Relationship between Temporal processing, Attention and Memory in Children with Learning Disability

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CERTIFICATE

This is to certify that this dissertation entitled **" Relationship between Temporal processing, Attention and Memory in Children with Learning Disability"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Audiology) of the student Registration Number: 15AUD033 This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore
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CERTIFICATE

This is to certify that this dissertation entitled **"Relationship between Temporal processing, Attention and Memory in Children with Learning Disability"** has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **"Relationship between Temporal processing, Attention and Memory in Children with Learning Disability"** is the result of my own study under the guidance of Dr. Prawin Kumar, Reader in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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Table of Contents

List of Tables

List of figures

Abstract

The present study aimed to find out the relationship between temporal processing, auditory working memory and attention in children with learning disability. There were total 32 children in the age range of 8-12 years considered for the study. Out of 32 children, 20 children served as children with learning disability and 12 children served as a control group. Further, children with learning disability (20 children) were grouped as good (10 children) and poor (10 children) performer based on their ability in speech perception in noise test. The temporal processing was assessed using gap detection test (GDT) and temporal modulation transfer function test (TMTF). Results showed statistically significant difference between typically developing and learning-disabled children for both GDT and TMTF test. Further, working memory and selective attention was assessed using digit span test and stroop test respectively. Results showed statistically significant difference between typically developing and learning-disabled children. Overall, Poor performer learning disabled children showed the worst performance followed by good performer learning disabled children in temporal processing skills, working memory and selective attention compared to typically developing children. Correlation analysis showed a statistically significant relationship between temporal processing test and auditory working memory test and also between temporal processing and attention test. The findings of this study may be helpful in deciding the need for the changes which has to be done on the test battery approach in assessing learning disabled children. To conclude, present study highlights the significance of working memory and selective attention test in addition to temporal based task while assessing children with learning disability.

Chapter 1

Introduction

Learning disabilities are defined to a "number of disorders which may influence the acquisition, organization, retention, understanding or use of verbal or nonverbal information and these disorders affect learning in individuals, who otherwise demonstrate at least average abilities essential for thinking and/or reasoning. As such, learning disabilities (LD) are distinct from global intellectual deficiency. Learning disabilities arise out of impairments in one or more processes related to perceiving, thinking, remembering or learning. These include, but are not limited to, language processing, phonological processing, visual spatial processing, processing speed, memory and attention and executive functions, i.e. planning and decision-making and studies reported majorities of these LD children do have temporal processing deficits, attention deficit and auditory memory deficit as co-morbid conditions" as defined by learning disabilities association of Canada in 2015. Ramus, 2003 did a study results revealed that there is a subgroup of children with learning disability having auditory processing disorders in children with dyslexia, which is estimated to be 40% (Ramus (2003).

Central auditory processing includes the auditory mechanism that underlies the following abilities or skills such as sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition, auditory performance in competing acoustic signals and degraded acoustic signal (Chermak & Musiek, 1997). Central auditory processing disorders can be demonstrated by poor performance in one or more of the above.

Chermak (2001) estimated that in Western population, auditory processing disorder occurs in 2 to 3% of children, with a 2:1 ratio between boys and girls. Similar findings have been reported in India by Muthuselvi & Yathiraj (2009) who found auditory processing disorders to have a prevalence of 3.2% in school aged children. Some of the population in whom auditory processing disorders may be affected include children with learning difficulties (Chermak, 1997), specific language impairment (Kohli, Kaur, Mohanty, & Malhotra, 2006; Korpilahti, 1995), and children with a history of otitis media (Bellis, 2011). Central auditory processing of an individual can be evaluated through either behavioural tests or electrophysiological tests.

Many studies done on learning disabled children have revealed that there is a presence of heterogeneity in learning disability in terms of characteristics, causes, and associated deficits. Children with learning disability have auditory processing disorders have been experimentally investigated by many studies, but either these auditory processing deficits are seen only in association with language disorders or as a causal factor is yet to be explored (Rosen, 2003). And also, studies have revealed that children with learning disability may have auditory and visual processing problems (Larsen, Rogers, & Sowell, 1976). However, whether central auditory processing problems are caused due to LD or not, is a divisive issue (Jerger, 1998).

1.1 Temporal processing in children with learning disability:

Acoustic stimuli vary over time, processing of these rapid change in the acoustic stimuli is referred as Temporal processing. Temporal processing ability is very important for us to be able to understand speech in quiet and in background noise, when the speech stimuli and other background sounds vary over time. Temporal processing deficits have been associated in children with learning disability (Tallal, Miller, & Fitch, 1993). Several authors have demonstrated that impaired temporal processing may result in language disorders, speech processing disorders and reading disorders (Jirsa & Clontz, 1990; Tallal et al., 1993; Merzenich et al., 1996; Cohen-Mimran & Sapir, 2007). These investigations hypothesized that impaired temporal processing disrupts the normal development of an efficient phonological system and these phonological difficulties may result in language and reading disorders (Jirsa & Clontz, 1990; Tallal et al., 1990; Merzenich et al., 1996; Tallal & Gaab,2006; Cohen-Mimran & Sapir, 2007; Moll & Gobel, 2016).

In psychoacoustics, two dominant paradigms for measuring temporal resolution of the auditory system are the temporal modulation transfer function (TMTF) paradigm and the gap detection paradigm (Reed, Braida, and Zurek, 2009). A temporal modulation transfer function is a function relating to a listener's threshold for detecting sinusoidal amplitude modulation to modulation rate. For broadband noise carriers, the TMTF typically exhibits a low-pass characteristic. That is, as the modulation rate (fm) increases, the modulation detection threshold is initially stable, then increases after the modulation rate exceeds a cut off rate (fc). This cut off rate has been traditionally described as reflecting the sluggishness of auditory temporal processing (Viemeister, 1979).

Tallal (1980) described a deficit in dyslexics involving processing of brief and rapidly changing auditory stimuli. The characteristic, brief and rapid spectral changes support the role of temporal processing in speech perception deficits in dyslexic. Basic temporal processing impairments underlie their inability to integrate sensory information that conveys in rapid succession in the central nervous system. Natural speech is a complex signal which has variation in frequency, amplitude with respect to time.

A number of investigations demonstrated that nearly perfect consonant identification and sentence intelligibility could be achieved with speech stimuli processed only with temporal modulation cues which is as low as 50 Hz (Shannon, 1992). Rosen (2003) said there are three main temporal features of speech and named it, has an envelope, periodicity and fine structure. The human auditory system has the capability to resolve the faster and slower changes in the amplitude, frequency with respect to time (separate fast and slow auditory system). Any deficits in the development of these two fast and slow auditory systems may be related to rapid processing deficits, which is common to specific language impairments or individuals with learning disability (Tallal, Merzenich, Miller, & Jenkins, 1998). Thus, this may affect their speech inaudibility in the presence of noise.

Bacon and Viemeister (1985) have done a study of temporal modulation transfer function on normal hearing listeners. The result of the study showed that for normal hearing listeners, on sinusoidal amplitude modulation sensitivity is relatively independent of modulation frequency up to 50 -60 Hz, and this sensitivity of the sinusoidally amplitude modulation decreases progressively at higher modulation frequency. As the modulation frequency increases beyond 16 Hz, temporal resolution starts to have an effect and sinusoidally amplitude modulation detection threshold increases (poorer).

Tallal, Bishop, and Leonard (2000) assessed TMTF in dyslexic children at two modulation frequencies (Fast and slow modulation frequencies). It is shown that they exhibit impaired ability to perceive the faster modulation may lead to a poor speech perception in noise. Riesz (1928) studied TMTF thresholds and results showed modulation frequency more than 4 Hz the amplitude modulation required was 3 dB/octave for less Df than 4Hz shows 2 dB/octave increase in threshold with decreasing modulation frequency. Zwicker (1956) showed slight 2 dB decrees in threshold from 1 to 4 Hz followed by a 3 dB /octave increases in threshold up to modulation frequencies of 60 Hz. Viemester 1979, showed that modulation thresholds are constant up to approximately 10 Hz sensitivity and further reduced (poorer) by 3 dB at approximately 50 Hz from this frequency up to 8000 Hz sensitivity decreases (poorer) at a rate of 3 dB/octave. Hall III and Grose (1994) measured TMTF in listeners from 4 years to 10 years. Sensitivity to sinusoidal modulation of the noise carrier was determined for modulation frequencies of 5, 20, 100, 150, 200 Hz. The results showed all the listeners indicated decreases in sensitivity to modulation as function of increasing frequency modulation.

Besides the TMTF paradigm, an alternative way of assessing temporal resolution is the gap-detection paradigm (Zwicker, 1956; Buunen & Van Valkenburg, 1979; Fitzgibbons, 1983; Shailer & Moore, 1983). Gap detection measures listeners' sensitivity to the presence of a silent temporal gap in a stimulus. Because GDTs can be measured using relatively small number of trials, it has been adopted widely in clinical research (Lister & Roberts, 2005; Roberts & Lister, 2004; Musiek, Bellis, & Chermak, 2005).

GDT involves the presentation of two relatively long sounds, with a brief silent period or gap between them (Phillips & Smith, 2004). In normal subjects can resolve gap detection threshold found to be as low as 2-3ms (Hirsh & Sherrick Jr, 1961). If GDT is greater than 15 to 20 ms then one can suspect temporal processing deficit. Shivaprakash and Manjula in 2003 studied GDT in 7 -12 years of aged children and found children required a gap of 3 to 4 ms with standard deviation of 1 ms. They also found that there is no age effect which is seen after age of 7 years. Shinn, Chermak, and Musiek (2009) did a study on 72 children's age ranged 7 to 18 years, results showed no age effect on GDT threshold with age.

Haggerty and Stamm (1978) used click fusion task, and they presented clicks with either ears once or one leading. Results showed that LD group required a longer inter stimulus interval. Zaidan and Baran (2013) taken 61 children n, separated into children with dyslexia and children with phonological deficit and age matched control group. Results showed children in group learning disabled needed longer GDT than control group.

McCroskey and Kidder in 1980 did a study where they used two tones having duration of 17 ms and inter-stimulus interval ranging from 0 to 40 ms. Results showed that learning disabled children required longer inter stimulus interval than normal to separate the tones. Stanley and Hall (1973) did a study where they presented two parts of a stimulus of 20 ms duration with varying inter stimulus interval. Results revealed that learning-disabled children required longer ISI to separate the two stimuli when compared to a normal control group.

Hautus, Setchell, Waldie, and Kirk (2003) studied temporal acuity using gap-detection task on children with dyslexia of age 6–9 years. Results showed that dyslexia exhibited a significant deficit when compared to the to age-matched controls. In contrast, this deficit was not observed in groups of older dyslexia individuals (ages10–11 years; 12–13 years) or in adults (ages 23–25 years). Thus, they concluded that early temporal resolution deficits present with those with reading impairments may significantly become better over time. However, deficit in temporal acuity in early age maybe due to other language-related perceptual problems (particularly those related to phonological processing) which may even persist after the primary deficit has resolved.

Thus, the review of literature shows that temporal processing might be affected in children with learning disability, which can be assessed by psychophysical test like temporal modulation transfer function or gap detection test. Individual with learning disability showed poor performance in both tests i.e. the children with learning disability required higher threshold (more gap) to detect the presence of silence between the two sounds and also required more modulation depth to detect the amplitude modulation in the given frequency when compared to typically developing children.

1.2 Auditory closure deficit in learning disabled children:

Speech in noise test is a method of reducing the redundancy of the speech signal, by presenting the signal in background noise (Chermak, Vonhof, & Bendel, 1989). Speech is a complex signal which has variation in its amplitude and frequency of the spectrum. Presence of background noise will mask the variations in frequency and amplitude of the signal and the signal becomes less redundant to be processed. Normal processing of the auditory system will be able to pay selective attention to the speech spectrum by ignoring the background noise were as an individual with an auditory processing problem will fail to extract the information from the complex signal. Lorenzi, Dumont, and Fullgrabe (2000) obtained unprocessed speech signal and speech envelope noise identification and observed that individual with dyslexic exhibit poor performance in processing the speech envelope in noise when compared to normal hearing subjects.

In spite of normal hearing sensitivity, some learning-disabled children report persistent listening difficulties, especially in noisy environments, such as classrooms (Lagacé, Jutras, & Gagné, 2010; Moore, Rosen, Bamiou, Campbell, & Sirimanna, 2013). Listening in background noise also depend on abilities such as attention, auditory processing, and memory and not only on to hearing sensitivity (Bronkhorst, 2000; Conway, Cowan, & Bunting, 2001; Haykin & Chen, 2005; Brungart & Simpson, 2007). There have also been suggestions that a proportion of children who complain of listening difficulties especially in noise may have deficits in auditory processing (Bamiou, Musiek, & Luxon, 2001).

Many studies have reported that listeners with language impairment and dyslexia also have difficulty listening in background noise (Alcántara, Weisblatt, Moore, & Bolton, 2004; Ziegler, Pech-Georgel, George, & Lorenzi, 2011). They have demonstrated frequency resolution deficit (Bishop & McArthur, 2004; Halliday & Bishop, 2006) deficits in auditory stream segregation (Helenius, Uutela, & Hari, 1999; Taylor, Batty, Chaix, & Démonet, 2003), and temporal envelope processing (Rocheron, Lorenzi, Füllgrabe, & Dumont, 2002; Cohen-Mimran & Sapir, 2007). There is some evidence which shows difficulties with listening in noise may underlie some memory deficits (Nelson & Warrington, 1980 ; Gathercole & Alloway, 2006; Montgomery, Magimairaj, & Finney, 2010).

Chermak et al. (1989) studied word identification performance in the presence of competing speech and noise in learning disabled children. Behavioural measures of speech intelligibility show that children with learning disability have poorer speech perception ability in the children without a learning problem. This difference in perception ability is enhanced in stressful environment conditions like in the presence of background noise, the perception abilities of children with a learning problem even more (Bradlow, Kraus, & Hayes, 2003). Study by Chermak (1997) showed poorer score in learning impaired children obtained in noisy condition than quiet condition on word identification and discrimination tasks when compared to normal children.

Thus, the review of literature on the learning-disabled children shows that auditory closure capability might be affected in these children, which can be assessed using speech in noise test. Children with learning disability showed poor performance in SPIN test. i.e. they do have difficulty in understanding the speech in presence of noise but in quiet they do not have difficulty in understanding speech.

1.3 Attention deficit in children with learning disability:

Auditory attention plays a major role in influencing the ability to listen in the presence of background noise (Fritz, Elhilali, David, & Shamma, 2007; Sturm, Willmes, Orgass, & Hartje, 1997). Studies showed there is a presence of attention deficits in children with listening difficulties (Moore, Ferguson, Edmondson-Jones, Ratib, & Riley, 2010) (Dhamani, Leung, Carlile, & Sharma, 2013).

Auditory attention includes sustained attention, phasic alertness, and attention switching ability, selective attention. In a majority of listening situations involving multiple talkers and distractors, there is temporal overlap of different sources in different spatial locations. Such situations require the listener to switch focus between different sources of information (attention switching) on the basis of their relevance, or selectively focus attention on the target information (selective attention) (Astheimer & Sanders, 2009).

Attention is a mental task where an individual has to narrow down their choices to select particular kind of stimulus which can be further processed, while neglecting other interfering stimuli. Alertness present in the mental and also physical status of an individual is termed as attention. Attention is defined as out of all sensation yielded, picks out certain one's worthy of its notice and suppress all the rest, main function of the attention is to select a particular information for processing. Distinct types of attention are present which will be used in different situations, which will be sensitive for many different variables. Attention can be classified mainly into three categories i.e. selective attention, divided attention, and sustained attention. Selective attention is the ability of an individual to focus on a particular stimulus of interest irrespective of another stimulus. The factor which mainly affect the selective attention is how familiar is the distractor (Lavie, Hirst, De Fockert, & Viding, 2004).

Wright and Elias (1979) did a study on selective attention in elderly (60 to 82 years) and young (18 to 25 years) individuals. They were tested on a visual task in which noise items were present, elderly persons had more difficulty ignoring irrelevant stimuli and suppressing response competition than do younger persons. Further, they also reported that if the distractor is more irreverent than they are easily neglected compared to when the distractors are relevant.

Stroop effect is a manifestation of interference in the reaction time of a task. Naming the colour of the word takes longer and is more prone to errors, than when the colour of the ink matches the name of the colour. This can be used to test the selective attention. For example, when the word orange would be listed as text, but printed in green it takes longer time when compared to when the colour of the ink matches the name of the colour.

Studies on the Stroop interference over age showed that stroop interference increases only up to the age of 5 or 6 years. After this age, stroop interference actually reduces as the individual gets older (Comalli Jr, Wapner, & Werner, 1962; Schiller, 1966). They reported decrease in Stroop interference as an individual gets older can be due to the increasing control of an automatic process. Rack, Snowling, and Olson (1992) studied performance of dyslexic children on the task of reading rare words or pseudo words, and results showed their accuracy is lower in the task and their performance time is longer on the task when compared to the that of regular readers. Similar finding was found by Kamhi and Catts 1986; Bowers and Swanson 1991; Manis, Seidenberg, Doi, McBride-Chang, and Petersen 1996). Turner Ellis, Miles, and Wheeler (1996) did a study on speed of multiplication in dyslexics and Non-dyslexics. The subjects were 90 boys aged between 7 and 15 years of whom 30 were dyslexic; 30 were chronological age controls (CA controls) and 30 for spelling age controls (SA controls). They were divided into 3 age-bands. Forty-four multiplication sums were given which includes every 'pair' from 1 x 1 to 12 x 12, which was presented on a computer screen in random order, and the subjects were required to type in the answer. All responses time was calculated and results showed that 79.60% responses were given correctly. Within each age-band the dyslexics were consistently slower in young, middle and old age group, when compared chronological age controls but it was consistently faster than the spelling age controls. The older children showed better scores in in all three groups than the younger children group.

Everatt, Warner, Miles, and Thomson (1997) studied children with dyslexia on word reading, colour name (congruent and incongruent) task. The age range of dyslexics ten-and-a-half years old (on average). The result of the study showed marked presence of Stroop interference of a colour word on the naming of a colour. They reported stroop interference was larger in the dyslexic group than the control group. The mean response time for congruent and incongruent condition was 28.15sec and 86.70 sec respectively in dyslexic group and 18.90 and 57.15sec in the control group for congruent and incongruent condition respectively. Due to a lack of control of the reading and colour naming processes the Stroop interference experienced by the dyslexic subjects were more.

Willcutt, Pennington, and DeFries (2000), studied relation between reading disability (RD) and attention-deficit/hyperactivity disorder (ADHD). Study include a total of 494 twins with a reading disability (223 girls, 271 boys) and 373 twins without a reading disability (189 girls, 184 boys) Results indicated that individuals with reading disability were more likely to meet criteria for ADHD than individuals without reading disability. The association between reading disability and ADHD showed that there is a stronger symptom of inattention than the symptoms of hyperactivity or impulsivity.

Mayes et al., (2000) studied 119 children ages 8 to 16 years. Attention-deficit/hyperactivity disorder (ADHD) was present in 70% of the children with a learning disability. Further the results of the study showed that within learning disability, children with deficit in written expression had ADHD two times more common i.e. 65%) than a learning disability who are having in deficit in reading, math, or spelling. Children with LD who had ADHD had more severe learning problems than children who had LD but no ADHD. Further, children with ADHD but no LD had some degree of learning problem, and children with LD but no ADHD had some degree of attention problem. Results indicate that learning and attention problems are on a continuum, are interrelated, and can usually coexist.

Ramus (2003), studied all measures of literacy: reading speed and accuracy, spelling, pseudo word reading accuracy and time in dyslexics and control group. Results showed scores were significantly poor than controls in all the test. In addition, all dyslexics were poorer than controls in the different phonological tests: their naming time was longer.

Breznitz (2002), studied the processing time and accuracy when performing errors during letter, word and sentence reading in dyslexic and regular readers. Results of both groups showed longer reaction times for incorrect response but the dyslexics group showed significantly higher reaction time than regular readers. Miller-Shaul (2005) did a study which includes four groups of subjects (two groups of fourth graders, dyslexic and normal readers, and two groups of students, compensated dyslexics and normal readers) Results showed that that dyslexics showed slow speed of processing in verbal and non-verbal tasks.

Moll et al. (2016) studied the temporal processing, processing speed and working memory in children with specific learning disorder. Results revealed that poor attention was associated with all these three risk factors. Further on controlling the attention, they found that reduced processing speed was related to the reading disorder children and not mathematical disorder but temporal processing was associated with the mathematical disorder and not reading disorder.

Thus, all the above study shows that there is a high probability of presence ADHD in learning disabled. In addition, there is also high chance that children who were diagnosed as learning disabled but not ADHD i.e. the children with learning disabled children have poor selective attention skills and they showed longer reaction time and poor accuracy rate when compared to normal in selective attention task. Thus, they may have some amount of attention deficit which may affect their different auditory processing skills and memory.

1.4 Auditory working memory deficit in children with learning disability:

Auditory working memory is a cognitive system with a limited capacity that is responsible for temporarily holding auditory information available for processing. Working memory is important for reasoning and the guidance of decision making. Auditory working memory helps the listener to temporarily store the auditory information and also actively process the auditory information Thus this helps speech understanding in the presence of noise which will be done by connecting the related information with respect to time and to ignore the irrelevant distractions (Pichora-Fuller, Schneider, & Daneman, 1995;Colflesh & Conway, 2007;Conway et al., 2001; Strait, Parbery-Clark, Hittner, & Kraus, 2012). This result is consistent with earlier studies conducted on adult listeners, which indicates that the performance of speech recognition in degraded speech is s correlated strongly with the verbal working memory skills (Rudner, Lunner, Behrens, Thorén, & Rönnberg, 2012).

As mentioned in literature, children with learning disability have shown poor performance in the auditory working memory task. Several studies investigated the degree to which working memory differences observed between performances of learning impaired and typical children. The results suggested that learning disabled children have generalized working memory deficits, which possibly may be due to storage limits in the executive system (Swanson, 1993; Bauer, 1977; McLean & Hitch, 1999; Gathercole & Alloway, 2006; Cohen-Mimran, & Sapir, 2007; Swanson, et al.,2009). Studies also reported that there is a co-morbidity of learning disability with attention problems and processing speed deficits (Bull & Johnston, 1997; Catts, Fey, Tomblin, & Zhang, 2002; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005; Wang & Gathercole, 2013).

Fletcher (1985) studied memory in typically developing children and four groups of disabled learners. They give stimuli which were verbal and nonverbal which was assessed during selective reminding procedures. The subjects who were included in the study are children with reading-spelling disabled, children with spelling-arithmetic disabled and children with reading-spelling-arithmetic disabled and children with arithmetic disabled. Each child had two memory tasks, one for nonverbal material (random dot patterns).and other one for verbal material (animal names). Results showed that relative to controls children with reading-spelling disabled children had difficulty only on verbal task; and children with spelling-arithmetic disabled children had difficulty on both verbal task and the nonverbal task. But children with arithmetic disabled children had difficulty on the nonverbal task, but did not differ on the verbal task.

Felton (1987) did a study to find out the naming abilities and verbal memory abilities in reading disable and control children. Theses reading disabled children were further divided into groups based on the presence or absence of attention deficit disorder (ADD). Results showed that deficits in naming task are specific to RD rather than ADD. But deficits in learning and memory for recently acquired information was due to ADD rather than RD. Thus, they conclude that ADD plays a major role in children with reading disability in terms of their memory because it is an additional and separate cognitive morbidity in Reading disabled children.

Siegel and Ryan (1989) studied the performance of working memory in arithmetic disabled, reading disabled and attentional deficit disordered in children of aged 7-13. Working memory was assessed by using two working memory tasks, one involving sentences and the other involving counting and they were compared with the typically developing children results showed that there is a significant growth of working memory as a function of age. Reading disability children showed significantly poorer scores on both tasks. And arithmetic disabled children showed lower scores only on the Counting task. Thus, they concluded that a reading disability appears to involve a generalized deficit in working memory.

Cohen-Mimran and Sapir (2007) studied memory task in children with and without Reading disability and the study included thirty-two adults. The working memory task included Digit Span test (Forward and Backward tests) and Token Test. These tests were done to find out the subtle deficits in auditory verbal working memory. Results of the study showed that when compared to normal, children with reading disability showed significant poorer performance on the working memory tests.

Malstädt, Hasselhorn, and Lehmann (2012), studied the free recall ability fifty-four eight-year-old children, with and without spelling impairment. Task included were a repeated free recall task and three working memory tasks. Results showed that children without spelling impairments showed better score on recall task when compared to those children with spelling deficits. Based on the video analysis it was revealed that the recall behaviour can be compared in both impaired and unimpaired children, which shows that both groups use similar activities for learning. They concluded that the group differences in the task of number of recalled items were due to differences in sub capacities of working memory between children with and without spelling impairment.

Sharma, et al., (2014), studied twenty-one children who have listening difficulty in noise and with 15 children do not have listening difficulty. They studied the auditory memory which included both short-term and working memory performance was assessed on the basis of a digit span test (including both forward and backward digits) The forward digit task requires the listener to recall numbers in correct serial order after hearing the numbers, and the backward task requires the listener to repeat the numbers in the last to the first order. Listening difficulty children showed poor performance when compared to typically developing children in a memory task.

Peng and Fuchs (2016), studied the numerical working and nonverbal working memory in children with reading difficulties (RD), children with mathematics difficulties (MD), and children with reading and mathematics difficulties (RDMD). A total of 29 studies were included in the study which includes 110 comparisons. Results showed that all learning difficulty children showed deficits in verbal WM and numerical WM, and among the learning-disabled children, children with RDMD showed the severe deficit on WM. All groups showed poorer performance on working memory when compared to typically developing children. On verbal WM deficits both MD children and RD children showed similar performance, but on numerical WM deficits children showed more deficit than RD children. WM deficit was not affected by either severity of learning difficulties or type of academic problem.

Study on the working memory test on the learning disabled shows that learning disabled children have a limited storage capacity and poor retrieval skills for the information which is stored in the working memory, hence they poor scored on the auditory working memory test when compared to typically developing children.

Thus, the review of literature of temporal processing, auditory closure skills, attention and auditory working memory are affected in children with learning disabled which was found by doing specific test related to above mentioned processes. Temporal processing was affected in children with learning disability, the children with learning disability required higher threshold (more gap) was needed to detect the presence of gap between in the two sounds and also required more modulation depth to detect the amplitude modulation in the given frequency when compared to typically developing children. In auditory closure skills, these skills might be affected in children with learning disability. Children with learning disability do not have difficulty in understanding the speech in quiet but in the presence of noise they have difficulty in understanding and identification of speech. Thus, they showed poor performance (low scores) in SPIN test. In attention skills study shows that there is a high probability of presence ADHD in learning disabled. Further there is also high chance that children who were diagnosed as learning disabled but not ADHD, i.e. they showed longer reaction time and poor accuracy rate when compared to normal in selective attention task. Thus, it shows that learning disabled have poor selective attention skills and they may have some amount of attention deficit which may affect their different auditory processing skills and memory. In auditory working memory skills, study showed that the learning-disabled children have a limited storage capacity and poor retrieval skills for the information which is stored in the working memory, hence they poor scored on the auditory working memory test when compared to typically developing children.

1.5 Need for the study*:*

American Academy of Audiology (2010) recommended temporal resolution tests which include the frequency pattern (Musiek et al., 2005), gap detection in noise (Jerger & Musiek, 2000), and listening in spatialized noise (Cameron & Dillon, 2007) tests while the additional test assessed are frequency resolution (Peters, Moore, & Baer, 1998; Darwin, 2008) as well as temporal envelope and fine structure perception (Zeng et al., 2004) skills. In addition to the assessment of auditory processing skills, a majority of clinical guidelines also suggest evaluation of attention and memory abilities in populations with listening difficulties (Cacace & McFarland, 1998; Jerger & Musiek, 2000; Conway et al, 2001; Moore, 2006 ; Mattys, Davis, Bradlow, & Scott, 2012; Moore, 2012).

Bradlow et al. (2003), found that both typically developing and LD children shows poor score on speech in noise test but learning-disabled children are more adversely affected than typically developing children. Similar findings were reported by Shivashankar (2003), thus this shows that overall all individuals with learning disability shows poor performance in adverse listening situation when compared to typically developing children.

Studies on temporal processing have shown that, learning disabled children have difficulty in temporal processing skills such as poorer performance of learning disabled individuals on TMTF and GDT tests which reflects difficulty in temporal resolution (Tallal, 1980; Zaidan and Baran (2013) and these individuals do have difficulty in auditory closure ability (Lorenzi et al., 2000).

Studies also reported poorer performance in auditory working memory tasks in children with learning disability (Cohen-Mimran & Sapir, 2007; Peng & Fuchs, 2016), they also found to have difficulty in selective attention skills (Mayes, Calhoun, & Crowell, 2000; Moll & Gobel, 2016). However, there are very limited studies have done to find out the relationship between temporal processing, attention and working memory.

Moll et al. (2016) studied processing speed, temporal processing, and working memory in children with listening difficulty, since attention problems frequently co-occur with learning disorders. The study examined whether these three factors, which are known to be associated with attention problems, i.e. measures of processing speed, temporal processing, and memory were linked to each other or not. Results revealed that all the three factors are linked to poor attention. Similarly, Sharma et al in 2014 studied attention, memory and auditory processing relationship in children with listening difficulties and the result revealed significant poor performance on attention, memory and auditory processing among these children. But they don't explain these deficits in modality specific disorders.

All the study which are done on the learning disabled, they have studied the deficit in different processes like attention, working memory or temporal processing individually and not as a relationship between these three processes and how they are related to each other Review of literature shows there is a high probability of occurrence of temporal processing deficit with attention and working memory deficit in learning disabled. However, there is a dearth of literature which shows the relationship between temporal processing, attention and memory in children with learning disability in the Indian population.

In addition, till now no correlation is attempted between temporal proceeding skills, auditory working memory and attention in learning disabled children. Hence the present study was conducted.

1.6 Aim of the study:

The aim of the study is to examine the relationship between temporal processing, attention and auditory working, memory abilities in children with learning disability in the Indian population.

1.7 Objectives of the study:

1. To examine the performance of children with learning disability (good and poor performer) on temporal processing task, (GDT and TMTF).
2. To examine the performance of children with learning disability (good and poor performer) on attention and auditory memory task.
3. To explore the relationship between temporal processing task, attention and auditory working memory in good and poor performer children with learning disability.

1.8 Hypothesis of the study:

The null hypothesis is assumed for the present study:

1. There is no difference in the performance of children with learning disability (good and poor performer) and typically developing children in temporal processing task.
2. There is no difference in the performance of children with learning disability (good and poor performer) and typically developing children on attention and memory tests.
3. There is no relationship between temporal processing, attention and memory in children with Learning Disability (good and poor performer) and typically developing children.

Chapter 2

METHOD

The present study was aimed to check the relationship between temporal processing, attention and auditory working memory abilities in children with learning disability in Indian population.

2.1 Participants:

Three groups of participants were included in the study, which includes two clinical groups and one age matched control group. The Clinical group included 20 children with learning disability in the age range of 8-12 years and 12 age-matched control group i.e. typically developing children without learning disability.

In clinical groups, children were further divided into two groups of 10 children each based on their performance on speech-in-noise (SPIN) test at 0 dB Signal-to-Noise Ratio (SNR) i.e. good performer and poor performer (Group 1 and Group 2). The cut-off criteria fixed were 50% based on the performance of typically developing children in SPIN test. Those who obtained more than 50% SPIN scores at 0 dB SNR was considered as good performer LD children (Group 1). Those who obtained less than 50% SPIN scores at 0 dB SNR was considered as poor performer LD children (Group 2) The diagnosis of learning disability was made by experienced Speech and Language Pathologist and/or Clinical Psychologist. Written consent was obtained from all the participants/ parents/ caregivers prior to the participation in the study and they were explained in detail about the procedure involve in the study.

2.2 Inclusion and exclusion criteria for Group 1, Group 2 and Group 3:

Children had pure tone average (air and bone conduction threshold) within 15 dBHL for frequencies between 250 Hz to 8000 Hz in both ears. Speech recognition thresholds were within +/- 12 dB of the pure tone average threshold and speech identification scores were above 80 in both ears in quiet condition along with an uncomfortable loudness level greater than 100 dBHL. All the participants had a normal middle ear function based on 'A/As' type tympanogram at 226 Hz probe tone frequency in both ears. All the participants had the presence of transient evoked otoacoustic emissions in both ears indicating normal outer hair cell functioning. They had normal or above average Intelligence Quotient (IQ) based on psychological test. They had an age adequate receptive and expressive language based on receptive and expressive language skills test. All the participants were going to English medium school from at least 2-3 years**.** They were assessed using Screening checklist for auditory processing (SCAP) developed by Yathiraj and Mascarenhas, (2004) and Screening test for auditory processing(STAP) developed by Yarhiraj and Maggu, (2012), indicating the presence/ absence of auditory processing disorder. Based on the structured case history, the participants were also ruled out for any history of otological and / or neurological disorders. In addition, those participants who had any peripheral hearing loss, clinically abnormal / absent ABR, any middle ear pathology, limited intellectual capacity and attention deficit hyperactive disorders were excluded from the study.

2.3 Test environment:

All the tests were carried out in a sound treated room where the noise levels were per the guidelines of ANSI S3.1 (1991) standards. The testing room was illuminated as air conditioned for the comfort of participant.

2.4 Instrumentation:

- Calibrated double channel clinical audiometer (GSI-61, USA) with Telephonics TDH-59 supra aural headphones were used for estimating the air conduction thresholds. Radio ear B-71 bone vibrator was used for bone conduction thresholds. Same audiometer was used for Speech in Noise Test (SPIN).

For assessing middle ear calibrated middle ear analyzer, GSI tympstar was used for tympanometry and reflexometry.

- ILO -292 DPEcho port systems (Otodynamics Inc., UK) was used to assess the transient evoked otoacoustic emission.
- Biologic Navigator Pro (Version 7.0) was used for recording click evoked ABR.

A Personal Computer, Intel i5 processor loaded with MATLAB software was used for temporal processing test (GDT and TMTF). The same computer loaded with and DMDX software was used for attention test given by Forster, & Forster, (2003) and Smirthi Shravan software developed by Kumar and Maruthy (2013) was used for memory test (digit span test).

2.5 Procedure:

The testing was carried out in two phases. The first phase included were complete hearing screening along with “Screening checklist for auditory processing’’, ‘’Screening test for auditory processing’’, and Speech in Noise Test. The second phase consisted of behavioural test of temporal processing (gap detection test and temporal modulation transfer function test), test of attention (stroop test) and auditory working memory test (digit span test).

2.5.1 Phase 1: Hearing screening, SCAP, STAP and SPIN

An initial otoscopic examination was carried out to rule out the presence or absence of wax in the external ear and status of the tympanic membrane. Pure tone audiometry was carried out based on Modified Hughson-Westlake (Carhart & Jerger, 1959) procedure for octave frequencies. A threshold was obtained in the frequency range of 250 to 8000 Hz for air conduction by using headphone TDH 39 and for bone conduction using bone vibrator B-71between 250 to 4000 Hz. In all three groups, the pure tone threshold was within ≤ 15 dBHL in both ears. Along with pure tone audiometry, speech audiometry was carried out to find speech recognition threshold and speech identification scores (SIS) for all three groups. The SRT was in agreement with PTA in all three groups. The stimulus was presented at 40 dB SL for SIS (Ref SRT). SIS was more than 80% in quiet for all three groups.

Immittance evaluation was carried out for both the ears using GSI-TS middle ear analyser with probe tone frequency of 226Hz. Ipsilateral and contralateral reflex threshold was measured for 500, 1k, 2k and 4 kHz. In all three groups, tympanogram was either 'A/As' type with ipsilateral and contralateral reflex presents at all the frequencies between 500 Hz to 4000 Hz. A significant change of admittance value of at least 0.03 ml was considered as presence of acoustic reflexes (Hunter & Shahnaz,2013).

Transient evoked otoacoustic emissions (TEOAE) were administered to rule out cochlear pathology. A good probe fit was ensured prior to the testing. Click stimuli of total 260 were presented and responses were averaged. Reproducibility of more than 80% and signal-to-noise ratio (SNR) of 6 dB was considered as responses present. A TEOAE responses was measured for 1000, 2000, 3000 and 4000Hz.TEOAE was present for frequency of 1000Hz to 4000Hz in all three groups.

For ABR testing, the subject was made to sit in a reclining chair. The skin surface of the high forehead, lower forehead and mastoid of both the ears was cleaned using skin abrasive to achieve an impedance of less than 5k ohms. The electrodes were placed using conduction paste and surgical plaster for firm attachment. The subjects were instructed to relax and minimize body movements to reduce the artifacts while recording. Click evoked auditory brainstem response was measured by the repetition rates of 11.1/sec and 90.1 /sec at the intensity level of 90 dB nHL and rarefaction as the stimulus polarity with the band pass filter of 100-3000 Hz for both the ears. Conventional electrode montage of non-inverting at the high forehead, inverting at the mastoid of both the ears, and ground at lower forehead was used. The protocol for ABR recording is mentioned in Table 2.1.

Table 2.1: *Protocol for click evoked auditory evoked potentials*

Transducer	ER 3A insert ear phones
Filter band	100 to 3000 Hz
No of sweeps	3000
Stimulus, duration	Clicks,0.1ms
Intensity	90 dBnHL
Polarity	Rarefaction
Repetition rate	11.1/sec& 90.1/sec
Time window	12 ms
Electrode placement	Inverting electrode (-): Mastoid Non-inverting electrode (+): upper forehead Ground: lower Forehead

Screening checklist for auditory processing developed by Yathiraj and Mascarenhas (2003) were administered on all children to rule out auditory processing disorder. This checklist consists of 12 questions. The checklist is scored on a 2-point rating scale as “Yes” or “No”. Each answer marked ‘yes’ scored one and each ‘no’ was scored zero and children who scored more than 50% (6/12) was considered to be at risk for CAPD. Screening Test for Auditory Processing (STAP)was also administered to all those who were referred based on SCAP. The STAP audiological test contains four subsections i.e. speech-in-noise test, dichotic consonant vowel test, gap detection test and auditory memory test. The CD of the test contained a 1 kHz calibration tone, overall instruction to the test, and instructions of each subsection prior to each subsection testing. The cut-off criteria defined by the developer were used for the pass and fail purposes.

A diagnostic speech in noise test was performed by presenting the phonetically balanced words developed for the children in the presence of ipsilateral broadband noise at 0 dB SNR. Speech stimuli used in the present study were taken from the phonetically balanced word list developed by Rout in 1996 to obtain the speech identification score. Subjects were instructed to repeat the words which were heard by them. The stimuli were presented monaurally in the presence of noise at 0dB SNR. On the basis of scores obtained for the control group, cut-off criteria of 50% was set for both clinical groups to decide good performing and poor performing children with learning disability.

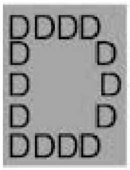
2.5.2 Phase 2: Tests of temporal processing, auditory working memory and attention

Temporal processing tests administered in the present study were temporal modulation transfer function and Gap Detection Test. The Gap detection threshold was measured using the maximum likelihood procedure (MLP) tool box in MATLab software. The maximum likelihood procedure uses a large number of candidate psychometric functions and after each trial calculates the probability of obtaining a listener response to the stimuli that have been presented given each psychometric function. The participant's ability to detect temporal gap which were embedded in the centre of a 750 ms broadband noise (Harris, Eckert, Alstrom & Dubno, 2010), is considered as response. The noise was designed to have 0.5ms cosine ramp at the beginning and ending of the gap. This broadband noise was used for the GDT as its spectrum does not change with the insertion of the gap (Moore, 2003) using MATLAB software three alternative forced choice (3-AFC) paradigm to estimate the threshold. The subjects were instructed as *"Please listen to the set of three noise burst, one of three noise burst contains a gap of varying duration. Subjects had to indicate verbally or can press the button to indicate that which of the three-noise burst in the set had the gap"*. The stimuli set presented monaurally at a comfortable level. Practice trial was given to familiarize the subjects before the actual testing performed. The minimum gap detected by the subjects was taken as the gap detection threshold.

TMTF was used to find the modulation detection threshold in an amplitude modulated white noise. The stimuli will be presented to subject in 3 AFC paradigm. Stimuli will be presented at different modulation frequency (200 Hz, 60 Hz 20 and 8 Hz) subject's task was to identify the interval containing the amplitude modulation at different modulation frequencies. A 500-ms Gaussian noise is sinusoidally amplitude modulated at different modulation frequencies. The depth of the modulation is expressed as 20log(m), where m is a modulation index that ranges from 0.0 (no modulation) to 1.0 (full modulation). The subject has to detect the modulation (in yes/no task) or to tell which interval has the modulated noise. The threshold is the modulation depth (in dB). The lowest level at which modulation detected is considered as threshold for TMTF.

Auditory working memory was assessed using auditory digit span for the forward and backward phase. In this task, cluster of digits was presented in random order with the increasing level of difficulty. The participants were asked to repeat the numbers in the same order for forward digit span test and in reverse order for backward digit span. The stimuli were presented using Smriti Shravan software (English language based test) installed in the PC. Auditory working memory capacity was calculated based on the total number of digit child could successfully recall.

For Stroop test, all the participants were assessed for the selective attention task in terms of reaction time and accuracy rate using DMDX software. The *Navon's letter* was presented visually on a laptop screen. Participants were instructed to press ‘1’for the congruency condition, if the letter shape matches with its elements and press ‘0’for the incongruent condition, if the letter shapes do not match with its elements. The font sizes of Navon’s figures were adjusted in such a way that it occupies the center of the screen. A total of twenty stimuli was presented in random order. Based on number of correct responses the accuracy rate was calculated in percentage and the time taken to give the correct responses was calculated to give the reaction time in millisecond.

a) 

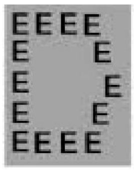
b) 

Figure 1: Examples for Navon’s letter (a) Congruent D, (b) Incongruent E

Example: In figure 1 (a) the expected response will be to press key 1 as letter D is made up of D itself and they match. In figure 1(b), letter D has E as its elements. The expected response will be to press a key ‘0’.

2.6 Statistical Analysis

The collected data were tabulated and entered in SPSS for the statistical analyses. Descriptive analysis was done to find out mean and standard deviation of temporal processing tests (GDT, &TMTF), test of auditory working memory (Digit span test) and test of attention (Stroop test). Shapiro Wilk test was done to check the normal distribution of the data. It was noticed that the data collected for GDT, TMTF, Digit span test and Stroop test were not normally distributed. Hence, non-parametric test was used for all the above measures. The non-parametric test, i.e. Man-Whitney U test was done to compare between two groups for Gap detection test, temporal modulation transfer function test, digit span test, and the stroop test. A spearman's correlation was done to check if there is any correlation between Temporal processing test, auditory working memory and attention in children with learning disability.

Chapter 3

Results

There were 12 typically developing children and 20 children with learning disability included in the control and clinical group respectively. Children with learning disability were further divided into two groups (good performing and poor performing children) based on the SPIN scores. Those children who obtained scores of more than 50% in SPIN were considered as good performing LD group (Group 1) and children who obtained below 50% were considered as poor performing group LD group (Group 2).

3.1 Gap detection test:

The mean gap detection threshold in children with learning disability was higher (poorer) in comparison to typically developing children. The mean score of poor performer learning disabled children were almost double of the good performer learning disabled children. Further, both LD group children (group 1 and 2) mean scores of GDT was several folds higher (poorer) in comparison to the typically developing children. Further, the SD was likewise higher among learning disabled children in comparison to typically developing children (Table 3.1 & Figure 3.1).

Table 3.1: Gap detection threshold in Children with Learning disability and typically developing children

	Children with Learning disability				**Typically developing children**	
	Group 1		**Group 2**		**Group 3**	
Variables	Mean	SD	Mean	SD	Mean	SD
GDT	28.40	25.08	48.66	24.04	3.50	0.89

Note: SD- Standard deviation; Group1: good performer; Group2: poor performer; Group 3: typically developing children

Man-Whitney U was done to check the statistically significant difference between typically developing children and children with learning disability. The Mann-Whitney U test showed a significant difference (Z=-3.956, p< 0.05) between group 1 and group 3, as well as between group 2 and group 3 (Z=-3.960, p< 0.05 However, there was no significant difference noticed between group 1 and group 2 (Z=-1.517, p>0.05) i.e. between good and poor learning-disabled children group. Hence, the null hypothesis is rejected since there is a significant difference between typically developing and children with learning disability.

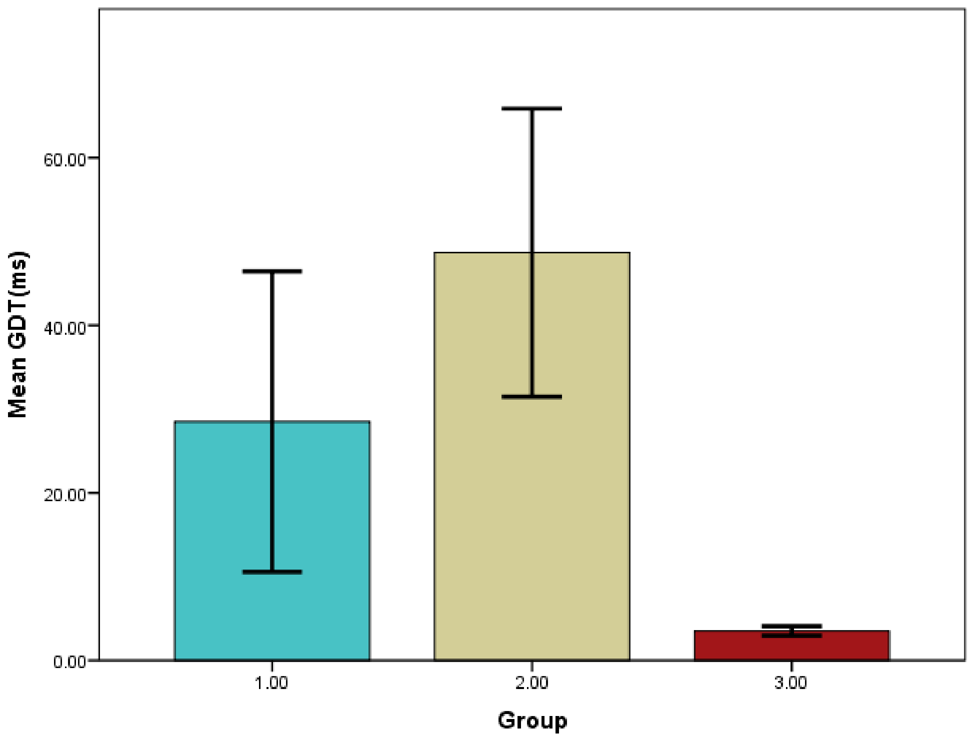


Figure 3.1: Mean and standard deviation (SD) of GDT scores (msec) for three different groups (Group1: good performer LD children; Group2: poor performer LD children; Group 3: typically developing children).

3.2 Temporal modulation transfer function test

Mean temporal modulation transfer function threshold was lower (poorer) in both groups of children with learning disability when compared to typically developing children in all four modulation frequencies i.e. 8, 20, 60 and 200 Hz. The mean TMTF thresholds were lowest (poorer) at higher frequencies i.e. at 200 Hz compared to other frequencies i.e. 8, 20, and 60 Hz in all the three groups (Table 3.2 & Figure 3.2).

Table 3.2: Temporal modulation transfer function threshold in Children with Learning disability and typically developing children

	Children with Learning disability				**Typically developing children**	
	Group 1		**Group 2**		**Group 3**	
VARIABLES	MEAN	SD	MEAN	SD	MEAN	SD
TMTF 200	-7.42	-3.71	-4.70	-2.94	-8.33	-2.97
TMTF 60	-9.89	-3.12	-6.50	-4.16	-11.31	-2.69
TMTF 20	-9.86	-3.32	-6.67	-4.84	-13.84	-2.89
TMTF 8	-11.22	-2.91	-6.86	-5.09	-13.56	-3.38

Note: SD- Standard deviation; Group 1: good performer LD children; Group 2: poor performer LD children; Group 3: typically developing children.

Man-Whitney U test was made to compare the significant difference between the three groups. Results revealed that between group 2 and group 3, there was a statistically significant difference at all modulation frequencies. i.e. at modulation frequency 200Hz ($Z=-2.537$, $p<0.05$), 20Hz ($Z=-2.919$, $p<0.05$),60Hz ($Z=-2.349$, $p<0.05$), and at 8Hz ($Z=-2.788$, $p<0.05$). When comparison was done between group 1 and group 3, there was statistical significant difference only at modulation frequency of 20 Hz (Z=-2.474, p <0.05). However, statistical significant differences did not notice between group 1 and 3 at TMTF frequencies of 200Hz (Z=-0.957, p>0.05), 60Hz (Z=-1.123, p>0.05), and 8Hz (Z=-1.486, p>0.05). Similarly, between group 1 and group 2, there was a significant difference observed only at modulation frequency of 200Hz (Z=-2.317, p<0.05). Other modulation frequencies did not show significant differences at 20Hz (Z=-1.791, p>0.05), 60Hz (Z=-1.708, p>0.05), and 8Hz (Z=-1.905, p>0.05) between two clinical groups.

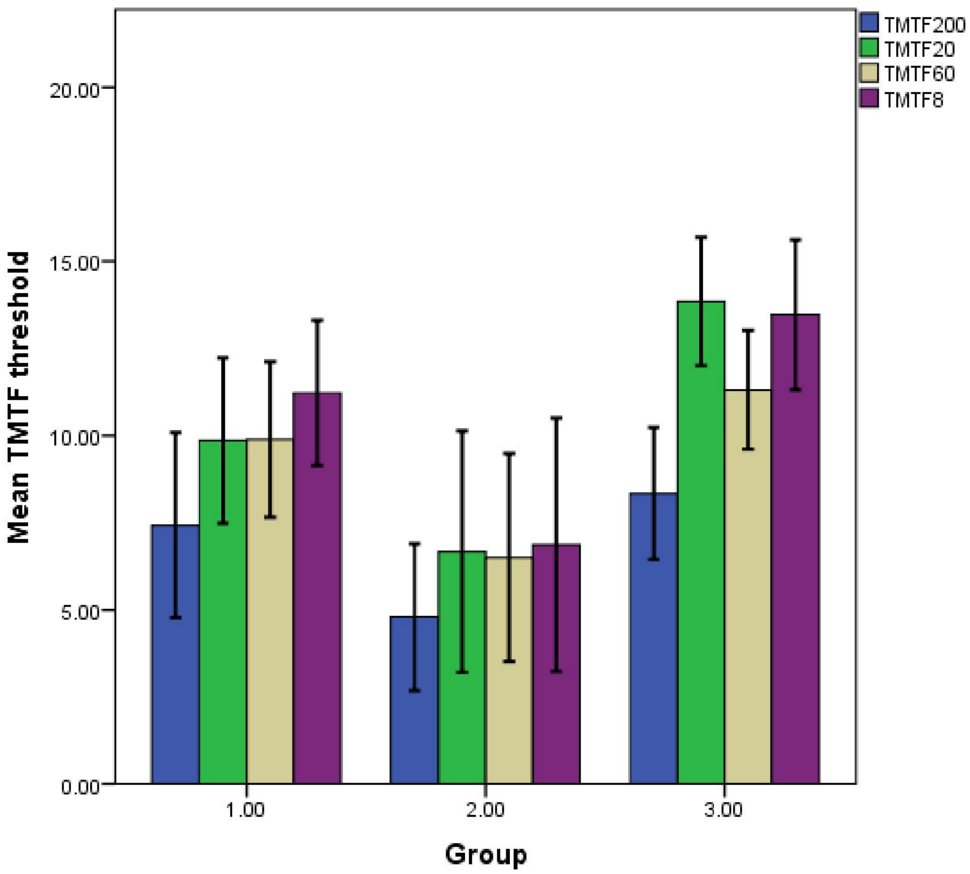


Figure 3.2: Mean and standard deviation (SD) of TMTF scores for three different groups (Group1: good performer LD children; Group2: poor performer LD children; Group 3: typically developing children).

3.3 Digit Span Test

The mean scores of typically developing children and children with learning disability shows lower (poorer) scores for clinical group compared to control group in both forward digit span test and backward digit span test. Among both the clinical group, the group 2 showed poorer mean scores for both FDS and BDS compared to group 1 (Table 3.3 & Figure 3.3).

Table 3.3: Digit Span test threshold in Children with Learning disability and Typically developing children

	Children with Learning disability				**Typically developing children**	
	Group 1		**Group 2**		**Group 3**	
Variables	Mean	SD	Mean	SD	Mean	SD
FDS	3.90	0.73	3.60	0.69	5.25	0.45
BDS	2.40	0.51	2.40	0.699	3.75	0.45

Note: SD- Standard deviation; FDS: Forward digit span; BDS: Backward digit span; Group 1: good performer LD children; Group 2: poor performer LD children; Group 3: typically developing children.

Man-Whitney U test was done to compare the statistically significant difference between the three groups. The result of forward digit span test showed a statistically significant score between group 1 and group 3 ($Z=-3.626$, $p <0.05$) and a significant difference of ($Z=-3.884$, $p <0.05$) between group 2 and group 3. But there was no significant difference between group 1 and group 2 ($Z=-9.46$, $p >0.05$).

The result of backward digit span test showed a significant difference between group 1 and group 3(Z=-3.794, p <0.05) and a significant difference between group 2 and group 3 (Z=-3.512, p <0.05). But between group 1 and group 2 there was no significant difference (Z=-0.271, p >0.05). Hence, null hypothesis is rejected since there is a significant difference between typically developing and children with learning disability.

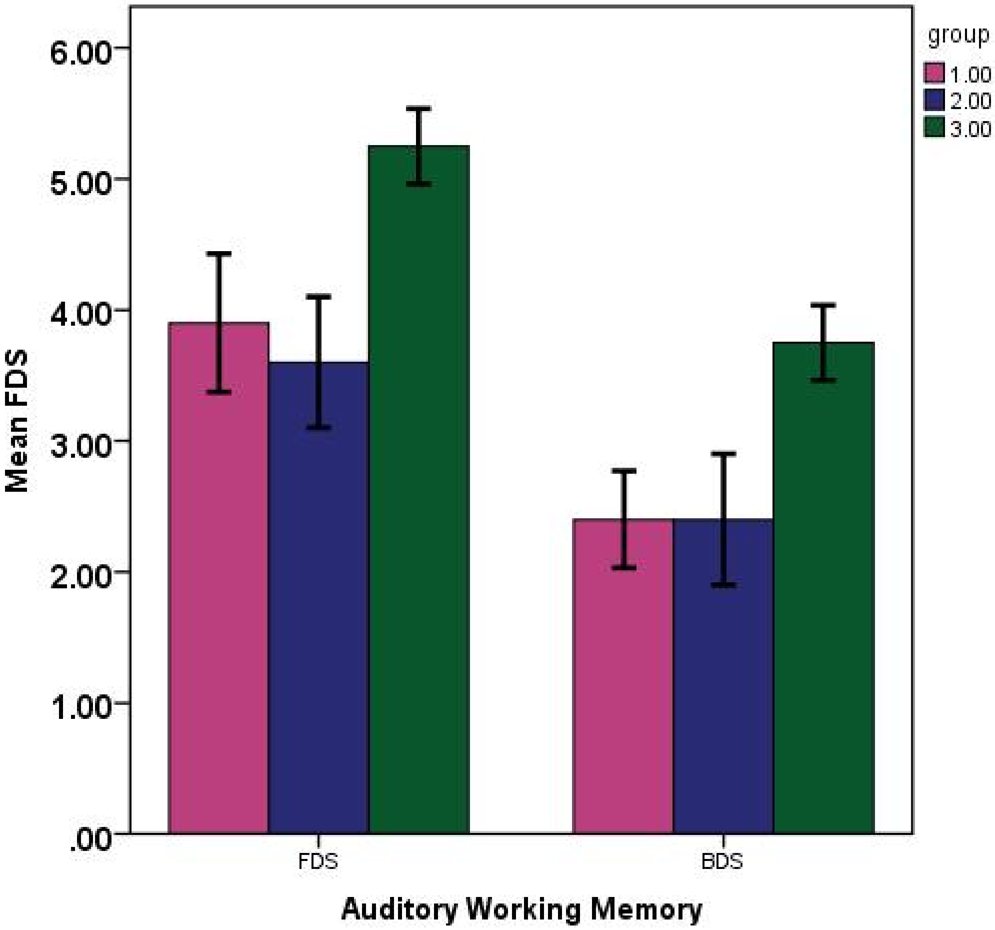


Figure 3.3: Mean scores of forward and backward digits span test for three different groups (Group1: good performer LD children; Group2: poor performer LD children; Group 3: typically developing children)

3.4 Stroop Test

The mean percentage of DMDX accuracy rate and DMDX reaction time in children with learning disability was lower (poorer) in comparison to typically developing children. Among clinical group, the accuracy rate of the group 2 was lower (poorer) than group 1. Similarly, the reaction time was highest for the group 2 children compared to group 1 (Table 3.4 & Figure 3.4; 3.5).

Table 3.4: DMDX accuracy rate and reaction time in Children with Learning disability and typically developing children.

	Children with Learning disability				**Typically developing children**	
	Group 1		**Group 2**		**Group 3**	
Variables	Mean	SD	Mean	SD	Mean	SD
DMDX AR (%)	84.00	10.74	76.10	19.31	92.91	4.50
DMDX RT (ms)	1251.89	222.10	1273.67	277.36	1074.50	96.68

Note: SD- Standard deviation; AR: Accuracy rate; RT: Reaction time; Group 1: good performer LD children; Group 2: poor performer LD children; Group 3: typically developing children.

Man-Whitney U test was performed on both DMDX accuracy rate and reaction time to find the statistical difference between typically developing children and children with learning disability. In DMDX accuracy rate, results showed statistical significant difference between group 1 and group 3 ($Z= -2.021$, $p<0.05$) and between group 2 and group 3 ($Z= -2.159$, $p<0.05$). However, there was no significant difference between group 1 and group 2($Z=-0.724$, $p>0.05$).

Mann-Whitney U test results revealed a significant difference between group 1 and group 3 (Z= -2.308, $p<0.05$) for DMDX reaction time. However, there was no significant difference noticed between group 2 and group 3 (Z=-1.814, $p>0.05$) as well as between group 1 and group 2 (Z=-0.76, $p>0.05$).

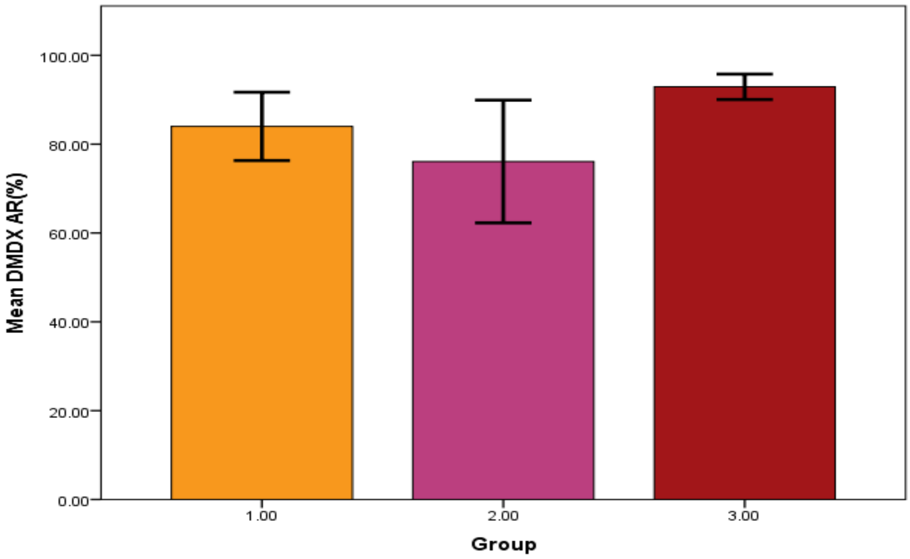


Figure 3.4: Mean DMDX accuracy rate scores (%)for three different groups (Group1: good performer LD children; Group2: poor performer LD children; Group 3: typically developing children).

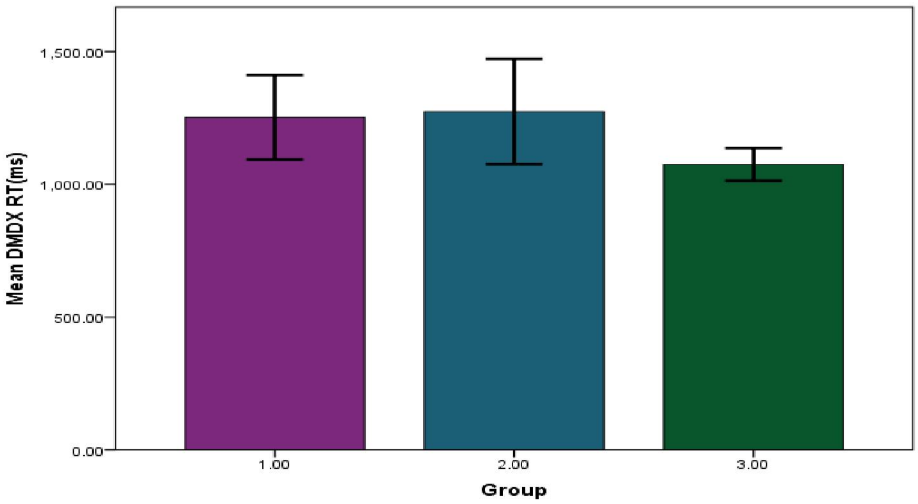


Figure 3.5: -Mean DMDX reaction time (ms) for three different groups (Group1: good performer LD children; Group2: poor performer LD children; Group 3: typically developing children).

3.5 Relationship between Temporal processing, Auditory working memory and Attention test in learning disabled children

Spearman's rank-order correlation test was used to check if there is any correlation between temporal processing temporal processing (GDT, TMTF), auditory working memory (Digit span test) and attention test (Stroop test) in learning disabled children (good performing and poor performing children) group (Table 3.5).

Table 3.5: Correlation scores of temporal processing, auditory working memory and attention test in learning disabled children.

	FDS	BDS	DMDX AR	DMDX RT
GDT	r =-0.253	r =-0.381	r =-0.632	r =0.526
	p=0.282	p=0.097	**p=0.003****	**p=0.017***
TMTF 200 Hz	r =0.197	r =0.330	r =0.620	r =-0.324
	p=0.406	p=0.156	**p=0.004****	p=0.0163
TMTF 20 Hz	r =0.113	r =0.119	r =0.365	r =-0.191
	p=0.635	p=0.617	p=0.114	p=0.420
TMTF 60 HZ	r =0.330	r =0.119	r =0.521	r =--0.295
	p=0.891	p=0.118	**p=0.019***	p=0.206
TMTF 8 Hz	r =0.330	r =0.343	r =0.449	r =-0.267
	p=0.155	p=0.138	**p=0.047***	p=0.256

*Note: *p<0.05; **p<0.01*

3.5.1 Relationship between GDT with FDS and BDS

Spearman correlation analysis showed a weak negative correlation between GDT and FDS as well as between GDT and BDS scores, though it was not statistically significant. The above correlation indicates as GDT scores increases (poorer) both FDS and BDS score decreases (poorer) in children with learning disabled group.

3.5.2 Relationship between GDT with stroop test (DMDX accuracy rate and DMDX reaction time)

Spearman correlation analysis showed a statistically significant moderate negative correlation between GDT and DMDX accuracy rate (Figure 3.6) i.e. as the GDT scores increases (poorer) DMDX AR score decreases(poorer). Whereas correlation analysis showed a significant moderate positive correlation between GDT and DMDX reaction time (Figure 3.7) i.e. as the GDT score increases (poorer), DMDX RT also increases (poorer).

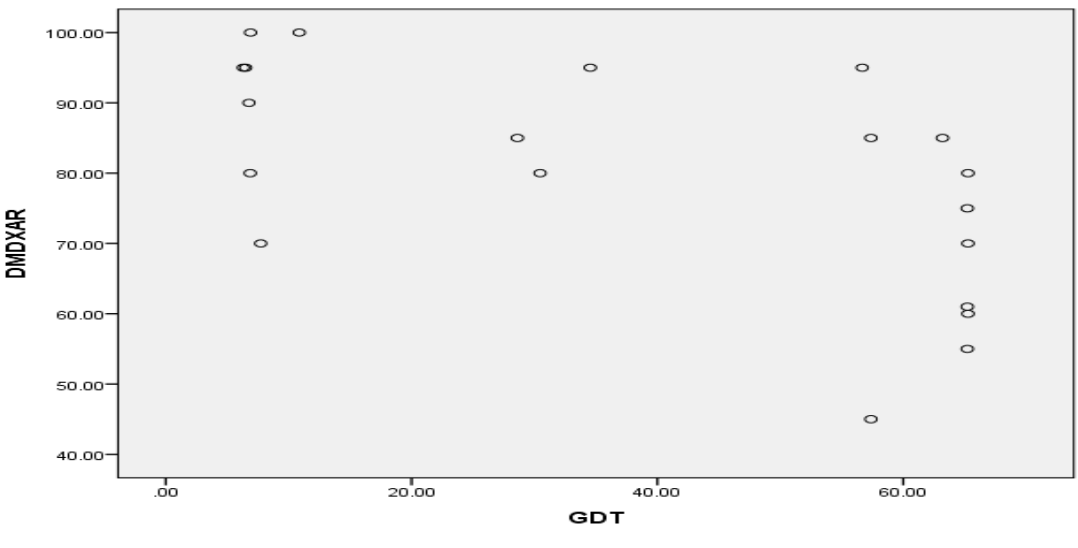


Fig 3.6: Scatter plot between GDT threshold (ms) and DMDX accuracy rate in (%)

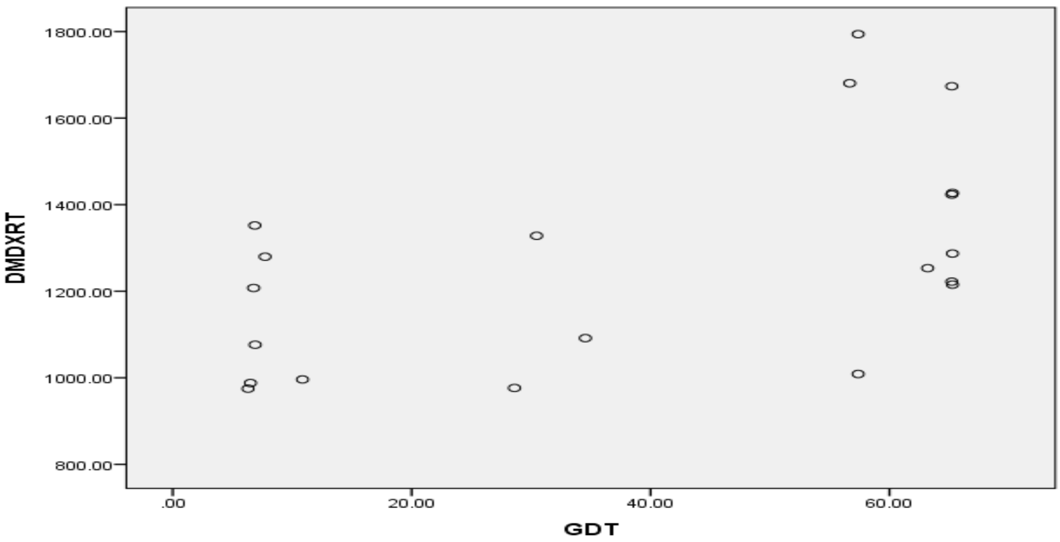


Figure 3.7: Scatter plot between GDT threshold (ms) and DMDX reaction time (ms).

3.5.3 Relationship between TMTF thresholds with FDS and BDS

Spearman correlation analysis showed a weak positive correlation between TMTF thresholds and FDS and BDS scores, though it was not statistically significant. I.e. as the TMTF thresholds increases (better) both FDS and BDS score increases (better).

3.5.4 Relationship between TMTF thresholds with DMDX accuracy rate and reaction time

Spearman correlation analysis showed a significant moderate positive correlation between TMTF thresholds (200 Hz, 60 Hz and 8 Hz) and DMDX accuracy rate (Figure 3.8, 3.9, & 3.10) i.e. as the TMTF thresholds increases (better) DMDX AR score increases(better). However, reaction time showed weak negative relationship with TMTF thresholds though it was not significant i.e. as the TMTF thresholds decrease (poorer), DMDX RT increases (poorer).

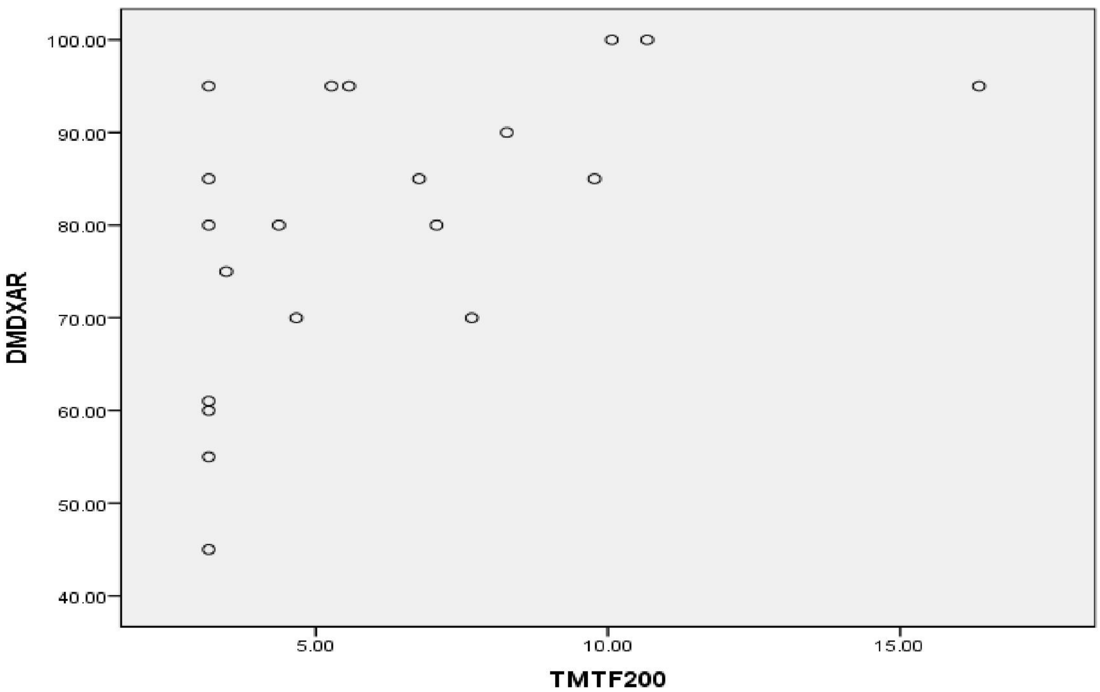


Fig 3.8: Scatter plot between TMTF 200 threshold (ms) and DMDX accuracy rate in (%)

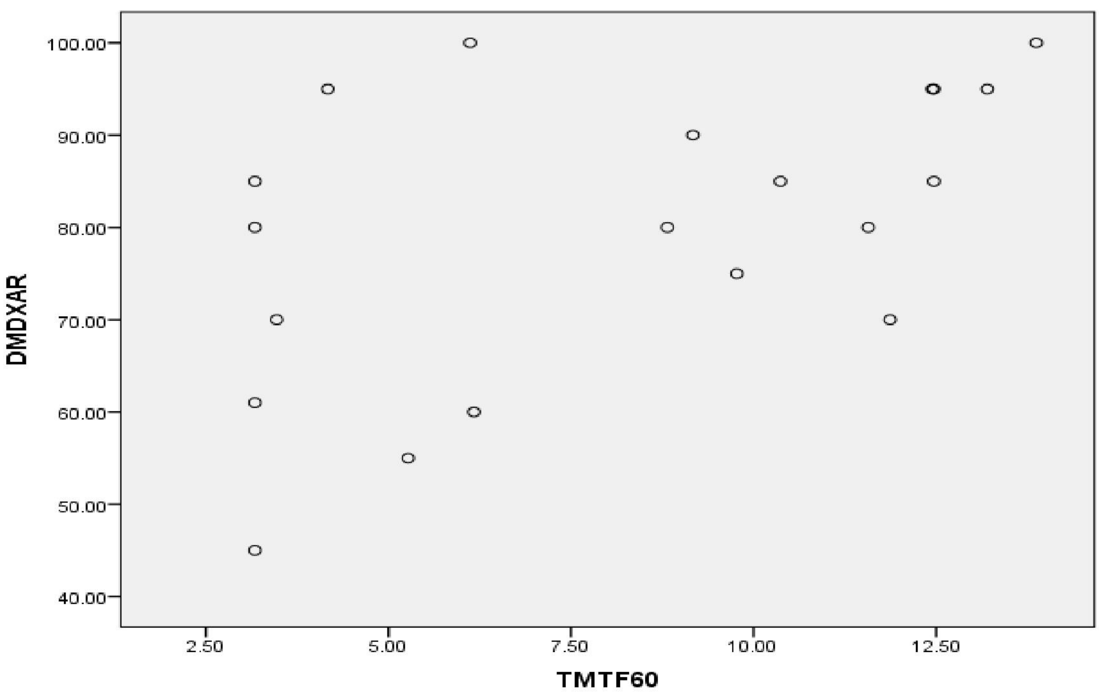


Figure 3.9: Scatter plot between TMTF 60 Hz threshold and DMDX accuracy rate in (%)

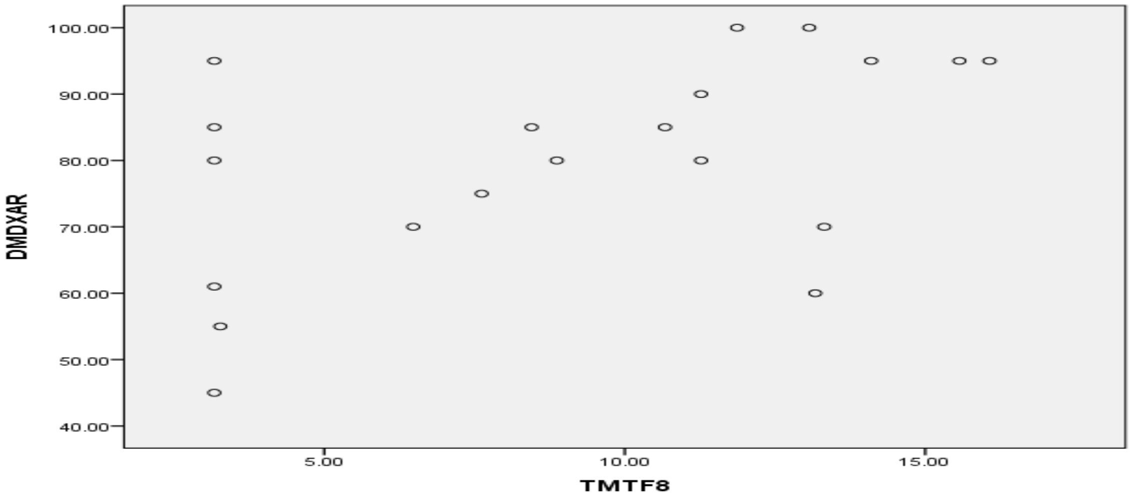


Figure 3.10: Scatter plot between TMTF 8 Hz threshold and DMDX accuracy rate in (%)

Chapter 4

Discussion

The present study was aimed to examine the relationship between temporal processing, selective attention and auditory working memory abilities in children with learning disability in the Indian population. Gap detection and temporal modulation transfer function test were done to assess the temporal processing ability in both groups. Auditory working memory was assessed using a digit span test. Selective attention abilities were assessed by using Stroop test. Auditory closure abilities were assessed using speech in noise test at 0 dB signal-to-noise ratio. Based on the SPIN scores children with learning disability were further divided into two groups (good performing and poor performing children). The children who obtained scores of more than 50% in SPIN were included in the good performing LD group and children who obtained below 50% were included in the poor performing group LD group.

4.1 Temporal processing abilities in children with learning disability

The temporal processing ability of children with learning disability and typically developing children was assessed using gap detection test and temporal modulation transfer function test. The Gap detection test was done which shows a statistically significant difference between children with learning disability and typically developing children. Children with learning disability exhibited poor performance in the gap detection test. Similar findings were reported by McCroskey and Kidder (1980), Haggerty and Stamm (1978), Hautus et al. (2003). In the present study learning disability children were grouped further based on speech perception abilities in the presence of noise (good performing and poor performing children). Within the group of learning disabled, poor performing LD children showed poorer (lesser) mean scores when compared to good performing LD children, though not statistically significant within the LD groups in GDT test. The present finding indicates those LD children who are having poorer abilities to perceive speech in presence of noise are having poorer temporal resolution abilities compared typically developing children.

Another test which was done in the present study for assessing temporal processing is temporal modulation transfer function test. Both typically developing and learning-disabled children showed as the modulation frequency increases from 8 Hz to 200 Hz, the TMTF threshold becomes higher (poorer). TMTF thresholds were poorer in children with learning disability compared to typically developing children. TMTF test showed statistically significant difference at all modulation frequencies between children with learning disability and typically developing children. Present study is in congruence with previous literature (Tallal, 1980); Hall III and Grose (1994) reported sensitivity to sinusoidal modulation of the noise carrier which was determined for modulation frequencies of 5, 20, 100, 150, and 200 Hz. The results showed all the listeners reported decrease in sensitivity to modulation as a function of frequency modulation increases.

Tallal (1980) assessed TMTF in dyslexic's children at two modulation frequencies 2 Hz and 28 Hz. Based on their study they said that dyslexic exhibits the impaired ability to perceive the faster modulation. (Rocheron, Lorenzi, Füllgrabe, and Dumont (2002)) assessed the ability to process temporal envelope cues in dyslexic children by measuring detection threshold of sinusoidal amplitude modulation. Each threshold was measured at slow rates and faster rates at 4 Hz and 128 Hz respectively. Overall sinusoidal amplitude modulation thresholds were higher in dyslexic than normal at both rates. Results of the study reveal that in addition to reduced audibility of slow and fast envelope cues, some dyslexic children show poor encoding fidelity for these cues. Present study showed within LD groups (good performing and poor performing children) there was significant statistical difference only at modulation frequency of 200 Hz. However, in present study few individuals with learning disability had showed equal performance to that of normal subjects. This may be because all individuals with learning disability may not have equal amount of impairment in the temporal processing skills. From the above findings, it can be concluded that learning disabled required higher modulation depth than typically developing children.

4.2 Auditory working memory abilities in children with learning disability

Present study shows learning disabled children has statistically significant lower (poorer) scores compared to typically developing children in both forward digit span test and backward digit span test. However, there was no significant difference within the groups of LDs (good performing and poor performing) children. Present study finding are in congruence with previous reported literature (Siegel & Ryan, 1989; Cohen Mimren & Sapir, 2007; Swanson et al., 2009) in likewise population. Siegel and Ryan (1989), studied the performance of working memory in arithmetic disabled, reading disabled and attention deficit disordered. Working memory was assessed by using two working memory tasks, one involving sentences and the other involving counting. Reading disability children showed significantly poorer scores on both tasks and arithmetic disabled children showed lower scores only on the Counting task. Thus, they concluded that a reading disability appears to involve a generalized deficit in working memory. Swanson, Zheng, and Jerman (2009), measured working memory abilities using simultaneous processing and storage of digits within sentence sequences and final words from unrelated sentences. Children with reading disability showed deficit in working memory suggesting that they fails to efficiently draw resources from both a phonological and executive system. Cohen-Mimran and Sapir (2007), studied memory task (digit span test) in children with and without reading disability. Results of the study showed that when compared with typical developing children, reading disables children showed significant poorer performance on the working memory tests. In contrary, Malstädt et al. (2012) studied the recall abilities in children with and without spelling impairment. Results showed children without spelling impairment had poor recalling abilities, they said this difference may be due to deficit in central executive and phonological loop functioning. Peng and Fuchs (2016) studied the verbal and nonverbal working memory deficit and the results showed reading disabilities and mathematical difficulties showed poor verbal working memory deficit whereas mathematical difficulties showed more difficulties in numerical working memory than reading difficulty children. Hence this depict that there is domain specific nature of working memory deficit. Woking memory is the joint retrieval of information while simultaneously holding other bits of information in storage characterized by rapid decay. It is more complex than the short-term memory and is deficient in the learning-disabled children.

4.3 Selective attention abilities in children with learning disability

Attention skills were tested using Stroop test in both learning disabled and typically developing children. Stroop test reaction time and accuracy rate was calculated. Stroop test showed the mean percentage of DMDX accuracy rate and DMDX reaction time in children with learning disability had statistically significant lower scores (poorer) in comparison to typically developing children.

DMDX reaction time also showed statistically significant lower scores (poorer) in comparison to typically developing children, but there was no significant difference between reaction time within the learning disability groups. Similar findings were reported by Ramus et al (2003), they studied all measures of literacy: reading speed and accuracy, spelling, pseudo word reading accuracy and time in dyslexics and control group. Results showed scores were significantly poor than controls in all the entire test. In addition, all dyslexics were poorer than controls in the different phonological tests: their naming time was longer. Mayes et al., (2000) did study ADHD and LD children and their results showed that children with ADHD but no LD had some degree of learning problem, and children with LD but no ADHD had some degree of attention problem. Results indicate that learning and attention problems are on a continuum, are interrelated, and can usually coexist. Although they differ by degree, depending on the child's ADHD or LD diagnosis. Horowitz-Kraus and Breznitz (2011) studied the processing time and accuracy when performing errors during letter, word and sentence reading in dyslexic and regular readers. Results of both groups showed longer reaction times for incorrect response but the dyslexics group showed significantly higher reaction time than regular readers. Miller-Shaul (2005) did a study which includes four groups of subjects (two groups of fourth graders, dyslexic and normal readers, and two groups of students, compensated dyslexics and normal readers). Results showed that that dyslexics had slow speed of processing in verbal and non-verbal tasks. Moll et al. (2016) studied the temporal processing, processing speed and working memory in children with specific learning disorder. Results revealed that poor attention was associated with all these three risk factors. Further on controlling the attention, they found that reduced processing speed was related to the reading disorder children and not mathematical disorder but temporal processing was associated with the mathematical disorder and not reading disorder.

4.5 Relationship between Temporal processing, Auditory working memory and Attention test in learning disabled children

Present study was done to find is there any relationship between temporal processing temporal processing (GDT, TMTF), auditory working memory (Digit span test) and attention test (Stroop test) in learning disabled children (good performing and poor performing children) group. Gap detection threshold with digit span test (FDS and BDS) showed there was a negative correlation between GDT and FDS as well as GDT and BDS scores i.e. as GDT scores increases (poorer) both FDS and BDS score decreases (poorer) though it was not statistically significant. Similarly, temporal modulation transfer function test with digit span showed there was a positive correlation between all the TMTF modulation frequencies (TMTF 200Hz, 20Hz, 60Hz,8Hz) and working memory test (FDS and BDS) scores i.e. as the TMTF threshold scores increases (better) both digit span test score increases (better) but it was not statistically significant. Studies done by several researchers were reported relationship between temporal processing and working memory skills in children with learning disability (Swanson, 1993; Shankweiler & Crain, 1986; Banai & Ahissar, 2004). Swanson (1993) claimed that working memory is more important for children and adults without learning disabilities. Shankweiler and Crain, (1986), found that children with learning disabled showed deficit in working memory along with poor temporal processing skills. Banai and Ahissar (2004) claimed that working memory underlies the difficulties that learning disabled exhibit in in auditory temporal resolution tasks, since it reduces the access to stored information.

Gap detection threshold with Stroop (DMDX AR & DMDX RT) test showed there was a statistically significant negative correlation between GDT and DMDX Accuracy rate i.e. as the GDT scores increases (poorer) DMDX accuracy rate decreases(poorer). Also, there was a statistically significant positive correlation between GDT and DMDX reaction time i.e. as the GDT score increases (poorer), DMDX reaction time also increases (poorer).

Similarly, temporal modulation transfer function test and Stroop test (DMDX AR and DMDX RT) showed there was a statistically significant positive correlation between TMTF 200 Hz, 60 Hz, and 20 Hz and DMDX AR i.e. as the TMTF scores increases (better) DMDX AR score increases (better). However, there was a negative correlation between all TMTF modulation frequency and DMDX Reaction time i.e. as the TMTF threshold score decrease (poorer), DMDX reaction time increases (poorer). Studies done by Martinussen, Hayden, Hogg-Johnson, and Tannock (2005) Shanahan, MacArthur, Graham, and Fitzgerald (2006)

Willcutt, Doyle, Nigg, Faraone, and Pennington (2005); and (Gooch, Snowling, and Hulme (2011)) reported some association between temporal processing, working memory, and attention problems in clinical population. (Martinussen et al. (2005) proposed that deficit in working memory are related to attention problems. Study done by Willcutt et al in year 2005 showed that slow processing speed and its risk factor for the occurrence of reading disability and attention problem are associated to each other. Gooch et al. (2011) claimed that if the individual difference in the attention is not taken into account then there is high chance of overestimating the deficits in the temporal processing skills. Thus, it can be concluded that the high variation on the temporal processing test results may be due to working memory and attention deficit in learning disabled children.

Chapter 5

Summary and Conclusion

The present study was undertaken to accomplish following objectives:

1. To examine the performance of children with learning disability (good and poor performer) on temporal processing task (GDT and TMTF).

2. To examine the performance of children with learning disability (good and poor performer) on attention and auditory memory task.

3. To explore the relationship between temporal processing task, attention and auditory working memory in good and poor performer children with learning disability

To accomplish following aims, 20 children with learning disability and 12 typically developing children in the age range of 8 to 12 years were included in the study.

The results of the study were as follows:

5.1. Test of temporal process:

I. Mean gap detection threshold was 3.50 ms for typically developing children and 28.40 ms for good performing learning-disabled children and 48.66 ms for poor performing learning disabled children. The Mann-Whitney U test showed a significant difference between typically developing children and learning-disabled children. However, there was no significant difference noticed between good and poor learning-disabled children group.

II. Mean temporal modulation transfer function threshold at different modulation frequency are as follows:

a) Mean temporal modulation transfer function threshold at 200 Hz for typically developing children was -8.33 dB, and for good and poor performing learning disabled children - 7.42 dB and -4.70 dB respectively.

b) Mean temporal modulation transfer function threshold at 20 Hz for typically developing children was -13.84 dB and for good and poor performing learning disabled children -9.86 dB and -6.67 dB respectively.

c) Mean temporal modulation transfer function threshold at 60 Hz for typically developing children was -11.31 dB, and for good and poor performing learning disabled children – 9.89 dB and -6.50 dB respectively.

d) Mean temporal modulation transfer function threshold at 8 Hz for typically developing children was -13.56 dB and for good and poor performing learning disabled children -11.22 dB and -6.86 dB respectively.

e) Man-Whitney U test revealed significant difference between group of poor learning disability and typically developing children at all modulation frequencies. (200 Hz, 60 Hz and at 8 Hz). However, there was statistical significant difference only at modulation frequency of 20 Hz between group of good performing learning-disabled children and typically developing children. Similarly, between good performing and poor performing learning disabled children there was a significant difference observed only at modulation frequency of 200 Hz.

5.2. Test of auditory working memory

i. Mean forward digit span score was 5.25 for typically developing children, 3.90 for good performing learning-disabled children and 3.60 for poor performing learning disabled children.

ii. For backward digit span test, mean score was 3.75 for typically developing children and 2.40 for both good performing and poor performing learning disabled children.

iii. Man-Whitney U test showed statistically significant difference in digit span test (forward digit span & backward digit span) between learning disabled children (both good performing and poor performing learning disabled children and typically developing children But between good performing and poor performing learning disabled children there was no significant difference for forward digit and backward digit span test.

5.3. Test of attention

i. Mean score on stroop test, i.e. DMDX accuracy rate was 92.91% for typically developing children, 84% for good performing learning-disabled children and 76.10% for poor performing learning disabled children.

ii. Mean score one DMDX reaction time was 1074.50 ms for typically developing children, 1251.89 ms for good performing learning-disabled children and 1273.67 ms for poor performing learning disabled children.

iii. Man-Whitney U test was performed on both DMDX accuracy rate and reaction time to find the statistical difference between typically developing children and children with learning disability (both good performing and poor performing learning disabled children). However, there was no significant difference between good performing and poor performing learning disabled children

iv. Mann-Whitney U test results revealed a significant difference in DMDX reaction time between good performing learning-disabled children and typically developing children in DMDX reaction time. However, there was no significant difference noticed between poor performing learning disabled children and typically developing children and as well as between good performing and poor performing learning disabled children

5.4. Relationship between temporal processing, auditory working memory and attention

i. Statistically significant relationship between temporal processing (gap detection & temporal modulation transfer function test) and auditory working memory test (digit span test) observed for children with learning disability.

ii. Statistically significant relationship between temporal processing (gap detection & temporal modulation transfer function test) and selective attention (Stroop test) test observed for children with learning disability.

The result of these findings revealed that there is relationship between temporal processing, auditory working memory and attention in learning disabled children. However, this relationship may not be present in all the children with learning disability.

Implication of the study

a) The findings of this study are helpful in deciding the need for the changes which has to be done on test battery approach in assessing learning disabled children.
b) Classification of learning disabled children into subgroups based on their performance on temporal processing, working memory and attention.
c) It may be helpful in selection of different rehabilitation program based on their presence or absence of comorbid condition.
d) Add on to the literature.

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