onset of voicing. Using the 'spgm' and 'analysis' programmes, the first four formant frequencies, their bandwidths, transitions and the source parameters (F0 and intensity) of the syllables with voiced stop consonants were measured. Klatt's parametric synthesis was used to synthesize the CV syllables /ga/, /da/, and /ba/. These synthesized syllables were used to generate further tokens. The spectral and source parameters used to synthesize the CV syllable /ga/ are shown in table 3.1.

Speech sound voicing	g v	g v	g b	**a** v	a v	a v
Starting duration	0	60	10	30	250	50
Ending duration	0	60	70	100	350	400
Spectral parameters						
Fl	384	384	384	700	700	700
Bl	50	50	50	50	50	50
F2	1395	1395	1395	1240	1240	1240
B2	70	70	70	70	70	70
F3	2100	2100	2100	2300	2300	2300
B3	110	110	110	110	110	110
F4	3600	3600	3600	3600	3600	3600
B4	200	200	200	200	200	200
Source parameters						
FO	200	220	0	235	235	210
AV	30	35	45	40	40	35
AH	0	0	0	0	0	0
OQ	0.5	0.5	0	0.5	0.5	0.5
SQ	4	4	0	4	4	4
LQ	0.4	0.4	0	0.4	0.4	0.4

Table 3.1: Parameters used to synthesize *I gal*, (v = voiced, b = burst, F - Formant, B - Bandwidth, FO - Fundamental frequency, AV - Amplitude of voiced sounds, AH - Amplitude of mixed sounds, OQ - Open Quotient, SQ - Speed Quotient, LQ - Leakage Quotient).

For generating the syllable /ga/, the first, second, third and fourth formants were kept constant for 60 msec at 384 Hz, 1395 Hz, 2100 Hz and 3600 Hz respectively. The bandwidths were kept constant for 60 msec at 50 Hz, 70 Hz, 110 Hz and 200 Hz, respectively. A 10 msec burst was introduced between 60 to 70 msec. From 70 msec to 100 msec, the formants transited from 384 Hz to 700 Hz (Fl), 1395 Hz to 1240 Hz (F2), 2100 Hz to 2300 Hz (F3) and the fourth formant was kept constant throughout. The first three formants and bandwidths were kept constant from 100 msec to 400 msec. F0 was increased from 200 Hz to 220 Hz between 0 msec to 60 msec and dipped to 0 Hz between 60 msec to 70 msec. The F0 was 235 Hz between 100 msec and 350 msec. In the last 50 msec F0 dipped from 235 Hz to 210 Hz. The intensity started at 30 dB, rose to 35 dB at 60 msec and to 45 dB at 70 msec. The intensity dipped to 40 dB at 100 msec to 350 msec and in the last 50 msec it further dipped to 35 dB.

The spectral and source parameters used to synthesize the CV syllable /da/ are shown in table 3.2.

Speech sound	d	d	d	a	a	a
voicing	v	v	b	v	v	v
Starting duration	0	60	10	30	250	50
Ending duration	0	60	70	100	350	400
Spectral parameters						
Fl	384	384	384	700	700	700
Bl	50	50	50	50	50	50
F2	1770	1770	1770	1240	1240	1240
B2	70	70	70	70	70	70
F3	2791	2791	2791	2000	2000	2000
B3	110	110	110	110	110	110
F4	3750	3750	3750	3000	3000	3000
B4	200	200	200	200	200	200
Source parameters						
FO	200	220	0	235	235	210
AV	30	35	45	•40	40	35
AH	0	0	0	0	0	0
OQ	0.5	0.5	0	0.5	0.5	0.5
SQ	4	4	0	4	4	4
LQ	0.4	0.4	0	0.4	0.4	0.4

Table 3.2: Parameters used to synthesize /da/, (v = voiced, b = burst, F - Formant, B - Bandwidth, F0 - Fundamental frequency, AV-Amplitude of voiced sounds, AH - Amplitude of mixed sounds, OQ - Open Quotient, SQ - Speed Quotient, LQ - Leakage Quotient).

For generating the syllable /da/, the first, second, third and fourth formants were kept constant for 60 msec at 384 Hz, 1770 Hz, 2791 Hz and 3750 Hz, respectively. The bandwidths were kept constant for 60 msec at 50 Hz, 70 Hz, 110 Hz and 200 Hz, respectively. A 10 msec burst was introduced between 60 and 70 msec. From 70 msec to 100 msec, the formants transited from 384 Hz to 700 Hz (Fl), 1770 Hz to 1240 Hz (F2), 2791 Hz to 2000 Hz (F3), and 3750 Hz to 3000 Hz (F4). The first four formants and bandwidths were transited from 260 Hz to 700 Hz (Fl), 942 Hz to 1240 Hz (F2), 1904 Hz to 2500 Hz (F^and

kept constant from 100 msec to 400 msec. F0 was increased from 200 Hz to 220 Hz between 0 msec to 60 msec but dipped to 0 Hz between 60 msec and 70 msec. It was again increased to 235 Hz between 100 msec to 350 msec. In the last 50 msec F0 dipped from 235 Hz to 210 Hz. The intensity started at 30 dB, rose to 35 dB at 60 msec and 45 dB at 70 msec. It dipped to 40 dB at 100 msec and 350 msec, and further dipped to 35 dB in the last 50 msec.

The spectral and source parameters used to synthesize the CV syllable /ba/ are shown in table 3.3.

Speech sound	b	b	b	a	a	a
voicing	v	v	b	v	v	v
Starting duration	0	60	10	30	250	50
Ending duration	0	60	70	100	350	400
Spectral parameters						
Fl	260	260	260	700	700	700
Bl	50	50	50	50	50	50
F2	942	942	942	1240	1240	1240
B2	70	70	70	70	70	70
F3	1904	1904	1904	2500	2500	2500
B3	110	110	110	110	110	110
F4	3600	3600	3600	3600	3600	3600
B4	200	200	200	200	200	200
Source parameters						
FO	200	220	0	235	235	210
AV	30	35	45	40	40	35
AH	0	0	0	0	0	0
OQ	0.5	0.5	0	0.5	0.5	0.5
SQ	4	4	0	4	4	4
LQ	0.4	0.4	0	0.4	0.4	0.4

Table 3.3: Parameters used to synthesize /ba/, (v = voiced, b = burst, F - Formant, B - Bandwidth, F0 - Fundamental frequency, AV-Amplitude of voiced sounds, AH - Amplitude of mixed sounds, OQ - Open Quotient, SQ - Speed Quotient, LQ - Leakage Quotient).

For generating the syllable /ba/, the first, second, third and fourth formants were kept constant for 60 msec at 260 Hz, 942 Hz, 1904 Hz and 3600 Hz, respectively. The bandwidths were kept constant for 60 msec at 50 Hz, 70 Hz, 110 Hz and 200 Hz, respectively. A 10 msec introduced between to 70 msec. From 70 msec to 100 msec, the formants transited from 260 Hz to 700 Hz (Fl), 942 Hz to 1240 Hz (F2), 1904 Hz to 2500 Hz (F3), and the fourth formant was kept constant throughout. The first three formants and bandwidths were kept constant from 100 msec to 400 msec. F0 was increased from 200 Hz to 220 Hz between 0 msec to 60 msec but dipped to 0 Hz between 60 msec and 70 msec. The F0 was 235 Hz between 100 msec and 350 msec. In the last 50 msec, F0 dipped from 235 Hz to 210 Hz. The intensity started at 30 dB, rose to 35 dB at 60 msec and to 45 msec at 70 msec. The intensity dipped to 40 dB at 100 msec and 350 msec and in the last 50 msec, it further dipped to 35 dB.

The synthetic tokens of lead VOT were generated using the 'waveform editor' and lead VOT was truncated in steps of 3 pitch pulses till the VOT was '0'. When VOT was '0', edited tokens with lag VOT were generated by inserting silence in steps of 10 msec between the burst and the following vowel till the lag VOT approximated the original VOT. The details of the synthetic tokens are in table 3.4.

VOT stimulus	/g/-/k/	/d/ - /t/	/b/- /p/
Synthetic TO	-60	-60	-60
Tl	-50	-50	-50
T2	-40	-40	-40
T3	-30	-30	-30
T4	-20	-20	-20
T5	-10	-10	-10
T6	0	0	0
T7	+10	+10	+10
T8	+20	+20	+20
T9	+30	+30	+30
T10	+40	+40	+40
Til	+50	+50	-
T12	-	+60	-
No. of iterations	03	03	03

Table 3.4: Details of synthetic tokens for VOT (in msec).

Each phoneme with its synthetic token was considered as a test and within each of the three tests, the tokens were paired with another using the A-B design (e.g., TO-TO, T0-T1, T0-T2 etc.) and iterated three times. Table 3.5 depicts a sample randomization of tokens for VOT.

Actual tokens	Paired tokens													No. of tokens
T0	T0	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	13
T1		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	12
T2			T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	11
T3				T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	10
T4					T4	T5	T6	T7	T8	T9	T10	T11	T12	9
T5						T5	T6	T7	T8	T9	T10	T11	T12	8
T6							T6	T7	T8	T9	T10	T11	T12	7
T7								T7	T8	T9	T10	T11	T12	6
T8									T8	T9	T10	T11	T12	5
T9										T9	T10	T11	T12	4
T10											T10	T11	T12	3
T11												T11	T12	2
T12													T12	1
														91

Table 3.5: Randomized token pairs for VOT at the dental place of articulation.

These synthetic token pairs in three places of articulation were then audio-recorded on metallic cassettes with an inter-token interval (ITI) of 2 sec and inter-pair interval of 5 sec using the 'play bat' programme. Ten practice items were also recorded preceding the experimental stimuli. The tokens were fed to the DSP sonograph 5500 and spectrograms were examined. None of the tokens revealed any noise or click. Thus a total of 705 token pairs (234 for /g-k/, 273 for /d-t/ and 198 for /b-p/) formed the stimuli. Fig. 3.2 depicts the VOT of the synthetic tokens.

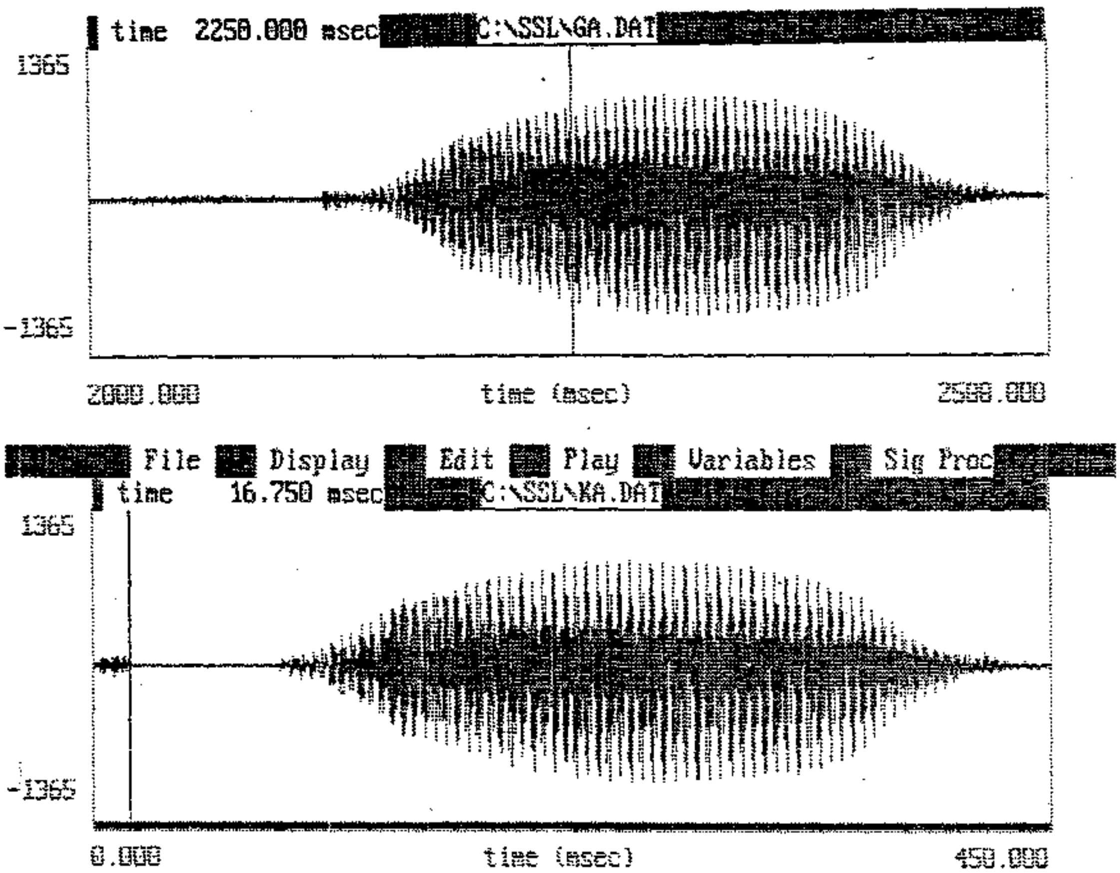

Fig. 3.2: Synthetic tokens (VOT)

Subjects: Thirty Malayalam speaking children with specific learning disability in the age group of 7-12 years and thirty Malayalam speaking age matched normal children participated in the experiment. Children were diagnosed to have learning disability by a team of professionals involving a speech-language pathologist, audiologist and a psychologist. NIMHANS index of specific learning disabilities (Kapur, John, Rozario, Oommen, 1991) was used by the specialists to identify and diagnose each of the learning disabled children. Children who performed two grades lower than the actual grade in minimum of two academic skills were included in the study.

The index (NIMHANS) consists of a battery of tests which are as follows:

1. Attention test (digit cancellation).
2. WISC (Weschler Intelligence Scale for children) - Indian adaptation by Malin (1968).
3. Test of academic skills (reading, writing, spelling and reading comprehension).
4. Arithmetic skills (addition, subtraction, multiplication, division and simple fraction).
5. Visuomotor skill (Bender Gestalt Test and the Developmental Tests of Visuo-motor Integration).
6. Memory (auditory and visual).

All children in the experimental (Learning Disabled) group had hearing thresholds within normal limits in the speech frequencies in both ears. They had Malayalam as first language and English as second language at school. They were placed in a regular classroom and were between grades III and VII. They attended remedial education programme in the schools (specific resource rooms for learning disabled) during their free hours. The children with learning disability considered in the study had attended one year of remedial education programme. All children were right handed and had a full scale IQ of 90 or greater. The mean verbal IQ for the learning disabled group was 106.3 and the mean performance IQ was 90.6.

All the children who participated in the experiment were from upper and middle class families. Though the children exhibited average IQ on both verbal and performance tasks, all of them performed poorly on tests of academic skills which are depicted in table 3.6.

Subject details					IQ			Grade obtained on tests of academic skills					Total No.	
Age group	Subject No.	Age	Gender	Grade in which studying	Verbal	Perfor-mance	Full scale	Reading	Spelling	Writing	Reading compre-hension	Arith-metic	Boys	Girls
Below 10 yrs 7-8	S-l	7.9	F	III	110	87	99	I	>I	I	>I	>I	1	1
	S-2	8.o	M	III	97	82	90	>I	I	I	>I	I		
8-9	S-3	8.5	M	III	105	80	93	I	>I	I	>I	>I	2	2
	S-4	8.6	M	III	99	97	98	I	I	>I	I	II		
	S-5	8.10	F	IV	101	84	93	III	II	II	III	III		
	S-6	8.11	F	IV	106	99	103	III	II	I	II	III		
9-10	S-7	9.4	M	HI	115	94	105	I	>I	I	I	I	6	3
	S-8	9.9	M	V	112	88	100	III	II	I	II	I		
	S-9	9.6	M	V	121	92	107	II	II	I	I	III		
	S-10	9.7	M	IV	104	85	95	II	II	I	III	III		
	S-l 1	9.3	M	III	94	90	.92	II	II	I	I	III		
	S-12	9.9	M	IV	104	100	102	I	II	II	III	II		
	S-13	9.0	F	IV	109	98	104	II	II	I	II	II		
	S-14	9.0	F	IV	106	96	101	II	II	I	I	I		
	S-15	9.8	F	IV	108	76	92	II	III	I	III	II		

Subject details					IQ			Grade obtained on tests of academic skills					Total No.	
Age group	Subject No.	Age	Gender	Grade in which studying	Verbal	Perfor-mance	Full scale	Reading	Spelling	Writing	Reading compre-hension	Arith-metic	Boys	Girls
Above lOyrs 10-11	S-16	10.0	M	rv	110	95	103	III	II	II	III	III	4	1
	S-17	10.0	M	V	95	85	90	IV	III	I	II	IV		
	S-18	10.11	M	V	96	84	90	III	II	I	II	III		
	S-19	10.0	M	IV	119	88	104	III	II	II	III	III		
	S-20	10.7	F	V	105	97	101	III	II	II	III	II		
11-12	S-21	12.0	M	VII	110	89	100	III	IV	III	III	V	6	4
	S-22	11.4	M	V	118	99	109	III	II	I	I	II		
	S-23	11.4	M	VI	101	87	94	rv	III	III	IV	IV		
	S-24	11.5	M	V	99	93	96	I	II	III	IV	III		
	S-25	11.0	M	VI	114	78	96	IV	IV	III	III	IV		
	S-26	12.0	M	VII	109	97	103	III	rv	V	rv	V		
	S-27	11.6	F	VI	103	95	99	III	III	II	II	I		
	S-28	12.0	F	VII	98	89	94	V	rv	III	IV	III		
	S-29	12.0	F	VII	99	99	99	V	IV	III	VI	IV		
	S-30	12.0	F	VII	120	96	108	IV	II	III	IV	III		
				Mean	106.2	90.6	98.6						19	11

Table 3.6: Details of subjects with learning disability.

The subjects included in the normal control group were required to demonstrate normal performance on all the academic skills mentioned above. They had bilateral normal hearing sensitivity in the speech frequencies. They had Malayalam as first language and English as second language at school. All of them were attending a regular school and were between grades III and VII. They were right handed and were intellectually normal. Of the thirty normal children, fifteen were boys and fifteen were girls. Children in both the groups were divided into two subgroups - below 10 years (15 children) and above 10 years (15 children).

Procedure: Subjects were tested individually in a quiet room in their schools. The synthetic token pairs were audio-presented binaurally through earphones at comfortable listening levels and the child was instructed to judge them as same/different. This was done by placing two similar toys on one side of the child and two different toys on the other side. If the child perceived the token pair as same, he/she was instructed to point out to the similar looking toys and if he/she perceived them as different, he/she had to point to the different looking toys. Each child was initially conditioned to the stimulus by presenting practice tokens using live voice before proceeding to the test. After familiarizing them to practice items with live voice, 10 taped practice items were presented. The child's response was recorded on a forced-choice binary response sheet immediately after the response. Testing was done over five day's period with breaks between sessions. Adequate verbal and tangible reinforcements were provided to the children to encourage, maintain their attention and to elicit reliable responses. A total of 705 responses for each child and a total of 42,300 responses for all children were obtained.

Analysis: The data obtained was tabulated and the percent response for each stimuli for each child was calculated by the following formula.

$$\frac{\text{No. of same/different response for the stimuli}}{\text{Total no. of tokens}} \times 100$$

The percent same/different response was tabulated for each of the test stimuli. An identification curve was plotted. Fifty percent crossover was considered to indicate shift of percept from voiced to unvoiced (fig. 3.3).

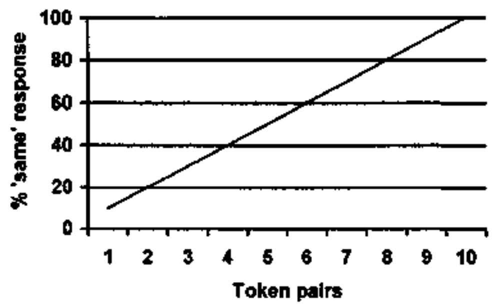

Fig. 3.3: Identification curve.

Just Noticeable Differences (JNDs) i.e. the smallest acoustic differences among the CV syllables, were measured in relation to the voiced stop consonants. The time duration at which the subject perceived the stimulus pairs as different was considered in each trial and this was averaged over the trials. For example, if the pairs were representing -60, -20; -60, -10; and -60, 0 (msec) and if the subjects response was 'same' for the first two pairs and 'different' for the third pair, the VOT difference between the two stimulus (-60 and 0) in the pairs i.e. 60 msec was considered as JND.

Statistical analysis: Using the SPSS software, the mean and standard deviation for JNDs were calculated for both groups in all the three places of articulation and two age groups. One-way ANOVA and post-hoc Duncan test were used to analyze the effects of group x age x sex, age x sex, group x age, and group x sex interaction.

Results

In general, while all the normal children could judge the token pairs as same or different, children with learning disability could not do so. Sixty nine percent of children with learning disability identified the token pairs as same/different. Table 3.7 shows the percentage of response by children with learning disability (LD) and normal children.

Place of articulation	% Response	
	LD group	Normal group
Velar	70.0	100
Dental	63.3	100
Bilabial	73.3	100
Average	68.8	100

Table 3.7: Percentage of children who identified token pairs as same/different.

JNDs in children with learning disability and normal children

The mean, SD and P values of JNDs and 50% crossover for the two groups on the three places of articulation are in table 3.8 and 3.9. T-test revealed a significant difference between children with learning disability and normal children on velar and dental place of articulation and no significant difference was observed for the bilabial place of articulation. Figure 3.4 shows JNDs in both the groups.

Place of articulation	Group	Mean	SD	Level of significance
Velar	LD N	23.26 1.65	16.96 7.43	.000
Dental	LD N	28.77 -0.66	20.34 8.29	.000
Bilabial	LD N	1.43 -5.43	17.45 8.29	.065
Average	LD N	17.82 -1.48		

Table 3.8: Mean (in msec), SD and P values of 50% crossover in children with learning disability (LD) and normal children (N).

Place of articulation	Group	Mean	Level of significance
Velar	LD N	83.26 61.65	.000
Dental	LD N	88.87 59.34	.000
Bilabial	LD N	61.43 54.57	.065
Average	LD N	77.85 58.52	

Table 3.9: Mean (in msec) and P values of JNDs for VOT in children with learning disability (LD) and normal children (N).

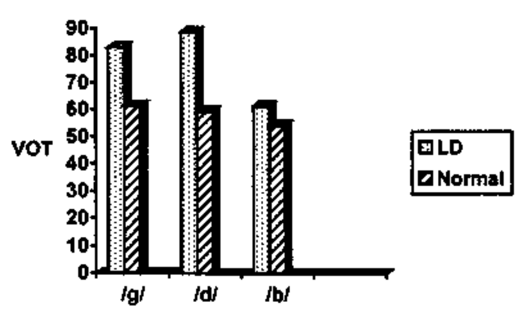

Fig. 3.4: Mean JND for VOT in children with learning disability (LD) and normal children (N).

It was observed that children with learning disability required longer VOT to shift their percept from voiced to unvoiced plosive. While normal children shifted their percept from voiced to unvoiced stop consonants at around -1.48 msec of VOT, children with learning disability shifted the percept at around +18 msec of VOT. Among the three places of articulation, normal children took longer VOT for the velar place of articulation followed by dental and bilabial place of articulation. However, children with learning disability took longer VOT for the dental place of articulation followed by the velar and bilabial.

The JNDs in children with learning disability (77.85 msec) were larger compared to normal children (58.52 msec). Among children with learning disability, JNDs were largest for dental place followed by velar and bilabial place of articulation. In normal children JNDs were largest for velar place followed by dental and bilabial place of articulation.

Effect of place of articulation on JNDs

Table 3.10 shows the result of one-way ANOVA and post hoc tests (Duncan) for the place differences. Significant differences between place of articulation for *Pol* vs. /g/, *Pol* vs. /d7 in both the groups were observed. However, there was no significant difference between /g/vs./d/.

A	LD group			Normal group		
	V	D	B	V	D	B
V		-	+		-	+
D	-		+	-		+
B	+	+		+	+	

Table 3.10: Significant difference between place of articulation for JND in children with learning disability and normal children (V-velar, D-dental, B-bilabial, + indicates significant difference, - indicates no significant difference).

Interaction between group, age and sex

A two-way ANOVA (age x sex) was performed on JNDs for both the groups. No effect of age and sex on JNDs for VOT was significant in normal children. However, the 2-way interaction of age vs. sex was significant for the bilabial place of articulation [F (1, 26) = 4.74, P = 0.039]. In the LD group, there was no effect of age and sex and age sex interaction on JNDs. However, females had longer JNDs than males.

Mean JND in two age groups of children and sex are shown separately in table 3.11 for both groups.

Place of articu-lation	LD group						Normal group					
	Below 10			Above 10			Below 10			Above 10		
	M	F	Avg.	M	F	Avg.	M	F	Avg.	M	F	Avg.
Velar	82.80	95.00	88.90	81.92	80.80	81.36	64.70	60.37	62.54	56.69	63.85	60.27
Dental	67.70	100.0	83.85	92.10	94.40	93.25	58.90	58.20	58.55	55.04	60.56	57.80
Bilabial	58.62	65.80	62.21	55.83	62.50	59.17	53.90	55.60	54.75	55.89	52.82	54.35
Average	69.70	86.93	78.31	76.61	79.23	77.92	59.17	58.06	58.61	55.87	59.08	57.47

Table 3.11: Mean JND (in msec) for VOT as a function of age and sex.

In general, normal children below 10 years of age had longer JND for all the three places of articulation compared to children above 10 years of age. JNDs were longest for velars followed by dentals and bilabials for both the age groups. Children with learning disability below 10 years of age had longer JND for velar and bilabial place of articulation compared to LD children above 10 years of age. While children with learning disability below 10 years had longer JND for velars followed by dentals and bilabials, those above 10 years of age had longer JND for dentals followed by velars and bilabials.

Discussion

The results revealed several points of interest. First of all, not all children with learning disability could judge the token pairs as same/different. Five out of thirty children with learning disability in the younger group (7-10 yrs) and three in the older group (10-12 yrs) were not able to discriminate the token pairs of /ba-pa/ continuum indicating a poor discrimination in children with learning disability. This is in consonance with the findings of Tallal & Stark (1981) who reported that the children with language impairment made more errors, required more trials to criterion and failed to reach criterion more often with the *Pol* vs. /d/ contrast, Elliott, Hammer & Scholl (1989) who reported that 18 of 138 children in the younger group (6-7 yrs) and 2 of 156 in the older group (8-11 yrs) with language-learning problems were not able to make any of the fine-grained auditory discrimination in the /ba-pa/ dontinuum and Steffens et al.;(1992) who reported that adult dyslexic subjects were less precise in speech identification and discrimination tasks. However, all the children demonstrated that they understood the concept of same and different.

Second, children with learning disability required longer VOT than normal children to discriminate the token pairs. This finding is in consonance with the study by Elliott et al., (1989) who reported that the language impaired children exhibited poorer JNDs than the normal children and Elliott & Hammer (1993) who reported 50% crossover of the younger group (6-8 yrs) with language-learning problems occurred at 23 msec and 17 msec for the control group, respectively. That is, these children required 35% longer VOT than the normal children to make the /ba/-/pa/ discrimination. In the present study, the JND for the younger children with learning disability occurred at 78.31 msec and at 58.61 msec for the normal group. That is, the children with learning disability required 33.68% longer VOT than normal children to make the auditory discrimination. Children with learning disability required 42%, 43%, and 14% longer VOT than normal children to make /ga-ka/, /da-ta/, and /ba-pa/ discrimination, respectively. This could be because of less sharp or blurred categorical boundaries in population with learning disability. Also children with learning disability may not necessarily use the acoustic cues in the same manner as the normal children.

However, the finding of the present study appears to diverge from the results of study by Brandt & Rosen (1980) and Godfrey, Syrdal-Lasky, Millay & Knox (1981) where they found that on both VOT continuum and the more highly abstracted place of articulation series, the dyslexic children labeled and discriminated the speech sounds (/ba/, /da/, /ga/) very much like normal reading children and adults. However, they reported that the performance at the /da/-/ga/ identification boundary was less steep for dyslexic subjects. A comparison of the 50% crossover points as obtained in various studies are in table 3.12.

Author/s	**Year**	**Language**	**50% crossover (msec)**
Yeni-Komshian, Preston & Cullen	1967	English	35
Lisker & Abramson	1967	Thai	-20 (approx)
Simon	1974	English	15-20
Zlatin & Koenigsknecht	1975	English	35
Williams	1977	English Spanish	English = +25 Spanish = -4
Williams	1980	English	>15 19(7-10yrs) 25 (adults)
Flege & Eefting	1986	English Spanish	English = 36.2 Spanish =19.9
Savithri, Pushpavathi & Sujatha	1995	Kannada	-16.8 (children) -10.66 (adults)
Sathya	1996	Telugu	-9.54 (children) -19.5 (adults)
Present study	2004	Malayalam	+18 (LD) -1.48 (normal children)

Table 3.12: 50% crossover values as obtained by various authors.

Williams (1977) speculated that Spanish listeners give greater weight to prevoicing as a cue to voicing than English listeners and greater weight to the presence of low frequency energy immediately following it, as cues to voicelessness. The findings of Williams (1977) show that the category boundary between *Pol* and /p/ occurred along a VOT continuum, occurred around -4 msec for Puerto-Ricans who were monolingual Spanish speakers suggesting that the phonetic processing of speech may be attuned to the acoustic properties of stops found in a particular language (Aslin & Pisoni, 1980). Flege & Eefting (1986) imply that cross language research suggests that the speakers of different languages may learn to perceive stops differently because they are exposed to different kinds of stop consonants. Further, English language environment listener tends to identify both *Pol* and /p/ as the prevoiced or voicing contrast is physiologically irrelevant in English. This contrast is perceived categorically in other languages for example Hindi, Spanish and Thai (Burnham, Earnshaw & Clarke, 1991). The results of the present study indicate that the JND occurred in the lead region is not in consonance with studies on English language for the same reason. While in English, a contrast between lead and lag VOTs are depicted, in 3-way category languages like Malayalam, it appears that the 50% crossover occurs in the lead VOT region. While in Malayalam, it occurred at around -1.5 msec, in Telugu it was around -10 msec and in Kannada it was around -17 msec. Aslin & Pisoni (1980) propose that the smaller incidence of discrimination of VOT differences in the minus region of voicing lead values is probably due to the generally poor ability of the auditory system to resolve temporal differences in which a lower frequency component precedes a higher frequency component (for voiced stops a lower frequency component voicing precedes a higher frequency component for burst release).

Aslin and Pisoni (1980) commenting on infant studies on VOT suggest that "the discrimination of the relative order between the onset of first formant and higher formants (Pisoni, 1977) is more highly discriminable at certain regions along the VOT continuum corresponding roughly to the location of the threshold for resolving these differences psychophysically. In the case of temporal order processing, this falls roughly near the region surrounding +/-20 msec, a value corresponding to the threshold for temporal order processing (Hirsh, 1959)."

Further commenting on Pisoni's (1977) experiment on TOT (Tone Onset Time), Aslin and Pisoni (1980) say that "two distinct regions of high discriminability are present in the discrimination functions. Evidence of discrimination of VOT contrasts that straddle the -20 and +20 msec regions of the stimulus continuum probably results from general sensory constraints on the mammalian auditory system to resolve small differences in temporal order and not from phonetic categorization."

This might be possible, as the differences obtained in the category boundaries for various languages varies from -4 to -20 msec (which is more than one stimulus, -10 msec, along the VOT continuum). In Telugu, this varied from -4 to -20 msec and from -14 to -19 msec in Kannada for various places of articulation and in Malayalam, it varied from -5 to +2 msec. All these variations are within +/- 20 msec.

Three views regarding the differences in perception of voicing contrast in various languages are held (Burnham, Earnshaw & Clarke, 1991): (1) Phonetic contrast in languages have evolved to take advantage of the natural psychoacoustic abilities inherent in the human auditory system rather than the other way round (Kuhl, 1978), (2) contrasts differ in their degree of robustness or perceptual salience and (3) the more perceptually salient a particular contrast, the more likely it is to have been favored in the evolution of world's languages. In

Malayalam, the contrast of voiced/unvoiced unaspirated is perceptually salient which is depicted in the result that JND is occurring in the lead region. It is possible that two category boundaries might be obtained if voiced unaspirated, unvoiced unaspirated and unvoiced aspirated are contrasted. However, the fact that 50% crossover occurred in the lag VOT region in children with learning disability suggests that they require longer VOTs to discriminate the voiced and unvoiced stop consonants.

JNDs for VOT were longest for velars in the normal group and shortest for bilabials in both the groups. This may be because the bilabials are easy to produce and are learnt first and velars have unique distributional properties and productive features (Bondorko, 1969; Kent & Moll, 1969). Sathya (1996) reported longest 50% crossover for velars and shortest for dentals in Telugu speaking normal children. However, the JNDs for VOT was longest for dentals in children with learning disability.

Third, significant differences between JNDs of bilabials versus velars and bilabials versus dentals were observed. However, no significant difference was found between the JNDs of velars and dentals in both the groups of children. This might be because of the differences in the VOT of bilabials (-60 to +40) and other place of articulation (-60 to +50 for velar and -60 to +60 for dental).

Fourth, there was no effect of age and sex and age sex interaction on JND. But JNDs in females (LD group) were longer than those in males (LD group) and this was more apparent in the younger age group. However, according to Steffens et al.,(1992), the dyslexic men tended to deviate more from the performance of the normal reading groups than the dyslexic women. Sathya (1996) reported in her study on Telugu speaking normal children that there was no effect of sex on 50% crossover but there was a significant effect of age on 50% crossover for all the four places of articulation.

Fifth, it was also observed that the normal children in the older group had shorter mean JND for all the three places of articulation than the younger group, but in children with learning disability, the mean JND of the older group was shorter only for bilabial and velar place of articulation. This result is in consonance with study by Elliott et al., 1981. A possible explanation is that the older group of children with learning disability would have learned to compensate for any difficulties in perceiving rapid spectral changes that they experienced as children. Yet another explanation could be that the younger children have poor auditory discrimination as they are in the process of acquiring some confidence in manipulating the adult phonological system and are still unsure and the older children have greater and more years of experience in listening to speech. Elliott et al., (1989) also pointed out that the younger group of children with language impairment may experience delayed maturation of the fine-grained auditory discrimination. The age related differences may reflect physiological maturation, continued development of neural pathways in the central auditory system, and continued maturation of the auditory cortex. The developmental refinement of acuity is supported by discrimination data collected by Elliott, Busse, Partridge, Rupert & DeGraff(1986).

It is also possible that the age difference could be due in part to differences in perceived speech rate. First, young children have a slower speech rate and more variable segment duration than adults (Smith, 1978; Kent & Forner, 1980; Smith, 1992). Longer and more variable durations have been specifically shown for the voicing parameters VOT (Zlatin & Koenigsknecht, 1976), word final closure duration and preceding vowel duration (Smith, 1978; Raphael, Dorman & Geffher, 1980; Lehman & Sharf, 1989), and word-medial closure duration (Smith, 1978; Kuijpers, 1993 a, b). Kuijpers showed that, mainly for Dutch unvoiced stops, 4 and 6 year olds have longer and more variable closure duration than 12 year old and adults (although speech rate was not solely responsible for these age differences). Second, speech rate has been shown to affect the location of the category boundary as well as the range of stimuli identified as members of a phonetic category (Miller, Green & Reeves, 1986; Miller & Volaitis, 1989). Although, it is not yet known whether perception of the voicing distinction by children is influenced by their speech rate, there could be a rate effect when children try to map the acoustic signal onto phonetic categories.

It is not clear as to why in the children with learning disability (the older group) had longer JND for dental place of articulation. Flege & Eefting (1986) attest this kind of difference to some unspecified change in peripheral or central auditory processing.

CHAPTER IV

Fine-grained auditory discrimination for Closure Duration

A word is dead

'When it is said

Some say.

I say it just

(Begins to five

That day

Emily (Dickinson
(from the -poems of'Emily (Dickinson,
Thomas. H.. Johnson, ed. Cam6ridge,
MA: The (Belnap (Press of Harward
"University)

Experiment II: Fine-grained auditory discrimination for closure duration

Introduction

Closure duration is the interval of stop closure indicating the time for which the articulators are held in position for a stop consonant. Fig. 4.1 depicts the closure duration for voiced and unvoiced stop consonants.

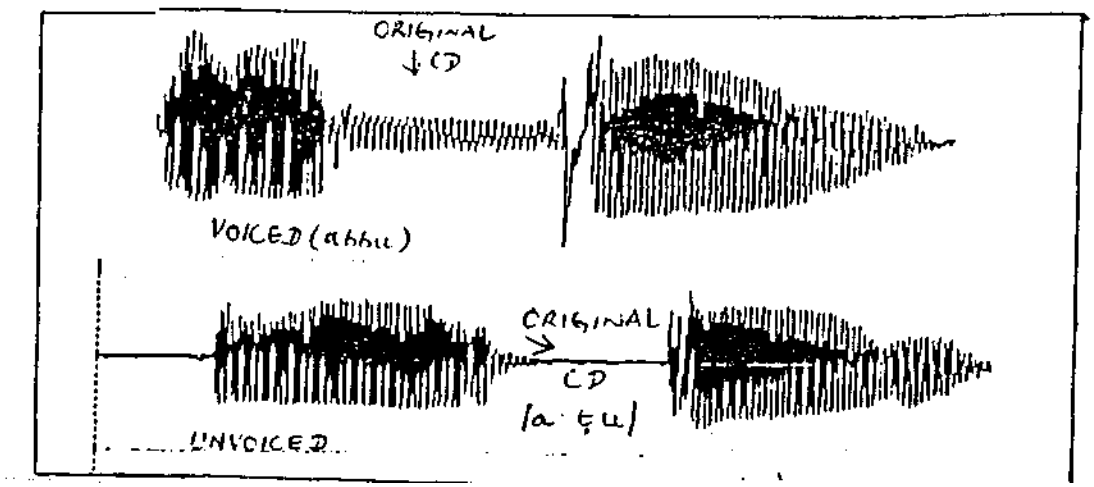

Fig. 4.1: Closure duration in voiced and unvoiced stop consonants.

There are a number of studies that have realized the importance of closure duration as an important cue to voicing in adults. In children, this cue has been dealt in single cue and multiple cue condition.

Allen & Norwood (1988) investigated the perception of intervocalic labial stops by English speaking 6-year olds and adults using the naturally produced words 'petal' vs. 'pedal'. The interaction of the three parameters VOT, closure duration and preceding vowel duration was investigated. They found that the shift from *I'd* to /d/ responses was the greatest for stimuli varying in VOT, followed by closure duration and preceding vowel duration. Moreover, VOT seemed to be a relatively stronger cue for children than for adults. With respect to the silent interval, pooled labeling responses to the stimuli showed that children and adults differed in the location of the phoneme boundary, the children's boundary being situated at approximately 110 msec and adults' at 130 msec.

Sathya (1992) studied closure duration as a cue to voicing of stop consonants (p, t, t, k) in 3-6 year old Kannada speaking children. A total of 81 synthetic stimuli varying in closure duration were presented to ten normal Kannada speaking children each in the age range of 3-4, 4-5 and 5-6 years. The results revealed that at short closure duration voiced percept was identified and at longer closure duration unvoiced percept was identified. As the age increased 50% crossover value reduced. Retroflex required shorter closure duration than velar, labial and dental. The results revealed that closure duration operated as a cue for voicing of word-medial stop consonants in children 3-6 years old.

Savithri, Pushpavathi & Sujatha (1995) found that closure duration (CD) was a cue for voicing of word-medial stop consonants in 4-7 year old children speaking Kannada. Six Kannada speaking normal children each in the age range of 4-5, 5-6 and 6-7 years participated in both speech production and speech perception tasks. For speech production task eight meaningful Kannada words consisting of [/k/, /t/, /t/, /p/, /g/, /d/, /d./,and /b/] in inter-vocalic position uttered five times by the subjects were analyzed for closure duration. The same subjects participated in the perception experiment. All the subjects responded to 570 synthetic tokens varying in closure duration. These synthetic tokens were prepared by truncating the closure duration of the unvoiced stop in 10 msec steps. The results of the experiment on speech production indicated that closure duration was longer for unvoiced stop consonants and that the category separation score was good for closure duration. In the perception task, closure duration was found to be an effective cue for voicing of word-medial stop consonants in Kannada language. Children reported voiced percepts at shorter closure durations.

Sathya (1996) investigated the development of auditory perceptual processing in 3 to 8 year old Telugu speaking normal children and adults. A total of 410 synthetic tokens with varying closure duration (CD) were used. The synthetic tokens of closure duration were generated by truncating the original closure duration in steps of 10 msec from the burst until the closure duration was almost removed. The results indicated that as the closure duration was truncated, there was a shift in the percept from unvoiced to voiced stop consonants in all the age groups. A developmental trend was also evident i.e. the 50% crossover linearly increased from 3-4 year old children (21.92 msec) to 7-8 year old children (44.59 msec). Adults perceived voiced stops at longer CDs. With respect to place of articulation, dental required the largest CD followed by retroflex, velar and bilabial. Thus the results suggested that closure duration was a prominent cue for word-medial stop voicing.

Kuijpers (1996) investigated the perception of medial voicing contrast by Dutch speaking children and adults. He examined their ability to categorize as voiced or unvoiced stimuli varying in closure duration (silent interval) by using a phoneme identification experiment. Four year olds, six year olds, twelve-year-old children and 31-year-old adults participated in the experiment. Two minimal pairs of bisyllabic pseudo words (nonsense words) were used for the experiment: Ta'ppi [tapi], Ta'bbi [tabi] and Pa'tto [pato], Pa'ddo [pado]. These naturally produced tokens were digitized on a digital micro VAX II computer using a 20 kHz sampling frequency with 12 bit quantization after low pass filtering. A speech editing system was used for manipulation of the tokens. Silent intervals ranging from 10 msec to 130 msec in 20 msec increments were inserted into each of the four words. This resulted in four, seven step continua. Pretest results showed that all children responded correctly to real word minimal pairs differing in stop voicing. Subsequently, subjects were tested on an identification task. The two older age groups consistently distinguished voiced and unvoiced stages i.e., the phoneme boundary width significantly decreased after the age of six. The younger children displayed a relatively high percentage of ambiguous responses, indicating that they had difficulties with the categorization of voiced and unvoiced stops i.e., they needed a relatively large difference in the silent interval to perceive a clear voicing distinction between voiced and unvoiced stops.

One study has been conducted in the clinical population by Steffens, Eilers, Gross-Glenn & Jallad (1992) who investigated speech perception (phonetic perceptual processing capabilities) in a carefully selected group of 36 adult subjects [18 (9 males and 9 females) with familial dyslexia and 18 normal readers]. Perception of three synthetic speech continua was studied: (1) */a/-/A/,* in which steady state spectral cues of the first three formants Fl, F2 and F3 distinguished the vowel stimuli. Fl decreased and F2 and F3 increased in frequency as the continuum stepped from /a/ to /a/*;* (2) /ba/-/da/ in which rapidly changing spectral cues (F2 and F3) were varied; (3) /sta/-/sa/, in which a temporal cue, silence duration was systematically varied. The perception of the consonant cluster /sta/ in step 1 resulted from 130 msec of silence inserted between the offset of/s/ and the onset of/a/. The silent interval was decreased in 10 equal steps till no silence occurred between the /s/ and /a/. These were generated on an IBM PC AT using Klatt's synthesis routines. These three continua, which differed with respect to the nature of the acoustic cues discriminating between pairs, were used to assess subjects' abilities to use steady state, dynamic and temporal cues. The subjects participated in one identification task and two discrimination tasks for each continuum. The identification task required the subjects to categorize the experimental stimuli (two repetitions of each stimulus separated by a 500 msec interval in reference to an end point stimulus. The first discrimination task (a same-different paradigm) required subjects to discriminate between all pairs of stimuli separated by three continuum steps (e.g.,stimuli 1 & 4, 2 & 5, etc). The second discrimination task (an ABX paradigm) required the subjects to match the X (or the third stimulus) with either the first (A) or the second stimuli (B) differing by three continua steps. ANOVA was used for the statistical analysis to study the three and two-way interaction. Results revealed systematic small differences in phonetic perception in the dyslexic subjects. The normal reading women and the dyslexic men identified more stimuli at continuum steps closer to the /A/ end point as /a/ than did the other two groups (normal reading males and dyslexic females). The dyslexic men were less accurate in labeling of the vowel stimuli. The dyslexic subjects identified more exemplars as /ba/ at the /da/ end of the continuum. The dyslexic readers required greater silence duration than normal readers to shift their perception from / *sa/* to /sta/. For all the groups the /ba/-/da/ continuum was the most difficult and the */a/-/A/* continuum was the least difficult. They concluded that although the dyslexic subjects were able to label and discriminate the synthetic speech continua, they did not necessarily use the acoustic cues in the same manner as normal readers i.e. they lack the precision demonstrated by normal readers in tests of identification and discrimination and their overall performance was generally less accurate.

There are limited studies on the perception of closure duration in children with learning disability. In this context, the present experiment aimed at investigating fine-grained auditory discrimination abilities for closure duration in Malayalam speaking children with learning disability.

Method

Stimuli: Four unvoiced stop consonants (velar /k/, retroflex /t./, dental /t/, and bilabial /p/) in the medial position of bisyllabic nonsense words were selected. Table 4.1 shows the words selected for experiment II.

Phoneme	Bisyllabic nonsense words
	Unvoiced
/k/	a:ka
/t/	a:ta
/t/	a:ta
/p/	a:pa

Table 4.1: Material selected for the experiment II. Phoneme underlined is the phoneme of interest.

These words were written, one each on a card. A 32 year old normal adult Malayalam female speaker was visually presented with one card at a time and was instructed to utter the word in a natural manner into a microphone kept at a distance of 10 cm from the mouth in a sound treated room. This was recorded through a data acquisition system and digitized onto a computer PC-AT 486 DX with a sampling rate of 16000 Hz and 12 bit resolution and stored in the computer memory. The digitized waveform was displayed on the screen of the computer and the closure duration was measured using the 'waveform display' for each of the stop consonant. Closure duration was measured as the time difference between the offset of the preceding vowel and the onset of the burst.

Edited tokens of closure duration were generated using the waveform editing procedure. The original closure duration of the unvoiced stop consonant was truncated in steps of 10 msec from the burst end till the closure duration was almost removed. The details of the original and edited stimuli are in table 4.2.

CD stimulus	/k/	/t/	/t/	/p/
Original TO	130	80	100	120
Tl	120	70	90	110
T2	110	60	80	100
T3	100	50	70	90
T4	90	40	60	80
T5	80	30	50	70
T6	70	20	40	60
T7	60	10	30	50
T8	50	0	20	40
T9	40	-	10	30
T10	30		0	20
Til	20		_	10
T12	10		_	0
T13	0	-		
No. of iterations	03	03	03	03

Table 4.2: Closure duration (CD) for the edited tokens (in msec).

Each word with its edited token was considered as a test and within each of the four tests the tokens were paired with another using the A-B design and iterated three times. The token pairing was done as in experiment I.

These edited token pairs with truncated closure duration in four places of articulation were then audio-recorded on metallic cassettes with an inter-token interval of 2 sec and inter-pair interval of 5 sec using the 'play bat' program. Ten practice items were also recorded preceding the experimental stimuli. Thus, a total of 921 token pairs (315 for /k-g/, 135for/t-d/, 198 for /t-d/, and 273 for /p-b/) formed the test material. An example of original closure duration and truncated closure duration is in figure 4.2.

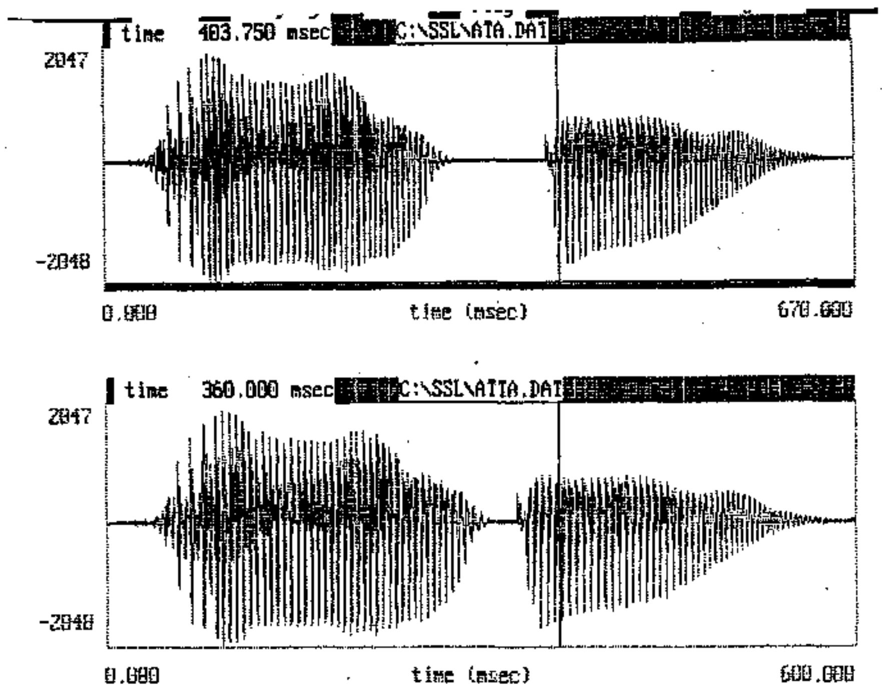

Fig. 4.2: Waveform depicting word with original and truncated closure duration.

The subjects, procedure and analysis were the same as in experiment I.

Results

In general, while all the normal children performed the task, only 67 percent of children with learning disability could differentiate the token pairs as same/different. Table 4.3 shows the percent response in both the groups.

Place of articulation	% Response	
	LD group	Normal group
Velar	43.3	100
Retroflex	93.3	100
Dental	60	100
Bilabial	70	100
Average	66.6	100

Table 4.3: Percentage of children who identified token pairs as same/different.

JNDs in children with learning disability and normal children

The mean and SD values of JND for the two groups on the four places of articulation are in table 4.4. T-test revealed no significant difference between children with learning disability and normal children in three places of articulation, viz., velar, retroflex and dental. A significant difference between the groups was found on the bilabial place of articulation. Figure 4.3 shows the JNDs for both the groups.

Place of articulation	Group	Mean	SD	Level of significance
Velar	LD	77.44	4.79	.33
	Normal	78.62	3.02	
Retroflex	LD	72.27	14.57	.14
	Normal	76.66	5.12	
Dental	LD	75.57	6.33	.08
	Normal	77.96	3.22	
Bilabial	LD	73.98	9.35	.017
	Normal	78.46	2.82	
Average	LD	74.82		
	Normal	77.98		

Table 4.4: Mean (in msec), SD and P values of JND for CD in children with learning disability (LD) and normal children (N).

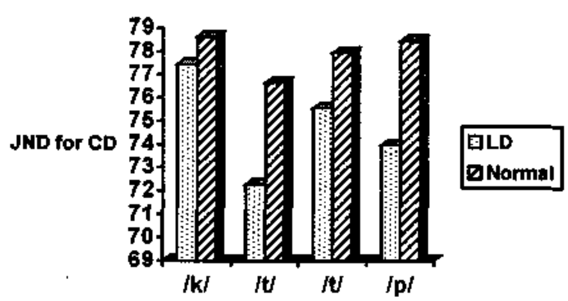

Fig. 4.3: Mean JND for CD in children with learning disability (LD) and normal children (N).

It was observed that children with learning disability shifted their percept from voiceless to voiced stop consonants at longer closure durations compared to normal children. That is the JNDs in children with learning disability were shorter compared to normal children. While the JND in normal children was 77.98 msec, that in children with learning disability was 74.82 msec. However, there was no significant difference between the JNDs of two groups of children. The difference in JND was most evident for bilabial place of articulation and least evident for velar place of articulation. The JND was shortest for the retroflex place of articulation and longest for the velar place of articulation in both the groups.

Effect of place of articulation on JNDs

Table 4.5 shows the results of one-way ANOVA and post hoc tests (Duncan) for place differences. No significant differences were observed between places of articulation in either group.

	LD group				Normal group			
	V	R	D	B	V	R	D	B
V		-	-	-		-	-	-
R	-		-	-	-		-	-
D	-	-	-	-	-	-	-	-
B	-	-	-		-	-	-	

Table 4.5: Significant difference between place of articulation for JND in children with learning disability and normal children (V-velar, R-retroflex, D-dental, B-bilabial, - indicates no significant difference).

JND was shortest for retroflex in both the groups i.e., the percept shifted from unvoiced to voiced stop consonant earliest for retroflex. This was followed by dentals, bilabials and velars in normal children and bilabials, dentals and velars in children with learning disability.

Interaction between group, age and sex

A two-way ANOVA (age x sex) was performed on JND for both the groups. No effect of age, sex and age vs. sex on JND for closure duration was found in any group. The mean JND for the two age groups of children and sex are shown in table 4.6.

Place of articu-lation	LD group						Normal group					
	Below 10			Above 10			Below 10			Above 10		
	M	F	Avg.	M	F	Avg.	M	F	Avg.	M	F	Avg.
Velar	78.35	75.0	76.68	77.00	78.75	77.88	79.27	78.53	78.90	77.30	79.20	78.25
Retroflex	67.50	70.0	68.75	74.35	78.00	76.18	76.30	77.80	77.05	75.57	75.94	75.76
Dental	76.67	75.0	75.80	75.02	76.25	75.64	78.53	78.54	78.54	77.52	76.70	77.11
Bilabial	71.00	71.7	71.40	77.23	72.02	74.63	78.90	78.35	78.63	80.00	76.40	78.20
Average	73.38	72.9	73.14	75.90	76.26	76.08	78.25	78.31	78.28	77.60	77.06	77.33

Table 4.6: Mean JND (in msec) for CD as a function of age and sex.

In general, in normal children above 10 years, JND for all the four places of articulation was shorter compared to those in normal children below 10 years of age. This was shortest for retroflex followed by dentals, velars and bilabials. Normal children below 10 years of age had shortest JND for retroflex followed by dentals, bilabials and velars. Children with learning disability below 10 years of age had shorter JNDs for all places of articulation except dentals compared to those in children with learning disability above 10 years of age. Children with learning disability below 10 years of age had shortest JND for retroflex followed by bilabials, dentals and velars, while children with learning disability above 10 years of age had shortest JND for bilabials followed by dentals, retroflex and velars.

Discussion

The results revealed several points of interest. First of all, not all children with learning disability could judge the token pairs as same/different. Only 67% of children with learning disability on an average could make the discrimination. Thirty three percent of children with learning disability did not judge the token pairs, indicating poor discrimination in children with learning disability.

Second, there was a significant difference between children with learning disability and normal children only on JND of bilabial place of articulation. It was interesting to note that JNDs were shorter in children with learning disability compared to normal children. However, this was not significant. Children with learning disability shifted their percept from voiceless to voiced stop consonants at longer closure durations (earlier) compared to normal children. Also, compared to the results of other studies both normal children and children with learning disability shifted their percept from voiceless to voiced stop consonants at longer closure durations (12 msec and 15 msec). This is in contrast with the results of Savithri et al. (1995 - 33 msec). This difference may reflect language differences. While in Kannada voicing contrast for stop consonants exists in medial position, in Malayalam, the contrast is only between voiced and weekly voiced (in the' word-medial position). The unvoiced stops are always geminated. Hence, children might have perceived a weekly voiced stop consonant.

Third, JNDs differed with place of articulation of the stop consonant. JND was longer for velars, and shorter for retroflex and dentals in both the groups. This is in consonance with Sathya (1996) where she found the shift in percept at longer closure duration for retroflex and dentals in Telugu speaking normal children. This could be because the retroflex had the shortest duration of closure. Sharf (1962), Dorman, Raphael, Liberman & Repp (1975), Port (1976), Fischer-Jorgensen (1979), Port (1979) and Repp (1984) opine that if closure duration is a major cue to intervocalic stops, it might also serve as a distinctive cue to a particular place of articulation. However, no significant difference between the JNDs of different places of articulation was observed.

Fourth, no effect of age, sex and age vs. sex on JND of closure duration was found in either of the groups. Sathya (1996) reported no significant effect of sex on any place of articulation on 50% crossover but found a significant effect of age on all four places of articulation. Also, no significant age and sex interaction effect was found in her study.

Normal children above 10 years had shorter JNDs for all the places of articulation compared to those above 10 years of age. However children with learning disability below 10 years of age had shorter JNDs for all the places of articulation, except dentals, compared to children with learning disability above 10 years of age. But this difference in JND was not significant. The results on normal children is in consonance with the findings by Sathya (1996) where she found an increase in 50% crossover with an increase in age in normal Telugu speaking children. The temporal shift observed that is longer 50% crossover in children might indicate a developmental trend and this shift in time has also been reported in the elderly in a few studies conducted (Price & Simon, 1984; Dorman, Murton, Hannley & Lindholm, 1985). Similar developmental trends have been observed in Kannada by Sathya (1992) and Sujatha, Rajendraswamy & Savithri (1994). Shorter JNDs in children with learning disability below 10 years may indicate irregular development in such children.

To summarize, children with learning disability indicated poor fine-grained auditory discrimination for closure duration. However, when they discriminated, they had shorter JNDs compared to normal children, though not significantly.

CHAPTER V

Fine-grained auditory discrimination for Closure Duration and Transition Duration

"If a problem is too complex to be solved all at once, then break it up into problems that are small enough to be solved separately"

- Advice from a philosopher, Rene Descartes

Experiment III: Fine-grained auditory discrimination for multiple acoustic cues (Closure duration + transition duration)

Introduction

The acoustic features that bear information on the identity of phonetic segments are commonly called "cues" to speech perception. These cues do not typically have one to one relationship with phonetic distinctions. Indeed, research usually shows more than one cue to be pertinent to a distinction, although all such cues may not be equally important. Thus, if two cues, x and y are relevant for a distinction, it may turn out that for any value x, a variation of y will effect a significant shift in listener's phonetic judgements, but there will be some values for which varying x will have negligible effect on phonetic judgements. We say then y is the more powerful cue.

The perception of most, if not all, phonetic distinctions are sensitive to multiple acoustic cues. That is, there are several distinct aspects of the acoustic speech signal that enable listeners to distinguish between, for e.g., a voiced and an unvoiced stop consonant, or between a fricative and an affricate. Although some cues are more important than others for a given distinction, listeners can usually be shown to be sensitive to even the less important cues when the primary cues are removed or set at ambiguous values. All cues, that are relevant to a given phonetic contrast, seem to carry information for listeners.

Whenever, several distinct acoustic cues provide listeners with functionally equivalent information about a single phonetic category contrast, then perceptual "trading relations" can be demonstrated. That is, strengthening the value of one cue can offset the weakening of another in listener's perception of the specific phonetic contrast. The relevance of a cue can be predicted from comparisons of typical utterances exemplifying the phonetic contrast of interest. Any acoustic property that systematically co-varies with a phonetic distinction may be considered a relevant cue for that distinction and may be expected to have a perceptual effect when the conditions are appropriate.

In many recent speech perception experiments several acoustic cue dimensions have been varied simultaneously. Provided the cues are adjusted so that each has an opportunity to influence the perception of the relevant phonetic distinction, it can easily be demonstrated that a little more of one cue can be traded against a little less of another cue, without changing the phonetic percept. This is called a phonetic trading relation. Phonetic trading relations are ubiquitous phenomena. Whenever two acoustic cues contribute to the same phonetic distinction, they can also be traded against each other, within a certain range. Thus, these trading relations are a manifestation of a more general principle of cue integration. In phonetic perception, the information conveyed by a variety of acoustic cues is integrated and combined to a unitary perceptual experience.

When the two acoustic parameters cue the same feature i.e., of voicing, place or manner then the two cues are said to be in cooperating condition. While on the other hand, when one of the parameter cues one feature say voicing and another cues place, then the cues are conflicting.

In the developmental literature on speech perception, there are several reports that children differ from adults in their responses to variations in single acoustic cues for phonetic contrast. While these differences between children's and adult's phonetic perception, as based on single acoustic cues, are interesting, evidence is accumulating in the adult speech perception literature, that multiple acoustic cues often interact to specify a single phonetic contrast.

It is known from many previous studies that virtually every phonetic contrast is cued by several distinct acoustic properties of the speech signal. It follows that, within limits set by the relative perceptual weights and by the ranges of effectiveness of these cues, a change in the setting of one cue (which, by itself would have led to a change in the phonetic percept) can be offset by an opposed change in the setting of another cue so as to maintain the original phonetic percept. According to Fitch, Halwes, Erickson & Liberman (1980) there is a phonetic equivalence between two cues with each other. Mann & Repp (1980) on the other hand maintain a distinction between phonetic trading and context effects.

The fact that there are multiple cues for most phonetic contrasts has been known for a long time. Extensive explorations at Haskins Lab (Delattre, Liberman, Cooper & Gerstman, 1952; Harris, Hoffman, Liberman, Delattre & Cooper, 1958) showed two formants, 2^{nd} and 3^{rd} contribute to place cue for stop. Lisker (1978 b), drawing on observations collected over a number of years, listed no less than 16 distinguishable cues to /b/ - /p/ distinction in intervocalic position.

From these and many other studies, a nearly complete list of cues has been accumulated over the years. However, the data were typically collected by varying one cue at a time, except Hoffman's (1958) study in which data was collected by varying three cues to stop place of articulation simultaneously. The stress on totality of cue was laid by Stevens & Blumstein (1978), Blumstein & Stevens (1980) where shape of total short term spectrum was critical perceptual cue.

Bailey & Summerfield (1980) have criticized and denied altogether the usefulness of fractioning the speech signal into cues. In adults, most studies on multiple cues have been done using synthetic speech, some obtained information by cross-splicing components of natural utterances or by combining such components with synthetic stimulus portions.

Cues to stop manner of articulation (i.e. presence vs. absence of a stop consonant) following a fricative and preceding a vowel were investigated by Bailey & Summerfield (1980), Fitch, Halwes, Erickson & Liberman (1980) and Best, Morrongiello & Robson (1981). In each case, the trading relation studied was that between closure duration and formant onset frequencies in the vocalic portion. Summerfield, Bailey, Seton & Dorman (1981) have shown that duration and amplitude contour of the fricative noise preceding the silent closure also contributes to the stop manner contrast. Gerstman (1957), Repp, Liberman, Eccardt & Pesitsby (1978), Dorman, Raphael & Liberman (1979), Van Heuvan (1979) and Dorman, Raphael & Isenberg (1980), studied four-way distinction between fricative-affricate and stop manners using several cues.

Explanation of trading relations on phonetic or auditory cues is still a controversy as revealed by the experiments of Cutting, (1974), Bailey, Summerfield & Dorman (1977), Fitch, Halwes, Erickson & Liberman (1980), Best Morrongiello & Robson (1981), Pastore (1981) and Remez, Rubin, Pisoni & Carrell (1981). Context effects due to immediate phonetic context e.g.j vowel following and preceding have been demonstrated by Summerfield (1975), Summerfield & Haggard (1974, 1977).

Miller, Wier, Pastore, Kelly & Dooling (1976), Pisoni (1977) & Pastore (1981) reported a failure to find equivalent effects of two different variables on VOT category boundaries. An effect of vocalic context on perception of stop place has been investigated by Hasegawa (1976), Bailey et al., (1977), Kunisaki & Fujisaki (1977), Mann & Repp (1980) and Whalen (1981). In a series of experiments by Mann and Repp (1980, 1981 a), Repp & Mann (1981 a, 1981 b) and Repp (1982, 1983, 1983 b, 1984), several effects of context on the perception of stop consonants have been discovered.

For stop consonants in intervocalic position, Lisker (1978 b) has catalogued all the different aspects of the acoustic signal that contribute to the voicing distinction. They include the duration and offset characteristics of the preceding vocalic portion, the duration of the closure interval, the amplitude of voicing during closure, and the onset characteristics of the following vocalic portion (Lisker, 1957, 1978 a, 1978 b; Lisker & Price, 1979; Price & Lisker, 1979). Trading relations between voicing cues for intervocalic stops have been studied in French (Serniclaes, 1974) and in German (Kohler, 1979).

Revoile, Pickett, Holden & Talkin (1982) and Revoile, Pickett, Holden-Pitt, Talkin & Brandt (1987) studied multiple cues of adjusted vowel duration, transition switched and transition deleted in order to find the relative saliency of different acoustic cues. Vowel length minimally affected voicing perception. Switching vowel transitions resulted in listeners perceiving the voicing characteristics of the following stop to be that of the stop in the syllable in which the vowel transition was produced. Deletion of vowel transition impaired the overall identification of voicing in the following stop.

Robson, Morrongiello, Best & Clifton (1982) extended their investigation to children's speech perception. By using the same stimuli as in Best et al., (1981) - "say" - "stay" contrast - systematically manipulated two acoustic cues that specify the presence/ absence of the alveolar stop following the word initial /s/, Fl onset frequency and duration of the silent closure. Five-year-old children were tested for perceptual trading between the same temporal cue (silence duration and a spectral cue - Fl onset frequency) for the say/stay distinction. Alternately, if children attend primarily to the acoustic properties of the stimuli, one would expect that they would fail to integrate perceptually the temporal and spectral cues as information about a unified phonetic category. In that case, they would hear the auditory difference between differently cued stimuli even within a phonetic category and would thereby discriminate the conflicting cue contrasts as well as they discriminate cooperating cue contrast. Children showed a smaller trading relation than that had been found with adults. They did not differ from adults, however, in their perception of an 'ay-day' continuum formed by varying Fl onset frequency only. In adults, the averaging trading relation obtained from listener's identification performance was evident in a "say"-"stay" boundary shift of 24.6 msec. In other words, in order to be perceived as "stay", a stimulus with a high Fl onset frequency (430 Hz) required approximately 25 msec additional silence between the *Is/* and the vocalic portion than did a stimulus token having a low Fl onset frequency (230 Hz). The cues made to "cooperate" or "conflict" phonetically supported the notion of perceptual equivalence of the temporal and spectral cues along a single phonetic dimension. The results indicated that young children, like adults, perceptually integrate multiple cues to a speech contrast in a phonetically relevant manner, but they may not give the same perceptual weights to the various cues as do adults.

Robson et al. proposed that the children may have weighted the transitional information relatively more heavily and the temporal information relatively less heavily than adults do i.e., perhaps the children were more sensitive to transitional cues than adults - a possibility encouraged by the finding that any transition even a brief one was sufficient to elicit some "stay" responses from the children. This suggestion provides a possible outcome that children would prove even more sensitive to some kinds of coarticulatory effects than adults.

Sathya (1996) investigated the development of auditory perceptual processing using the cue closure duration (CD) and transition duration (TD) in 3-8 year old Telugu speaking normal children and adults. Four unvoiced stop consonants in the word-medial position (unvoiced velar /k/, unvoiced retroflex /t./, unvoiced dental /t/ and unvoiced bilabial /p/) were selected for this experiment. The synthetic tokens of CD+TD were generated by substituting the transition duration (TD) of the vowel preceding the unvoiced stop with that preceding the voiced stop using the VSS-SSL software. The CD was truncated in 10 msec steps. The results revealed a developmental trend in that the 50% cross over increased from 3-4 year old children (26.41 msec) to 7-8 year old children (41.71 msec). With respect to place of articulation, 50% cross over was longest for bilabial and shortest for retroflex. Further, on comparison between the single cues and multiple cues, it was found that in the multiple cue condition, with the TD, the shift in percept from unvoiced to voiced occurred at shorter CD when compared to single cue condition in children and adults.

Savithri, Swapna & Rajeev (1996) studied the development of perception using the cue CD+TD in six Kannada speaking normal children in the age range of 4-7 years and six adults. Four unvoiced stop consonants in the medial position (velar /k/,, retroflex /t/, dental /t*l* and bilabial /p/) were selected for this experiment. The synthetic tokens of CD+TD were generated by substituting the transition duration (TD) of the vowel preceding the unvoiced stop with that preceding the voiced stop using the VSS-SSL software. The CD was truncated in 10 msec steps. The results revealed that the 50% cross over increased from the age of four years to seven years and further in adults for velars and dentals showing clear developmental trend, but this trend was not observed for retroflexes and bilabials. Among the place of articulation, retroflex exhibited longer 50% cross over in 4-5, 5-6 years and adults and velar exhibited the shortest.

One study has been conducted in the clinical population by Bradlow, Kraus, Nicol, McGee, Cunningham, Zecker & Carrell (1999) who investigated the precise acoustic feature of stop consonants that pose perceptual difficulties for some children with learning problems. The discrimination thresholds (JND) along two separate synthetic /da-ga/ continua were compared on a fine-grained auditory discrimination task in a group of children with learning problems (11 children with learning disability, 41 with attention deficit disorder and 7 with both) and a group of normal children aged 6-16 years. Two /da-ga/ place of articulation continua were created using the Klatt cascade-parallel formant synthesizer (Klatt, 1980). In the first continua, the length of the formant transition duration was 40 msec and in the second continua, it was increased to 80 msec. A control condition /ba-wa/ (a stop-glide continuum) was also created. Results indicated that the discrimination thresholds were elevated in the children with learning problems in the /da-ga/ continua at both 40 and 80 msec transition duration. There was no significant difference between both the groups in the /ba-wa/ continua. Thus lengthening the formant transition duration from 40 to 80 msec did not result in improved discrimination thresholds for the group of children with learning problems. An electrophysiological response that is known to reflect the brains representation of a change from one auditory stimulus to another - the Mismatch Negativity (MMN) - was recorded which indicated diminished responses in the group of children with learning problems to /da/ vs. /ga/ when the transition duration was 40 msec. In the lengthened transition duration condition, the MMN responses from both the groups were similar and were enhanced relative to the short transition duration condition. These data suggest that extending the duration of the critical portion of the acoustic stimulus can result in enhanced encoding at a pre attentive neural level; however, this stimulus manipulation on its own is not a sufficient acoustic enhancement to facilitate increased perceptual discrimination of this place-of-articulation contrast. Taken together, these behavioral and neurophysiologic data suggest that the source of the underlying perceptual deficit may be a combination of faulty stimulus representation at the neural level as well as deficient perception at an acoustic-phonetic level, which suggest a 'biological basis' for the impaired behavioral perception.

Particularly, as studies on multiple cues in children with learning disability are lacking, experiment III was planned to investigate the fine-grained auditory discrimination in Malayalam speaking children with learning disability for multiple acoustic cues.

Method

The experiment involved the multiple acoustic cues i.e. the presence of several distinct aspects of the acoustic speech signal that enables listeners to distinguish between a voiced and an unvoiced stop.

Stimuli: The material was the same as in experiment II. In addition to those words with unvoiced consonants, the nonsense words having the voiced cognate pair of the stops i.e., voiced velar /g/ (a : ga), voiced bilabial *Pol* (a : ba), voiced dental /d/ (a : da), and voiced retroflex /d/ (a : da) were acquired in the same manner. The original closure duration was measured using the waveform display of VSS-SSL for each of the stop consonants. The words were spectrographically analyzed to extract the spectral and source parameters. Transition duration of F2 of the plosive in the medial position was measured from the spectrograph. Transition duration was measured as the time difference between the offset of F2 steady - state of the vowel to the offset of F2 of the vowel preceding the stop consonant. Using the waveform editor, the vowel-consonant transitions (from the waveform) preceding the unvoiced plosive were truncated and the scaled transitions of the voiced counterpart (measured in the same manner) were concatenated in their place. The closure duration was then, truncated in 10 msec steps till the closure duration was almost zero. The details of the original and edited stimuli are given in table 5.1.

CD+TD stimulus	/k/	**/t/**	/t/	/p/
Original TO	130	-80	100	120
Tl	120	70	90	110
T2	110	60	80	100
T3	100	50	70	90
T4	90	40	60	80
T5	80	30	50	70
T6	70	20	40	60
T7	60	10	30	50
T8	50	0	20	40
T9	40	-	10	30
T10	30	-	0	20
Til	20	-	-	10
T12	10	-	-	0
T13	0	-	-	-
No. of iterations	03	03	03	03

Table 5.1: Edited tokens for CD+TD.

Each word with its edited tokens was considered as a test and within each of the four tests, the tokens were paired with another using the A-B design and iterated three times as in the previous experiments. These computer edited tokens with altered CD+TD in four places of articulation were then audio-recorded on metallic cassettes with an inter-token interval of 2 sec and inter-pair interval of 5 sec using the 'playbat' programme. Ten practice items were also recorded preceding the experimental stimuli.

Considering four places of articulation and three iterations, the total number of token pairs were 921 (315 for /k - g/, 135 for /t. - d./, 198 for /t - d/, and 273 for /p - b/) which served as the test stimuli. An example of original stimuli and edited stimuli with closure duration truncated and transition duration substituted is shown in figure 5.1.

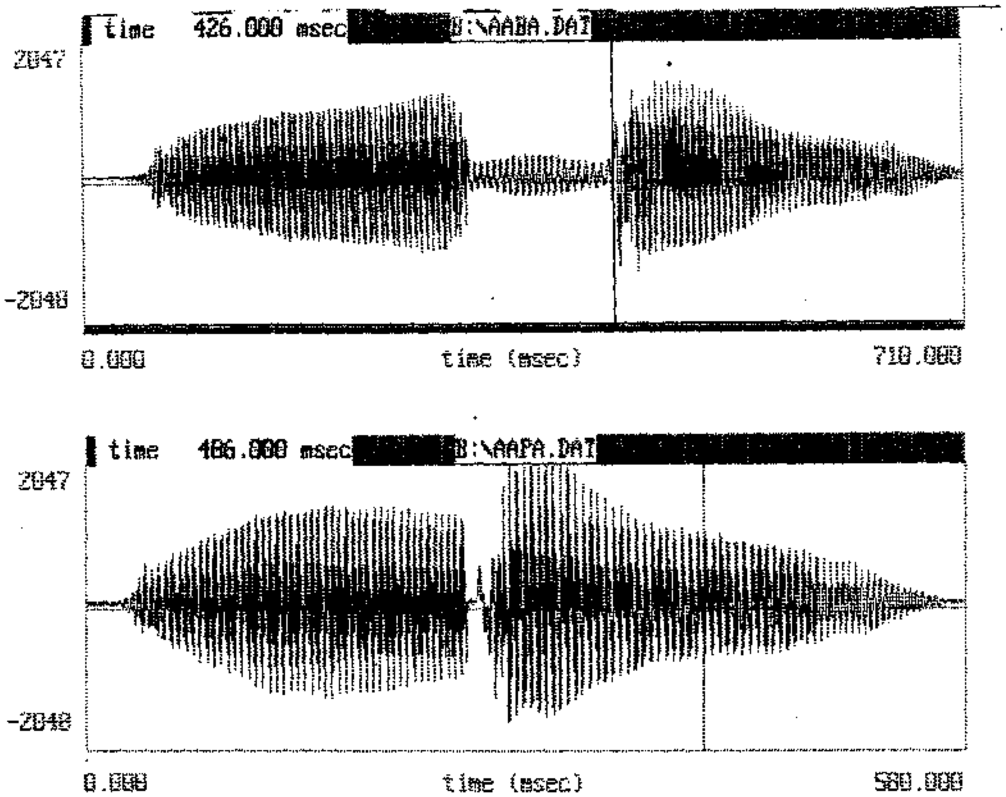

Fig. 5.1: Waveform of a word with original CD and CD + TD condition.

The subjects, procedure and analysis were the same as mentioned in experiment I.

Results

In general, while all the normal children performed the task, only 87 percent of children with learning disability could differentiate the token pairs as same/different. Table 5.2 shows the percent response in both the groups.

Place of articulation	% Response	
	LD group	Normal group
Velar	90	100
Retroflex	83.3	100
Dental	90	100
Bilabial	83.3	100
Average	86.6	100

Table 5.2: Percentage of children who identified token pairs as same/different.

JNDs in children with learning disability and normal children

The mean and SD values of JND for the two groups on the four places of articulation are in table 5.3. T-test revealed significant differences between children with learning disability and normal children on all four places of articulation.

Place of articulation	Group	Mean	SD	Level of significance
Velar	LD	42.49	21.29	0.000
	Normal	79.04	14.91	
Retroflex	LD	27.95	14.78	0.011
	Normal	36.08	7.38	
Dental	LD	34.35	17.27	0.006
	Normal	47.25	16.59	
Bilabial	LD	45.29	18.14	0.000
	Normal	68.03	12.83	
Average	LD	37.52		
	Normal	57.60		

Table 5.3: Mean (in msec), SD and P values of JND for CD+TD in children with learning disability (LD) and normal children (N).

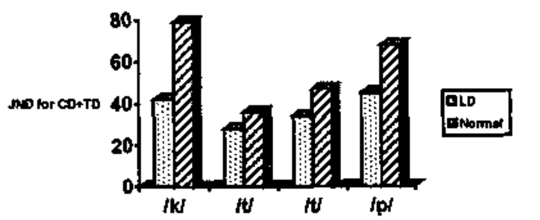

Figure 5.2: Mean JND for CD+TD in children with learning disability (LD) and normal children (N).

It was observed that children with learning disability shifted their perception from unvoiced to voiced stops earlier compared to normal children. That is the JNDs were shorter in children with learning disability. While in normal children JND was 57.6 msec, in children with learning disability, it was 37.52 msec. In the multiple cue condition, the shift in the percept was advanced by 37 and 20 msec in children with learning disability and normal children, respectively. Significant differences between JNDs of children with learning disability and normal children were found for velar and bilabial place of articulation. The JND was most evident for velar place of articulation and least evident for retroflex place of articulation. Children with learning disability and normal children had longer JND for bilabial and velar place of articulation, respectively.

Effect of place of articulation on JNDs

Table 5.4 shows the results of one-way ANOVA and post hoc tests (Duncan) for the place differences. Significant differences between place of articulation /t/ vs./k/,*/t/* vs. /p/, and *IXJ* vs. /t/ were observed in normal children. In children with learning disability, significant differences between place of articulation /t/ vs. /t/, */t/* vs. /k/, /t/ vs. /k/, */t/* vs. /p/, and /p/ vs. /k/ were observed.

	LD group				Normal group			
	V	R	D	B	V	R	**D**	B
V		+	+	+		+	-	-
R	+		+	+	+		+	+
D	+	+		-	-	+		-
B	+	+	-		-	+	-	

Table 5.4: Significant difference between place of articulation for JND in children with learning disability and normal children (V-velar, R-retroflex, D-dental, B-bilabial, + indicates significant difference, - indicates no significant difference).

JND was longer for bilabials in children with learning disability and for velars in normal children. This was followed by velars, dentals and retroflex in children with learning disability and bilabial, dental and retroflex in normal children.

Interaction between group, age and sex

A two-way ANOVA (age x sex) was performed on JND for both the groups. No effect of age and sex and 2-way interaction of age vs. sex on JND for CD+TD was significant in normal children. In children with learning disability, no effect of age, sex and age sex interaction on JND was significant except for the effect of sex on JND for the velar place of articulation which was significant [F (1, 23) = 5.412, P= .029)]. The mean JND for the two age groups of children and sex are shown separately in table 5.5 for both groups.

Place of articu-lation	LD group						Normal group					
	Below 10			Above 10			Below 10		Above 10			
	M	F	Avg.	M	F	Avg.	M	F	Avg.	M	F	Avg.
Velar	28.1	50.40	39.25	41.60	56.70	49.15	73.75	80.78	77.27	88.35	75.1	81.73
Retroflex	27.3	20.00	23.65	29.30	34.20	31.75	37.99	34.84	36.42	38.92	32.3	35.61
Dental	27.0	31.10	29.05	35.70	45.36	40.53	49.00	48.60	48.80	56.70	43.4	45.00
Bilabial	44.8	41.36	43.08	48.14	45.40	46.73	67.90	69.70	68.80	71.20	62.8	67.00
Average	31.8	35.72	33.76	38.69	45.42	42.05	57.16	58.48	57.82	63.79	53.4	58.60

Table 5.5: Mean JND (in msec) for CD+TD as a function of age and sex.

In general, children with learning disability and normal children below 10 years had shorter JNDs than those above 10 years. In children with learning disability below 10 years, JND was shortest for retro flex followed by dental, velar and bilabial. In all the other groups, JND was shortest for retroflex followed by dental, bilabial and velar.

Difference between single and multiple cues

T-test revealed a significant difference between the single and multiple cue condition on all the four places of articulation in normal children and children with learning disability. Table 5.6 depicts the mean, SD, and significant differences for both the groups of children.

	LD group			Normal group		
	Mean	SD	Sig.	Mean	SD	Sig.
CDTD/k/ vs. CD/k/	-34.95	21.94	.000	-0.42	0.7	.000
CDTD /t/ vs. CD/t/	-44.32	20.7	.000	-40.58	9.5	.000
CDTD /t/ vs. CD/t/	-41.22	12.7	.000	-30.71	16.9	.000
CDTD /p/ vs. CD/p/	-28.69	21.16	.000	-10.43	12.7	.000

Table 5.6: Mean (in msec), SD and P value of paired differences (JND) for children with learning disability (LD) and normal children (N) on single and multiple cues.

Discussion

The results revealed that 87% of children with learning disability could discriminate the token pairs as same or different. The percentage of children who discriminated the token pairs in multiple cue condition was higher than those in single cue condition (69% and 67% for VOT and CD, respectively). It is known that VOT and CD are strong cues for voicing of stop consonants and TD is not a strong cue in isolation. When TD, a weak cue, is combined with CD, it creates a cooperating condition, thus enhancing voicing perception. The results support the notion that children perform more accurately when they are presented with stimuli that vary in more than one dimension as shown by Greenlee (1978, 1980).

It was interesting to note that children with learning disability had shorter JNDs compared to normal children and this difference was significant for velar and bilabial place of articulation.

No effect of age and sex and 2-way interactions of age vs. sex on JND was significant. This is in contrast to Sathya (1996) who reported a significant effect of sex on

50% crossover for bilabials and a significant effect of age for all the four places of articulation. In children with learning disability, only the effect of sex on JND for the velar place of articulation was significant.

There was a significant difference between single cue condition (CD) and multiple cue condition (CD+TD). This is in consonance with Sathya (1996) where she reported that the 3 year olds did not exhibit the upper limit and phoneme boundary width for CD in isolation, but exhibited the upper limit and phoneme boundary width in CD+TD combined cue condition. She also reported that the 50% crossover and lower limit was on an average advanced by 10 msec in multiple cue condition, and the phoneme boundary width was shorter in multiple cue condition. In the present study, the JND was advanced by 37 msec and 20 msec in children with learning disability and normal children, respectively.

To summarize, multiple cue condition enhanced the performance of both children with learning disability and normal children. Both the groups shifted their percept of voicing at shorter closure duration and had shorter JNDs compared to single cue condition. It was interesting to observe that the shift in the percept occurred earlier and that the JND was shorter in children with learning disability compared to normal children. This may indicate that children with learning disability use multiple cues better than the normal children.

CHAPTER VI

General Discussion

"What we can-put on our shelves we should not-put into our brains"

Auguste Forel

This study has helped to delineate the fine-grained auditory discrimination in Malayalam speaking children with learning disability. Out of the array of cues on the temporal dimension, voice onset time (VOT), closure duration (CD), and transition duration (TD) were selected. The effective use of these cues in children with learning disability and normal children were examined. The differences in JND were analyzed across all the places of articulation. The effects of place of articulation on JNDs, interaction of group, age and sex and the differential use of multiple and single cues were also examined. Table 6.1 summarizes the results.

Para-meter	Group	JND	Differences in place of articulation	Effect of age and sex
VOT	LD	(at lag VOT region) 77.85	Significant difference for *Ibl* vs. /g/ and *Pol* vs. (dental) /d/. Longest JND - dental Shortest JND - bilabial	Two-way interaction of age vs. sex significant for bilabial place of articulation
	N	(at lead VOT region) 58.52	Significant difference for /b/ vs. /g/ and /b/ vs. (dental) /d/. Longest JND - velar . Shortest JND - bilabial	No effect
CD	LD	74.82 (shorter)	No significant difference. Longest JND - velar Shortest JND - retroflex	No effect
	N	77.98 (longer)	No significant difference. Longest JND - velar Shortest JND - retroflex	No effect
CD+TD	LD	37.52 shorter compared to (a) single cue condition (b) normal children	Significant difference for (retroflex) *IXl* vs. (dental) /t/ and (dental) /t/ vs. /k/*l*. (retroflex) /t/ vs./k/, (retroflex) /t/ vs. /p/, /p/ vs. /k/ Longest JND - bilabial Shortest JND - retroflex	Effect of sex on JND for velar place of articulation was significant.
	N	57.6	Significant difference for (retroflex) /t/ vs. /k/ and (retroflex) /t/ vs. /p/ (retroflex) /t/ vs. (dental) /t/ Longest JND - velar Shortest JND - retroflex	No effect

Table 6.1: Summary of results. (LD=children with learning disability, N=normal children).

In general, the results indicated several interesting points. First, not all children with learning disability could discriminate the token pairs. Table 6.2 depicts a comparison of percentage discrimination of token pairs in children with learning disability and normal children on three different temporal cues.

Parameter	% Discrimination	
	LD group	Normal group
VOT	69	100
CD	67	100
CD+TD	87	100

Table 6.2: Percentage discrimination of token pairs in children with learning disability (LD) and normal children (N).

Table 6.2 indicates that lesser number of children with learning disability had difficulty in discriminating the token pairs in the multiple cue condition (i.e., CD+TD). These results support the notion that children perform more accurately when they are presented with stimuli with multiple cues. In the presence of a single cue condition, they experience greater difficulty, which is in consonance with the findings of Steffens et al., (1992) in adult dyslexic subjects. Similar results were also reported by Tallal & Stark (1981) and Elliott, Hammer & Scholl (1989) in children with language-learning problems. However, all the children demonstrated that they understood the concept of same and different.

Second, children with learning disability showed longer JNDs for VOT (LD group = 78 msec, normal group = 58 msec). Similar findings were reported by Elliott et al., (1989) and Elliott & Hammer (1993) in children with language-learning problems. In the present study, children with learning disability showed shorter JNDs for CD and CD+TD condition compared to normal children (LD group = 75 msec, 38 msec, normal group = 78 msec, 58 msec for CD and CD+TD, respectively). Table 6.3 shows the JNDs for VOT, CD, and CD+TD.

Parameter	LD group	Normal group
VOT	78	58
CD	75	78
CD+TD	38	58

Table 6.3: JNDs for VOT, CD and CD+TD in children with learning disability (LD) and normal children (N).

In the multiple cue condition JND was advanced around 37 and 20 msec in children with learning disability and normal children, respectively. The result that JNDs were shorter in children with learning disability was in contrast with those of Steffens et al.,(1992) who found less accurate performance in dyslexic subjects compared to normal readers.

Third, while children with learning disability had longest JND for dental place of articulation (VOT), velar place of articulation (CD), and bilabial place of articulation (CD+TD), normal children had longest JND for velar place of articulation for all the parameters investigated. Also, both groups of children had shortest JND for bilabial (VOT) and retroflex place of articulation (CD, CD+TD). Table 6.4 shows the JNDs for all the places of articulation in both the groups. The fact that the JND was shortest for retroflex may be attributed to the fact that retroflex are the shortest speech sounds and hence have shorter duration of closure.

Parameter	LD group				Normal group			
	V	R	D	B	V	R	D	B
VOT	83	-	89	78	62	-	59	59
CD	77	72	76	74	79	77	78	78
CD+TD	42	28	34	45	79	36	47	68

Table 6.4: JNDs for four places of articulation in children with learning disability (LD) and normal children (N) (V-velar, R-retroflex, D-dental, B-bilabial).

Fourth, significant differences were found between the JND of bilabials vs. velars and dentals for VOT, but no significant difference was found between velars and dentals in either group of children. No significant differences between JNDs of different places of articulation in either group were noticed when the token pairs were altered for duration of closure. When CD+TD were altered, significant differences between JNDs of retroflex vs. bilabial, velar and dental were observed in normal children. In children with learning disability, significant difference between JNDs of retroflex vs. dental, velar, bilabial and between dental vs. velar and bilabial vs. velar was observed.

Fifth, in children with learning disability, there were no effects of age and sex on JND and the two-way interaction of age vs. sex was not significant for VOT (except for bilabials) and CD. However, the effect of sex on JND (CD+TD) for the velar place of articulation was significant.

Sixth, the younger group (below 10 years) of children with learning disability had longer JND in all places of articulation, except dental, for VOT. For CD and CD+TD, the younger group had shorter JNDs in all places of articulation compared to the older group (above 10 years). Normal children in the older group had shorter mean JND for all places of articulation for VOT and CD and for all places except velar for CD+TD. Table 6.5 shows the JNDs in all the four groups of subjects.

Parameter	LD group		Normal group	
	Below 10	Above 10	Below 10	Above 10
VOT	78	78	59	57
CD	73	76	78	77
CD+TD	34	42	58	59

Table 6.5: JNDs in all the four groups of subjects.

These results partially support the fact that auditory discrimination undergoes refinement as age increases. These age related differences may reflect physiological and neurological maturation for the acquisition of relevant acoustic cues for the discrimination of speech sounds of a language. It is not clear as to why older children with learning disability had longer JNDs compared to the younger children. This kind of difference may be due to some unspecified change in peripheral or central auditory processing.

Seventh, there was a significant difference between the single and the multiple cue condition. Sathya (1996) reported in her study on Telugu speaking normal children that 50% crossover and lower limit was on an average advanced by 10 msec and the phoneme boundary width was shorter in multiple cue condition compared to single cue condition. In the present study, the JND was advanced by 37 msec (children with learning disability) and 20 msec (normal children) in multiple cue condition compared to single cue condition. Thus, multiple cue condition enhanced the auditory discrimination in both the groups of children.

In general, the results indicate that children with learning disability have poorer auditory discrimination abilities (for VOT) compared to normal children. This ability to make auditory discrimination may contribute to success in learning to read. Hence the fine-grained auditory discrimination should be considered as an important part of the entire rehabilitation process in children with learning disability and attention, therefore, should be given to instruct children along these lines. Auditory discrimination should be tested for any child who does not learn to read easily. Special help to improve auditory discrimination may be useful in some children in improving reading as intensive training in the weak modality would increase the rate of learning to read.

These synthetic tokens could be used to train such children with poor auditory discrimination abilities. This skill could also be incorporated in greater detail in their diagnostic batteries before making prediction regarding a particular child's academic abilities. These tokens could also be used to study the JNDs in children with other language problems like specific language impairment, aphasia, delayed speech and language etc. Finally these cues and tokens could be used to evaluate JNDs in children with learning disability who speak other Indian languages. This will help in understanding the auditory discrimination abilities in children with learning disability.

In the light of the above findings, it appears that auditory discrimination is a significant and crucial factor in the development of speech and language skills as well as academic skills. The results of this study strengthen the fact that some children with learning disability have auditory discrimination problems.

Future research in this area is needed to determine the values of specific instruction in the deficit modalities, both before reading instruction begins and concomitant with instruction. More number of experimental studies are required, for e.g. groups comparable in reading abilities at the beginning of first grade should be treated differentially, with one group receiving instruction directed at improving auditory discrimination while the other group is given instruction in reading. Varying the nature (but not the extent) of readiness training would make possible less ambiguous statements regarding the influence of auditory discrimination abilities on subsequent achievement in reading. Studies to date have reported on the auditory discrimination abilities of children with learning disability compared to those of age-matched controls. Although this type of comparison is of interest, comparing the abilities of the former group to those of children who are younger but who have normally developing academic skills and matched to grade level may also provide further information about the links among developing academic skills and auditory discrimination skills. Additional research should also be done in locating and constructing tests, which are sensitive especially to auditory discrimination.

CHAPTER VII

Summary and Conclusions

'The whole end of speech is to 6e understood[1]

Confucius

The aim of the study was to investigate the fine-grained auditory discrimination in 7 to 12 year old Malayalam speaking children with learning disability, specifically with reference to temporal cues to stop consonant voicing. The objectives of the study were multifold. The main objective was to investigate the difference between children with learning disability and normal children in fine-grained auditory discrimination abilities when the temporal cues voice onset time (VOT) and closure duration (CD) in isolation, and CD and transition duration (TD) in combination were altered in synthetic words. It was designed to determine whether the just noticeable difference (JND) was different for both the groups. The second objective was to determine the children's weightage of single cues (VOT and CD) and multiple cues (CD+TD) in cooperating conditions. The third objective was to determine whether these children as a group demonstrate different JNDs depending on the place of articulation.

Three experiments were conducted in order to investigate the fine-grained auditory discrimination abilities. The experiments aimed at (1) developing synthetic speech material that would permit the observation of the effects of altering the three temporal cues - VOT, CD, and CD+TD substitution, and (2) investigating auditory discrimination in 7-12 year old Malayalam speaking children with learning disability.

Three CV syllables with voiced stop consonants [velar /g/, dental *Id/*, and bilabial /b/] were selected for the first experiment and four unvoiced stop consonants [velar /k/, retroflex /t./, dental /t/, and bilabial /p/] in the medial position of bisyllabic nonsense (VCV) words were selected for the second experiment. For the third experiment, voiced cognate pair of the stops i.e., velar /g/, retroflex /d/, dental /d/, and bilabial /b/ in the medial position of bisyllabic nonsense words were selected. Table 7.1 shows the syllables/words used for various experiments.

Key phoneme	Bisyllabic word		Experiment for which selected
	Voiced	Unvoiced	
/g/	ga	-	I
Id/	da	-	I
Ibl	ba	-	I
/k/	a:ga	a: ka	II & III
/t/	a: da	a: ta	II & III
/t/	a: da	a: ta	II & III
/p/	a: ba	a :pa	II & III

Table 7.1: Syllables/words selected for the experiments. (Phoneme underlined is the phoneme of interest).

These syllables as uttered by a 32 year old normal female Malayalam speaker were recorded on a data acquisition system at 16 kHz sampling frequency with a 12 bit A/D converter. The syllables thus recorded were subjected to a number of spectrographic analysis, waveform editing operations (Voice and Speech Systems, Bangalore) and parametric synthesis (using modified klatt synthesizer) which manipulated both single and combination of two cues. All editing/synthesis tasks were performed using VSS-SSL system (Voice and Speech Systems, Bangalore, India).

For VOT, CV syllables with voiced stops (g, d, and b) were generated using the Klatt synthesizer. The lead voicing in voiced stops was truncated in steps of three pitch pulses and when VOT was equal to zero, the lag VOT was generated by inserting silence in steps of 10 msec between the burst and the onset of voicing for the following vowel. This was done till the lag VOT approximated the original VOT of the unvoiced stop. For closure duration, the closure duration of the unvoiced stops was truncated in steps of 10 msec from the burst end till the closure duration was almost removed. For CD+TD, the TD of the vowel preceding the unvoiced stop was subsdtuW with that preceding the voiced stop and closure duration was truncated in steps of 10 msec.

Tokens in each parameter was considered as one test and within the test, die tokens were paired with another using the A-B design and iterated three times and later randomized. The synthetic token pairs (a total of 2547) generated on each of the tests in each of the experiments I-III were audio-recorded on metallic cassettes with an inter-token-interval of 2 sec and inter-pair-interval of 5 sec and this formed the stimuli for fine-grained auditory discrimination. Table 7.2 shows the details of the stimuli.

Expt. No.	Parameter operated and position	Steps used	Value (msec)	Total token pairs
I	VOT (Initial, single)	Truncation of three pitch pulses and addition of 10 msec of silence	/g/ = -60 to +50 /d/ = -60 to +60 Pol = -60 to +40	234 273 198
II	CD (Medial, single)	Truncation in 10 msec steps	/k/=130toO /t/ = 80 to 0 /t/=100toO /p/=120toO	315 135 198 273
III	CD/TD substi-tution (Medial, multiple)	TD of voiced substituted for unvoiced and truncation of CD in 10 msec steps	/k/=130toO /t./=80toO /t/=100toO /p/=120toO	315 135 198 273
			Total No. of token pairs	2547

Table 7.2: Details of the experiments conducted.

The experimental group consisted of 30 Malayalam speaking children with learning disability in the age group of 7-12 years and the control group consisted of 30 Malayalam speaking age matched normal children. Of these 15 children were below 10 years and 15 children were above 10 years in both experimental and control groups. Children with learning disability were diagnosed by a multidisciplinary team involving a speech-language pathologist, audiologist, and a psychologist. NIMHANS index of specific learning disabilities was used for the purpose of diagnosis. Children with learning disability performed below grade level on all the academic skills where as the normal children were at grade level. All children who participated were right handed, had normal hearing thresholds in both ears, had a full scale IQ of 90 or greater and were from upper and middle socio-economic class.

The synthetic token pairs were presented through headphones. The subjects were tested individually on a same-different paradigm. Two similar toys were placed on one side of the child and two different toys were placed on the other side. If the child perceived the tokens in a pair as same, he/she was instructed to point out to the similar looking toys and if he/she perceived them as different, he/she had to point to the different looking toys. The experimenter recorded the child's response on a forced choice binary response sheet immediately after the child's response. Testing was done over five day period with breaks between sessions. A total of 2547 responses for each child and a total of 1,52,820 responses for all children were obtained.

The data obtained for each of the task was tabulated and the percent response for each stimuli for the child was calculated using the following formula.

$$\frac{\text{No. of same/different response for the stimuli}}{\text{Total no. of tokens}} \times 100$$

The percent same/different response was tabulated for each of the test stimuli. Just Noticeable Differences (JNDs), i.e., the smallest acoustic differences among the stimulus-pairs, were measured in relation to the voiced stop consonant for VOT and in relation to the unvoiced stop consonant for CD and CD+TD. The time duration at which the subject perceived the tokens in a pair as different was considered for each trial and this was averaged across the trials. For example, if the pairs were representing 90-70, 90-60, 90-50 and 90-40 (msec) and if the subjects response was 'same' for the first three pairs and 'different' for the last pair, the time difference between the two stimulus (90 and 40 msec) in the pairs, i.e., 50 msec was considered as JND.

Using the SPSS software, the mean and standard deviation for JND were calculated for both groups in all places of articulation and two age groups. Paired sample T-test was used to analyze the significant differences between single and multiple cues. One way ANOVA and post hoc Duncan test were used to analyze the effects of group x age x sex, age x sex, group x age and group x sex interaction.

The results of the experiments conducted indicated that only 74% of the children with learning disability could discriminate the token pairs across the three cues. Moreover, lesser number of children with learning disability had difficulty in discriminating the token pairs in the multiple cue condition (i.e., CD+TD). Children with learning disability showed longer JNDs for VOT (LD group = 78 msec, normal group = 59 msec) and shorter JNDs for CD and CD+TD (LD group = 75 msec, 38 msec, normal group = 78 msec, 58 msec). In the multiple cue condition JND was advanced around 37 msec and 20 msec in children with learning disability and normal children, respectively.

Children with learning disability had longest JND for dental place of articulation (VOT), velar place of articulation (CD), and bilabial place of articulation (CD+TD); normal children had longest JND for velar place of articulation for all the cues. Also, children with learning disability and normal children had shortest JND for bilabial (VOT) and retroflex place of articulation (CD, CD+TD).

Significant differences were found between JNDs of bilabial vs. velar and dental for VOT, but no significant difference was found between velar and dental in either group of children. No significant difference between JNDs was observed between places of articulation in either of the group for CD. For CD+TD, significant difference between JNDs of retroflex vs. bilabial, velar and dental was observed in normal children and in children with learning disability, significant difference between JNDs of retroflex vs. dental, velar, bilabial, dental vs. velar and bilabial vs. velar was observed.

In children with learning disability there were no effects of age and sex on JND and the two-way interaction of age vs. sex was not significant for VOT (except for bilabials) and CD. For CD+TD effect of sex on JND for the velar place of articulation was significant. The younger group (below 10 years) of children with learning disability had longer JND in all places of articulation except dental for VOT. For CD and CD+TD, the younger group had shorter JNDs in all places of articulation compared to the older group (above 10 years). Normal children in the older group had shorter JND for all places of articulation for VOT and CD and for all places, except velar, for CD+TD.

The results of this study suggest that on the average," in a single cue condition, the JND was around 77 msec and 68 msec for children with learning disability and normal children, respectively. This indicates that the discrimination is poorer in children with learning disability.

In general, the results indicate that children with learning disability exhibit a difficulty in fine-grained auditory discrimination for VOT, which implies deficit in speech perception and a subsequent problem in the acquisition of speech and language skills and academic skills. As the fine-grained auditory discrimination plays an important role in the acquisition of various skills, it becomes imperative to include this in the schedules of training the children with learning disabilities. The fine-grained auditory discrimination should be considered as an important part of the entire rehabilitation process in children with learning disability and attention therefore should be given to instruct children along these lines. Thus auditory discrimination should be tested for any child who does not learn to read easily. Special help to improve auditory discrimination may be useful to some children in improving reading as intensive training in the weak modality would increase the rate of learning to read.

The synthetic tokens generated in the study could be used for training such children with auditory discrimination problems. This skill could also be incorporated in greater detail in their diagnostic batteries before making prediction regarding a particular child's academic abilities. These tokens could also be used to study the perceptual deficits in children with other language problems like specific language impairment, aphasia, delayed speech and language etc.

In the light of the above findings, it appears that the fine-grained auditory discrimination is a significant and crucial factor in the development of speech and language skills as well as academic skills. The results of this study strengthen the fact that some children with learning disability have auditory discrimination problems.

Future research in this area is needed to determine the values of specific instruction in the deficit modalities, both before reading instruction begins and concomitant with instruction. More number of experimental studies are required, for e.g., groups comparable in reading abilities at the beginning of first grade should be treated differentially, with one group receiving instruction directed at improving auditory discrimination while the other group is given instruction in reading. Varying the nature (but not the extent) of readiness training would make possible less ambiguous statements regarding the influence of auditory discrimination abilities on subsequent achievement in reading. Studies to date have reported on the auditory discrimination abilities of children with learning disability compared to those of age matched controls. Although this type of comparison is of interest, comparing the abilities of the former group to those of children who are younger but who have normally developing academic skills and matched to grade level may also provide further information about the links among developing academic skills and auditory discrimination skills. Additional research should also be done in locating and constructing tests, which are sensitive especially to auditory discrimination.

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APPENDIX I

Place of Articulation	Voiceless		Voiced	
	Unaspirated	Aspirated	Unaspirated	Lax
Bilabial	p	p^h	b	P
Dental	$\underline{t}$	$\underline{t}^h$	$\underline{d}$	$\underline{T}$
Alveolar	t	-	-	-
Retroflex	ṭ	$ṭ^h$	ḍ	-
Velar	k	k^h	g	K

Table A.1: Stop consonants in Malayalam language (Syamala Kumari, 1972).

APPENDIX II

RESPONSE SHEET FOR VOT

Name: Carl — Age/Sex: 8 /M

School: Chinmaya Vidyalaya — Standard: III B

Date: 13.10.1998 — Socio-economic status: Upper class

Mother tongue: Malayalam — Other languages known: English

Handedness: Right — Hearing ability: Normal in the speech frequency range

Tests administered: NIMHANS index of specific learning disabilities

Test results:

IQ:
- Verbal - 94
- Performance - 90
- Full scale - 92

- Reading - II grade
- Spelling - II grade
- Writing - I grade
- Reading comprehension -1 grade
- Arithmetic - III grade

Remedial education program: Attending

Duration of remedial education: 11 months

Provisional diagnosis: Learning Disability

Any other information: Nil.

VOTG							VOTD							VOTB						
	TI		TII		TIII			TI		TII		TIII			TI		TII		TIII	
	1		2		2			1		2		2			1		1		1	
Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D
ga60-ga60	✓		✓		✓		da60-da60	✓		✓		✓		ba60-ba60	✓		✓		✓	
ga60-ga50	✓		✓		✓		da60-da50	✓		✓		✓		ba60-ba50	✓		✓		✓	
ga60-ga40	✓		✓		✓		da60-da40	✓		✓		✓		ba60-ba40	✓		✓		✓	
ga60-ga30	✓		✓		✓		da60-da30	✓		✓		✓		ba60-ba30	✓		✓		✓	
ga60-ga20	✓		✓		✓		da60-da20	✓		✓		✓		ba60-ba20		✓	✓		✓	
ga60-ga10	✓			✓	✓		da60-da10	✓		✓		✓		ba60-ba10	✓		✓		✓	
ga60-ga0	✓		✓		✓		da60-da0	✓		✓		✓		ba60-ba0		✓		✓		✓
ga60-ka10		✓		✓		✓	da60-ta10	✓		✓		✓		ba60-pa10		✓		✓		✓
ga60-ka20	✓			✓		✓	da60-ta20	✓			✓		✓	ba60-pa20		✓		✓		✓
ga60-ka30		✓		✓		✓	da60-ta30	✓			✓		✓	ba60-pa30		✓		✓		✓
ga60-ka40		✓		✓	✓		da60-ta40		✓		✓		✓	ba60-pa40		✓		✓		✓
ga60-ka50		✓	✓		✓		da60-ta50	✓			✓		✓							
							da60-ta60		✓		✓		✓							

VOTG1						
	TI		TII		TIII	
	2		6		4	
Stim. pair	S	D	S	D	S	D
ga50-ga50	✓		✓		✓	
ga50-ga40	✓		✓		✓	
ga50-ga30	✓		✓		✓	
ga50-ga20	✓		✓		✓	
ga50-ga10	✓		✓		✓	
ga50-ga0	✓		✓		✓	
ga50-ka10	✓			✓	✓	
ga50-ka20	✓		✓			✓
ga50-ka30		✓		✓	✓	
ga50-ka40		✓		✓		✓
ga50-ka50		✓		✓	✓	

VOTD1						
	TI		TII		TIII	
	2		6		4	
Stim. pair	S	D	S	D	S	D
da50-da50	✓		✓		✓	
da50-da40	✓		✓		✓	
da50-da30	✓		✓		✓	
da50-da20	✓		✓		✓	
da50-da10	✓		✓		✓	
da50-da0	✓		✓		✓	
da50-ta10	✓		✓		✓	
da50-ta20	✓		✓		✓	
da50-ta30	✓		✓		✓	
da50-ta40		✓		✓		✓
da50-ta50	✓		✓			✓
da50-ta60		✓	✓			✓

VOTB1						
	TI		TII		TIII	
	2		5		3	
Stim. pair	S	D	S	D	S	D
ba50-ba50	✓		✓		✓	
ba50-ba40	✓		✓		✓	
ba50-ba30	✓		✓		✓	
ba50-ba20	✓		✓		✓	
ba50-ba10	✓		✓		✓	
ba50-ba0		✓	✓		✓	
ba50-pa10		✓	✓		✓	
ba50-pa20		✓		✓		✓
ba50-pa30		✓		✓		✓
ba50-pa40		✓		✓		✓

VOTG2						
	TI		TII		TIII	
	3		9		6	
Stim. pair	S	D	S	D	S	D
ga40-ga40	✓		✓		✓	
ga40-ga30	✓		✓		✓	
ga40-ga20	✓		✓		✓	
ga40-ga10	✓		✓		✓	
ga40-ga0		✓		✓		✓
ga40-ka10		✓		✓	✓	
ga40-ka20	✓		✓			✓
ga40-ka30	✓			✓	✓	
ga40-ka40	✓		✓			✓
ga40-ka50	✓		✓			✓

VOTD2						
	TI		TII		TIII	
	3		9		6	
Stim. pair	S	D	S	D	S	D
da40-da40	✓		✓		✓	
da40-da30	✓		✓		✓	
da40-da20	✓		✓			✓
da40-da10		✓	✓		✓	
da40-da0	✓		✓		✓	
da40-ta10		✓	✓		✓	
da40-ta20		✓	✓		✓	
da40-ta30		✓		✓	✓	
da40-ta40		✓	✓			✓
da40-ta50		✓	✓			✓
da40-ta60		✓	✓			✓

VOTB2						
	TI		TII		TIII	
	3		8		5	
Stim. pair	S	D	S	D	S	D
ba40-ba40	✓		✓		✓	
ba40-ba30	✓		✓		✓	
ba40-ba20	✓		✓		✓	
ba40-ba10	✓		✓		✓	
ba40-ba0		✓	✓			✓
ba40-pa10	✓			✓	✓	
ba40-pa20		✓		✓		✓
ba40-pa30		✓		✓		✓
ba40-pa40		✓		✓		✓

VOTG3							VOTD3							VOTB3						
	TI		TII		TIII			TI		TII		TIII			TI		TII		TIII	
	4		8		8			4		8		8			4		7		7	
Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D
ga30-ga30	✓		✓		✓		da30-da30	✓		✓		✓		ba30-ba30	✓		✓		✓	
ga30-ga20	✓		✓		✓		da30-da20		✓	✓		✓		ba30-ba20	✓		✓		✓	
ga30-ga10	✓		✓		✓		da30-da10	✓		✓		✓		ba30-ba10	✓		✓		✓	
ga30-ga0	✓		✓		✓		da30-da0		✓	✓		✓		ba30-ba0		✓	✓		✓	
ga30-ka10	✓		✓		✓		da30-ta10		✓	✓			✓	ba30-pa10	✓			✓		✓
ga30-ka20		✓	✓		✓		da30-ta20		✓		✓		✓	ba30-pa20		✓		✓		✓
ga30-ka30	✓		✓		✓		da30-ta30		✓	✓		✓		ba30-pa30		✓		✓		✓
ga30-ka40		✓	✓		✓		da30-ta40	✓		✓			✓	ba30-pa40		✓		✓		✓
ga30-ka50	✓		✓		✓		da30-ta50		✓	✓		✓								
							da30-ta60		✓	✓			✓							

VOTG4							VOTD4							VOTB4						
	TI		TII		TIII			TI		TII		TIII			TI		TII		TIII	
	5		5		10			5		5		10			5		4		9	
Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D
ga20-ga20	✓		✓		✓		da20-da20	✓		✓		✓		ba20-ba20	✓		✓		✓	
ga20-ga10	✓		✓		✓		da20-da10	✓		✓		✓		ba20-ba10	✓		✓		✓	
ga20-ga0	✓		✓		✓		da20-da0	✓		✓		✓		ba20-ba0		✓	✓		✓	
ga20-ka10	✓		✓		✓		da20-ta10	✓		✓		✓		ba20-pa10		✓	✓			✓
ga20-ka20	✓		✓		✓		da20-ta20	✓		✓		✓		ba20-pa20	✓		✓		✓	
ga20-ka30		✓	✓		✓		da20-ta30	✓		✓		✓		ba20-pa30	✓			✓		✓
ga20-ka40	✓		✓		✓		da20-ta40		✓	✓		✓		ba20-pa40	✓		✓			✓
ga20-ka50		✓		✓	✓		da20-ta50	✓		✓			✓							
							da20-ta60	✓		✓		✓								

VOTG5							VOTD5							VOTB5						
	TI		TII		TIII			TI		TII		TIII			TI		TII		TIII	
	6		3		11			6		3		11			6		2		10	
Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D
ga10-ga10	✓		✓		✓		da10-da10	✓		✓		✓		ba10-ba10	✓		✓		✓	
ga10-ga0	✓		✓		✓		da10-da0	✓		✓		✓		ba10-ba0	✓		✓		✓	
ga10-ka10	✓		✓		✓		da10-ta10	✓		✓		✓		ba10-pa10	✓		✓		✓	
ga10-ka20	✓		✓		✓		da10-ta20	✓		✓		✓		ba10-pa20	✓			✓	✓	
ga10-ka30	✓		✓		✓		da10-ta30	✓		✓		✓		ba10-pa30	✓		✓			✓
ga10-ka40	✓			✓		✓	da10-ta40	✓		✓		✓		ba10-pa40	✓		✓		✓	
ga10-ka50	✓		✓		✓		da10-ta50		✓		✓	✓								
							da10-ta60		✓	✓		✓								

VOTG6							VOTD6							VOTB6						
	TI		TII		TIII			TI		TII		TIII			TI		TII		TIII	
	7		11		9			7		11		9			7		10		8	
Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D
ga0-ga0	✓		✓		✓		da0-da0	✓		✓		✓		ba0-ba0	✓		✓		✓	
ga0-ka10	✓		✓		✓		da0-ta10	✓		✓		✓		ba0-pa10	✓		✓		✓	
ga0-ka20	✓		✓		✓		da0-ta20	✓		✓		✓		ba0-pa20	✓		✓		✓	
ga0-ka30	✓		✓		✓		da0-ta30	✓		✓		✓		ba0-pa30		✓	✓		✓	
ga0-ka40	✓			✓	✓		da0-ta40	✓		✓		✓		ba0-pa40	✓		✓		✓	
ga0-ka50	✓		✓		✓		da0-ta50		✓	✓		✓								
							da0-ta60		✓	✓		✓								

VOTG7							VOTD7							VOTB7						
	TI		TII		TIII			TI		TII		TIII			TI		TII		TIII	
	8		10		7			8		10		7			8		9		6	
Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D
ka10-ka10	✓		✓		✓		ta10-ta10	✓		✓		✓		pa10-pa10	✓		✓		✓	
ka10-ka20	✓		✓		✓		ta10-ta20	✓		✓		✓		pa10-pa20	✓		✓		✓	
ka10-ka30	✓		✓		✓		ta10-ta30	✓		✓		✓		pa10-pa30	✓		✓		✓	
ka10-ka40		✓	✓		✓		ta10-ta40	✓		✓		✓		pa10-pa40	✓		✓		✓	
ka10-ka50	✓		✓		✓		ta10-ta50		✓	✓		✓								
							ta10-ta60	✓		✓		✓								

VOTG8							VOTD8							VOTB8						
	TI		TII		TIII			TI		TII		TIII			TI		TII		TIII	
	9		7		5			9		7		5			9		6		4	
Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D
ka20-ka20	✓		✓		✓		ta20-ta20	✓		✓		✓		pa20-pa20	✓		✓		✓	
ka20-ka30	✓		✓		✓		ta20-ta30	✓		✓		✓		pa20-pa30	✓		✓		✓	
ka20-ka40	✓		✓		✓		ta20-ta40	✓		✓		✓		pa20-pa40	✓		✓		✓	
ka20-ka50	✓		✓		✓		ta20-ta50	✓		✓		✓								
							ta20-ta60	✓		✓		✓								

VOTG9							VOTD9							VOTB9						
	TI		TII		TIII			TI		TII		TIII			TI		TII		TIII	
	10		4		3			10		4		3			10		3		2	
Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D
ka30-ka30	✓		✓		✓		ta30-ta30	✓		✓		✓		pa30-pa30	✓		✓		✓	
ka30-ka40	✓		✓		✓		ta30-ta40	✓		✓		✓		pa30-pa40	✓		✓		✓	
ka30-ka50	✓		✓		✓		ta30-ta50	✓		✓		✓		pa40-pa40	✓		✓		✓	
							ta30-ta60	✓		✓		✓								

VOTG10							VOTD10						
	TI		TII		TIII			TI		TII		TIII	
	11		1		1			11		1		1	
Stim. pair	S	D	S	D	S	D	Stim. pair	S	D	S	D	S	D
ka40-ka40	✓		✓		✓		ta40-ta40	✓		✓		✓	
ka40-ka50	✓		✓		✓		ta40-ta50	✓		✓		✓	
ka50-ka50	✓		✓		✓		ta40-ta60	✓		✓		✓	
							ta50-ta50	✓		✓		✓	
							ta50-ta60	✓		✓		✓	
							ta60-ta60	✓		✓		✓	