# VALIDATION OF SCREENING TEST FOR AUDITORY PROCESSING IN CHILDREN AGED 6 TO 8 YEARS

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## CERTIFICATE

This is to certify that this dissertation entitled **"VALIDATION OF SCREENING TEST FOR AUDITORY PROCESSING IN CHILDREN AGED 6 TO 8 YEARS"** is a bonafide work in part of fulfillment for the degree of Master of Science (Audiology) of the student with Registration No. 13AUD004. 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,
May 2015

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## DECLARATION

This is to certify that this dissertation entitled **"VALIDATION OF SCREENING TEST FOR AUDITORY PROCESSING IN CHILDREN AGED 6 TO 8 YEARS"** is the result of my own study under the guidance of **Dr. Asha Yathiraj**, Professor 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.

Mysore
May, 2015

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## Abstract

The negative impact of an auditory processing disorder (APD) on the functioning of individuals having the condition, necessitates its early identification and intervention. Several tools to screen for APD have been reported in literature that includes screening checklists and screening tests. A screening tool 'Screening Test for Auditory Processing' (STAP) developed by Yathiraj and Maggu (2012) has been validated on children aged 8 to 13 years but not on children below this age. The present study focussed on validating STAP on school-going children aged 6 to 8 years. The sensitivity and specificity of STAP on children aged 6 years to 8 years were determined by comparing the outcomes of the screening test with a battery of APD diagnostic tests. Four hundred and twenty-six children aged 6 to 8 years were initially screened using the 'Screening Checklist for APD' (SCAP) given by Yathiraj and Mascarenhas (2003) by class teacher. STAP was administered on 100 of these children who had either passed or were at-risk for APD on the screening checklist, using a blind approach. The children who were administered STAP consisted of 43 children who were at-risk for APD based on SCAP. A battery of diagnostic tests (Speech-in-Noise in Indian-English, Dichotic CV, Gap Detection Test, & Auditory Memory and Sequencing test) was administered on 35 children who were referred and/or passed on the screening procedures. The results on STAP revealed that gap detection subsection was the least affected, followed by auditory memory and speech in noise subsections. Dichotic CV was found to be the most affected in all the children. A moderate to strong correlation was found between the subsections of STAP and APD diagnostic tests. The sensitivity of STAP was found to be 73% and specificity was

66.66%. A combination of SCAP and STAP showed a higher sensitivity (83%) and specificity (69%). The 6 to 7 year old children were able to perform the tests although their scores were significantly poorer than that of children aged 7 to 8 year on some of the subsection of STAP / diagnostic APD tests. Based on these findings, it is recommended to use both SCAP and STAP be used as a part of screening program for APD and STAP can be utilised in the children aged 6 years and above. However, a revision in the cut-off scores for pass/refer criteria needs to be considered to improve its sensitivity without compromising on the specificity.

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# Chapter 1

## Introduction

Auditory processing disorder (APD) continues to enthral researchers even after many years of discussion and is far from ending queries that have been raised. Stuart (2005) considered APD as a riddle due to poor consensus on the nature of the disorder and on account of its heterogeneity, its diagnosis, implications and intervention. Aspects related to efficient early detection, diagnoses and treatment of APD in young school-going children are still questioned. According to  Bellis and  Ferre (1999), APD may be seen as a multidimensional entity with effects on communicative, educational and psychosocial well-being of an individual. Owing to these potential effects on the quality of life of individuals affected by APD, many professionals have tried defining APD over the years, based on the processes involved and symptoms exhibited by the individuals. As early as 1972, Eisenson explained auditory processing as the means by which individuals organize and interpret sensory data received, on the basis of past auditory experience. ASHA (2005) elucidated that for processing auditory signals, several skills are required such as sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition such as temporal integration, temporal discrimination, temporal ordering, temporal masking and auditory closure. Individuals showing deficits in any of the required skills were considered to have an APD.

Auditory processes are considered important for normal language comprehension and learning (Bellis & Ferre, 1999). Over several years, researchers have contributed to the area of APD by devising and administering assessment tools that have shown to be sensitive to specific deficits. Early identification and intervention of APD is considered essential as it has been noted that a failure to do so can bring about academic, behavioural and social difficulties (Dawes & Bishop, 2007; Bellis & Ferre, 1999). The adverse impact of APD on the academic performance of children has also been noted in literature (Bellis, 1996; Chermak & Musiek, 2007; ASHA, 2005).

Studies have indicated that a fair number of children demonstrate symptoms of APD, making it necessary to identify them. Muthuselvi and Yathiraj (2009) screened 3120 children using 'Screening Checklist for Auditory Processing' (SCAP) developed by Yathiraj and Mascarenhas (2002, 2003) to identify children with APD symptoms. They reported that 3.2% of the children were at-risk for APD in India. A similar prevalence has been reported by Chermak & Musiek ( 1997) in the western population. Earlier in 1990, Musiek et al., reported that about 2 to 7% of the population is affected with APD. In addressing APD prevalence specifically in older adults, the simultaneous presence of peripheral auditory deficits has been noted to make it difficulty in demarcating purely central auditory disorders. Reports of prevalence of APD in the older adult population vary, ranging from well over 50% in clinical studies (Stach et al., 1991) to around 23% in a longitudinal population study by Cooper and Gates (1991).

The rationale to evaluate APD in school-going children has been considered to lie in the premise of the condition being a cause for many learning related problems (Cacace & McFarland, 1998). The same has been supported by Carter and Musher (2006) who stressed the importance of identifying auditory processing difficulties as they lead to reading and language disabilities. Benasich, Thomas, Choudhury and Leppánen (2002) reported that assessing the ability to process rapidly delivered speech stimuli at a very young age can be predictive of later language outcomes. They suggested that such assessment could serve as a sensitive tool in identifying children with APD as it evaluated difficulties in auditory processing.

Studies have reported that specific training of auditory processes may be beneficial in many children with APD (Alexander & Frost, 1982; Katz, Chertoff, & Sawusch, 1984; Tallal et al., 1996). Further, it has been considered important to detect the presence of a possible auditory processing disorder in young school-going children as early as possible to ensure that the children receive appropriate intervention (Stollman, Neijenhuis, Simkens, & Snik, 2004; Stollman, Simkens, Snik, & Marie, 2004). Thus, early intervention followed by early identification of APD might help children cope with their problems and facilitate language acquisition and academic performance.

Chermak (1996) opined that screening is important to allow timely intervention and it would minimize distress and maximize communicative, educational and social functions. Musiek et al. (1990) reported that without the use of screening procedures, the condition will either not be identified or will be identified late. One of the ways to identify children at-risk for APD is through the symptoms they display. A few commonly reported behavioural signs are difficulty in hearing in noisy situations; following long conversation; hearing conservations on the telephone; learning a foreign language; remembering spoken information; taking notes; maintaining focus on an activity; poor organization skills; multistep directions; and reading or spelling (Olsen et al., 1975; Musiek et al., 1982; Jerger et al., 1987; Chermak & Musiek, 1997; Schminky & Baran, 1999; Stach, 2000). Bamiou, Musiek and Luxon (2001) reported other common difficulties among children with APD like difficulties following oral instructions; difficulties with rapid speech, auditory closure and poor attention that are also in seen in individuals with dyslexia, language impairment and attention deficit hyperactivity disorder. APD is also reported as coexisting with several other speech and language disorders or delays, learning disabilities and attention/hyperactivity disorders (ASHA, 2005). Tallal (2005) described children with dyslexia having difficulty in processing brief, transient auditory stimuli, affecting their speech perception in noisy situations. Likewise, children with Attention Deficit Hyperactivity Disorder have been found to exhibit behavioural characteristics very similar to APD (Jerger & Musiek, 2000; ASHA, 2005). Thus, from literature it can be construed that APD can be exist as an independent condition or coexist along with other disorders.

Checklists / questionnaires having symptoms of APD have been utilised to screen for the presence of the condition. Additionally, screening tests have also been used. Several authors have given screening checklists or questionnaires that can be used to screen children and refer them for a detailed diagnostic evaluation. Some of the screening checklists for children are ‘Selective Auditory Attention Test’ (Cherry, 1980), ‘Scales of Auditory Behaviours’ (Simpson, 1981), ‘Screening Instrument for Targeting Educational Risk’ (Anderson, 1989), ‘Children’s Auditory Processing Performance Scale’ (Smoski, Brunt, & Tannahill, 1990), ‘Children Home Inventory for Listening Difficulties’ (Anderson & Smalidino, 1996), ‘Screening Checklist for Auditory Processing’ (Yathiraj & Mascarenhas, 2003), ‘Screening Checklist for Auditory Processing in Adults’ (Yathiraj & Vaidyanathan, 2014). A few screening tests used to detect APD in children include ‘Screening test for central auditory processing disorders’(Keith, 1986), ‘Screening test for Central Auditory Processing Disorders - Adults’ (Keith, 1995), ‘Screening test for Central Auditory Processing Disorders - Children’ (Keith, 2000), ‘Test of Auditory Perceptual Skills - Revised’ (Gardner, 1997), ‘Multiple Auditory Processing Assessment’ (Domitz & Schow, 2000), ‘Bamford-Kowal-Bench Speech In Noise test’ (Etymotic Research, 2005) and ‘Screening Test for Auditory Processing’ (Yathiraj & Maggu, 2012). However, there lacks a consensus regarding the use of screening checklists versus screening tests. Stach (1992) argued against the use of screening checklists as APD was symptomatic in nature and referrals would be made by teachers and parents based on subjective judgements. Sanchez and Lam (2007) however emphasize the use of standardized screening tests rather than screening checklists as detect individuals who truly have APD. On the other hand, Shiffman (1999) recommended the use of a combination of both screening checklists and screening tests.

**Need for the study**

According to the ASHA technical report (2005), APD is associated with language and academic problems and children with the condition are more prone to emotional and social difficulties. Early identification and intervention in such children may help reduce the impact of the conditionon the quality of their life. Thus, screening young children would help making appropriate referrals before they face considerable difficulties in education, which in turn could bring about behavioural and social difficulties. However, it is important to establish the validity, sensitivity and specificity of the tests to use them effectively to screen individuals who might be at-risk of APD. Considering the importance and advantages of early identification and intervention in children with APD, there is a need to check if a screening APD test developed for older children can be utilised on younger children. Yathiraj and Maggu, (2013, 2014) evaluated the utility of STAP on children above the age of 8 years and found it to be useful in identifying the condition. There is a need to determine whether the same screening test can be used in younger children to enable early detection APD.

**Aim**

The present study aims to validate STAP on school-going children aged 6 to 8 years.

**Objectives**

- To check the efficacy of STAP in school aged children aged 6 to 8 years.
- To measure sensitivity and specificity of STAP in children aged 6 to 8 years.
- To compare performances of the children across SCAP, subsections of STAP and the four diagnostic tests of APD (‘Speech-In-Noise in Indian-English’, ‘Dichotic Consonant Vowel Test’, ‘Gap Detection Test’ and ‘Revised Auditory Memory and Sequencing Test in Indian-English’)
- To establish relationship between STAP and diagnostic tests.
- To compare performance across two age groups (6 to 7 years & 7 to 8 years).

## Chapter 2

## Review

The diagnosis and management of auditory processing disorders (APD) has been a great challenge for audiologists (Lucker, 2007). Chermak (1996) opined that screening is important to allow timely intervention of auditory processing disorder and it would minimize distress and maximize communicative, educational and social functions. However, it is essential to relate maturational changes of the auditory pathway to the functional development of different auditory processes. This would provide information about age related performance of different auditory processes. Several screening checklists (Anderson, 1989; Fisher, 1976; Smoski et al., 1992; Yathiraj and Mascarenhas, 2003, 2004; Muthuselvi and Yathiraj, 2009) and screening tests (Gardner, 1997; Keith, 1986, 1995, 2000; Bellis, 1996; Chermak & Musiek, 1997) have been designed to detect individuals with APD. However, to confirm the presence of APD in those who are suspected to have the condition, there exists a conflict regarding gold standard tests (Cacace & McFarland, 2005; Musiek, Bellis, & Chermak, 2005). Domitz and Schow (2000), Schow, Seikel, Chermak and Berent (1996) recommended the use of a test battery comprising of tests that can tap various auditory processes rather than one single test. Diagnosis of APD is considered essential since several authors have documented the negative impact of APD on learning and academic abilities (Hus, 1997; Cunningham et al., 2001; Banai et al., 2005; McCroskey & Kidder, 1980, Pinheiro, 1977; Willeford, 1977). Also, the problem of identifying and understanding the disorder has been found to become more complex when other additional disorders such as attention deficit disorder, language delays, reading and learning disabilities exist (Keith, 1999). Thus, the below section provides a review of literature on aspects that are essential when establishing the sensitivity and specificity of a screening tool to identify APD in young children.

### 2.1 Maturation and development of auditory processes

It is well established that the human brain is not fully developed at birth. However, the development of new and more efficient synaptic connections continues into adulthood (Kalil, 1989; Restak, 1986). Romand (1983) reported that there are a variety of age dependent morphological changes that occur in the brain; especially the degree of myelination that results in changes in auditory behaviours. The process of myelination, according to Yakovlev and Lecours (1967) has been noted to take place in a caudal to rostral direction. It is reported to be first complete in the brainstem structures which are necessary for survival before first year of life, whereas it is reported to continue in the cortical regions that are necessary for communication, till adolescence. Salamy (1978) added that the corpus callosum is found to be mature by the age of three years.

According to Whitelaw and Yuskow (2005) different auditory processes continue to develop to different ages. Hearing in noise was found to show an improvement till the age of 10 to 11 years, Dichotic listening matured by 10 years of age, Binaural interaction matured by 6 to 8 years of age while temporal processing reached adult values by 10 years of age. Bellis (2003) reported that the dichotic task performance showed improvement till 12 to 13 years of age. Temporal patterning reached adult scores by 12 years while temporal resolution becomes adult like by 8 to 10 years of age. The author also reported that localization was precise by 5 years of age. Other authors also report of auditory processes maturating by 10 to 12 years of age (Neijenhuis, 2002; Keith, 1995, 2000b). Such maturational changes are important to be considered while assessing individuals (Bellis, 1996; 2003).

Yathiraj, Vanaja and Muthuselvi (2012) carried out a study with a battery of diagnostic tests on 280 typically developing children aged 6 to 10 years. They aimed at tracking the maturational changes in auditory processes and to establish normative values for the tests that tapped auditory closure, binaural integration, temporal processing abilities and auditory memory and sequencing abilities. They used 4 tests which included Speech-in-Noise in Indian-English (SPIN-IE) (Yathiraj, Vanaja & Muthuselvi, 2009), Dichotic CV (DCV) by Yathiraj (1999), Duration Pattern Test (DPT) by Gowri (2003) and Revised Auditory Memory and Sequencing Test in Indian-English (RAMST-IE) (Yathiraj, Vanaja & Muthuselvi, 2009). With increase in age the performance on all the tests improve, thought to different levels. The performance of the 6 year old children was observed to be significantly poorer than older children in the tests and there was a plateau of performance observed in the 6 year olds and the 7 year olds. Thus, the authors construed that maturation was nonlinear in nature. However, they concluded that it was possible to test children as young as 6 years.

From the studies on the maturation of auditory process it can be observed that there are several physical and functional changes in the brain occurring in the young children and it continues till adolescence. Studies also report an improvement of performance of the children in various tests that tap their auditory processing abilities also with increasing age.

### 2.2 Screening tools for APD

According to ASHA technical report (2005), APD is associated with language and academic problems and such children are prone to emotional and social difficulties. Thus, the report emphasizes the need for early identification and intervention of children with APD to lessen the impact on their academic, emotional and social life. Screening for the presence of APD has been considered important in order to refer individuals for further diagnostic evaluation.

Screening is defined as "the process of applying certain rapid and simple tests, examination or other procedures to, generally, a large number of populations that will identify those persons with high probability of a disorder from those persons who probably do not have the disorder" (Northern & Downs, 1991, Pp.259 ). Screening tools have been found to enable obtaining preliminary information about APD characteristics from the individuals closely working with the children like parents, educators and to assist in educational planning (Musiek et al., 1990). Also, they are considered to assist in providing directions to different professionals who work with individuals with APD (Bellis, 2003) and in providing timely intervention and implementing management strategies (Musiek et al., 1990; Chermak, 1996; Bellis, 2003).

Chermak and Musiek (1997) opined that an effective screening tool for APD should have clearly defined pass/fail criteria; independent of regional language changes and their sensitivity and specificity established. Jerger and Musiek (2000) also agreed by confirming that a screening tool must emphasize tasks that are essential in the processing of complex auditory stimuli, meet the psychometric standards of sensitivity and specificity, must have clearly defined pass or refer criteria with reliability and validity. The authors also recommended that a screening procedure should take about 8 to 12 minutes only to complete. In literature, SCAN is reported to take about 20 minutes (Lampe, 2011); MAPA to take 30 minutes (Domitz & Schow, 2000); STAP about 12 minutes(Yathiraj & Maggu, 2012).

According to Van Herick et al. (1969), Sackett et al. (1991) and Lalkhen and McCluskey (2008), the sensitivity of a clinical test should be established by determining the number of individuals correctly identify by the test from those individuals confirmed to have the disease. Likewise, they noted that specificity of a test should be calculated by determining the number of individuals identified as not having the disease by the test from those confirmed to not have the disease. The other measures used to judge the utility of a test are Positive predictive value (PPV) and negative predictive value (NPV). PPV has been found to be useful in determining the likelihood of an individual to have the disorder in case the test result is positive. In cases of a new diagnostic test, PPV helps in commenting about the test's performance close to the gold standard. NPV answers the likelihood of an individual not having the condition given the test results is negative. The authors give the formula for calculating PPV and NPV as follows;

PPV = (True positive) / (True positive + False positive)

NPV = (True negative) / (False negative + True negative)

According to the authors, positive and negative predictive values are directly related to the prevalence of the disease in the population.

### *2.2.1 Screening checklists*

A variety of tools have been developed and used to screen individuals for the presence of APD across different age groups. Examples of checklists used to screen for APD include the Fisher's Auditory Problems Checklist (Fisher, 1976); 'Screening Instrument for Targeting Educational Risk' (Anderson, 1989), 'Children's Auditory Processing Performance Scale'(Smoski et al., 1992), 'Children's Home Inventory for Listening Difficulty' (Anderson & Smaldino, 2000), 'Scales of Auditory Behaviours' (Summers, 2003), 'Screening Checklist for Auditory Processing' (SCAP; Yathiraj and Mascarenhas, 2003, 2004); 'Screening Checklist for Auditory Processing in Adults' (Ramya & Yathiraj, 2014). Questionnaires and checklists have been noted to be easy to administer, are cost effective and provide a range of information about the condition (Brown et al., 2011). Schow and Seikel (2007) delineate the disadvantages which include subjectivity and biases of the individuals administering them. The authors also argued that only a questionnaire might not be suitable for screening and suggested that they be used only to supplement and correlate with the behavioural findings after detailed diagnostic assessments.

‘Fishers Auditory Problems Checklist’ (Fisher, 1976), developed with a focus on language based deficits, contained 25 items in 13 categories. It is reported that it can be administered on children above 7 years of age and can be administered by teachers, parents, audiologists, Speech language pathologists or audiologists. Strange, Zalewskiand Waibel-Duncan (2009) explored the usefulness of this checklist as a screening tool on 40 children between the ages 4 and 13 years. The authors examined the relationship between Fisher’s checklist and Buffalo Model Diagnostic Battery which comprised of Staggered Spondaic Word test ( Katz, 1962), Phonemic Synthesis Test (Katz, 1981) and Modified W-22 Speech-in-Noise test (Katz, 1998) along with diagnosis of type of APD (decoding, tolerance fading memory, integration & organization). The study showed that children who scored at or below the cut-off score (72%) were significantly more likely to have been diagnosed as having APD. The authors opined that the checklist might have a potential to be a useful tool for screening. Strange, Zalewski Waibel-Duncan also reported that the study did not give details about the sensitivity and specificity of the checklist as the sample taken might not have been a good representative of the APD group. Although, the study intended to measure the efficacy in children aged 5 to 13 years, the authors reported that children of the youngest age did not meet the inclusion criteria and hence were not taken for the study. The authors hereby stressed on establishing the validity of the checklist in kindergarten and pre-kindergarten going children. However, Smoski, Brunt and Tannahill (1992) criticized the checklist as it covered a wide range of characteristics and limited number of behaviours related to listening. They also recommended that a screening checklist must include questions related to a variety of listening tasks and environments.

Nunes et al. (2013) assessed the efficacy of the 'Scale of Auditory Behaviours (SAB)' given by Simpson (1981) that had 12 questions regarding difficulty in background noise, poor listening skills and difficulty in carrying out oral instruction. It had two subscales designed for teachers and parents separately. It contained a 5 point rating scale where '5' indicated 'never' and '1' indicated 'frequent'. Nunes et al. evaluated 51 children aged 10 to 13 years using the scale along with various other tests (sound localization, verbal sequential memory, non-verbal sequencing memory, speech in noise, dichotic digits, and harmonic pattern with dichotic digits, duration pattern recognition, & gaps-in-noise). The authors reported that there is a significant correlation between SAB questionnaire and the diagnostic tests of APD with the best correlation being with the temporal processing test. The authors recommended obtaining the validity of SAB in children of age 7 to 9 years.

'Evaluation of Classroom Behaviour' by Vandyke (1984) was designed to identify listening and academic problems. It contained 10 questions to be rated from 1 to

5 by teachers. The questions tapped a child's ability to listen in a class at various distances in quiet and noise as well as the ability to follow instructions in quiet and noise. However, its efficacy was not ascertained.

'Screening Instrument For Targeting Education Risk' (Anderson, 1989) consisted of 3 versions targeting different age groups: children studying in kindergarten, school-going children and adults. Wilson et al., (2011) investigated the relationships between 3 screening tools ('Children's Auditory Processing Performance Scale', 'Screening Instrument For Targeting Educational Risk' and 'Test of Auditory Perceptual Skills-Revised') and 4 diagnostic tests (Low Pass Filtered Speech, Competing Sentence test, Two-pair Dichotic digit and Frequency patterning test). The study evaluated 104 children aged 6.9 years to 14.3 years. The results showed a weak to moderate correlation between short term memory and working memory test results of the 'Test of Auditory Perceptual Skills-Revised' with Dichotic Digit test and Frequency Patterning Test. A regression analysis indicated that these tests were not good in predicting scores in individual diagnostic tests.

'Children's Auditory Processing Performance Scale' (CHAPPS) given by Smoski et al. (1990) consisted of 36 items in 6 listening conditions. It had a 7 point rating scale with '+1' rating 'less difficult' and '-5'indicating 'cannot function at all'. Drake et al (2006) compared CHAPPS and APD diagnosis to check its efficacy. The checklist was administered on 40 subjects in the age range of 8 to 15 years out of which 20 were diagnosed as having APD and others were not. The results were computed using a Chi-Square test of contingency. The authors reported that CHAPPS under-identified 5 subjects and over-identified 15 subjects. It showed very poor relationship with APD diagnosis and hence could not be used as a standard stand-alone screening tool. Lam and Sanchez (2007) showed that the six listening conditions and the average total score of the CHAPPS had no significant predictive ability for APD, based on an analysis of the area under receiver operator characteristic curves for 17 children with a mean age of 8 years 8 months.

Another checklist available for children is the 'Children's Home inventory for Listening Difficulties' by Anderson and Smaldino (2000). This checklist was designed to detect characteristics of APD. It probed about the hearing status of children and their comprehension difficulties in quiet and noisy conditions. This family centred parent survey was recommended to be used in children aged 3 to 12 years. However, its sensitivity and specificity was not reported.

Yathiraj and Mascarenhas (2003) developed the 'Screening Checklist for Auditory Processing (SCAP)' consisting of 12 questions. These 12 questions tapped information about auditory perceptual processing, auditory memory and other miscellaneous behaviours commonly observed in children with APD. This checklist was meant to be administered by teachers having taught children for at least one year or parents on a 2-point rating scale.  A cut-off score of 6 and higher was used to label children as ‘at-risk’ for APD. Muthuselvi and Yathiraj (2009) checked the utility of SCAP in detecting children with APD by comparing the relation between SCAP with five diagnostic tests on 42 school-going children. The diagnostic tests included speech-in-noise, gap detection, dichotic consonant vowel tests, masking level difference and auditory memory and sequencing. The study showed that there was no agreement between a single symptom on SCAP and the presence of APD. On the other hand, the authors reported of a significant correlation between SCAP and the speech-in-noise test and the auditory memory test. The sensitivity of the checklist was reported to be 71% and specificity was 68%.

Although several screening checklists to identify APD have been used, as per the reports in the literature, Emerson et al. (1997) cautioned that use of only such tools could lead to over-referrals. Jerger and Musiek (2000) attributed the over-referrals to the influencing non-auditory factors. The researchers opined that screening tests that can reduce over-referrals and should be preferred to the use of screening checklists.

*2.2.2 Screening tests*

Screening tests for APD have been recommended with the aim of trying to detect a larger number of individuals who are at-risk for the condition, in lieu of screening checklists. Jerger and Musiek (2000) recommended that a screening test must have tasks that taps various auditory processes, information on sensitivity and specificity, validity, standard procedure for testing and should be brief (8 to 12 minutes). A few of the screening tests for APD that have been listed in literature include Selective Auditory Attention Test (SAAT; Cherry, 1980); SCAN (Keith, 1986); SCAN-C (Keith, 2000); SCAN-3: C (Keith, 2009); Multiple Auditory Processing Abilities (MAPA; Domitz & Schow, 2000); STAP (Yathiraj & Maggu, 2012).

Selective Auditory Attention Test (SAAT) given by Cherry (1980) is one of the earliest screenings tests used with children having possible attention problems. The test was designed to tap auditory closure / monaural separation and is reported in literature as a commonly used screening test for APD (Parthasarathy, 2005). Dalebout et al. (1991) reported a poor sensitivity and specificity of the test.

SCAN (Keith, 1986) was developed to identify children at-risk for APD and other educational difficulties in children in the age range of 3 to 11 years. The author reported of moderate internal consistency, but weak test-retest reliability. The test was later revised exclusively for the age group of 5 to 11.11 years and was called SCAN-C (Keith, 2000). It comprised of 4 subtests (Filtered Words, Auditory Figure Ground Test, Competing Words, & Competing sentences tests). In 2009, Keith developed SCAN-3 C for children aged 5 to 12.11 years. This test comprised of Gap detection test, Auditory Figure Ground Test and Competing Words test. Children who did not pass the screening test were required to undergo detailed APD diagnostic tests. The utility of the SCAN norms on children from United Kingdom was evaluated by Marriage, King, Briggs and

Lutman (2001). The test, administered on 133 children, showed that it was not valid for direct application in the United Kingdom.

Another screening test, Auditory Continuous Performance Test (Keith, 1994) was designed to identify auditory processing difficulties in individuals with attention deficits. The author provided normative value for children aged between 6 to 11.11 years. The test was carried out on 480 children of the considered age group with no co-morbid conditions. Keith (1994) reported a hit and correct rejection rate of 70% and a false alarm and a miss rate of 30%.

Chermak et al. (1995) compared the efficiency of SCAN and SAAT. Both the tests were used to identify children at-risk for CAPD. Despite the authors using the tests on the same group of children, the two tests identified different children and 'at risk' for APD, although a few children were identified in both. The authors attribute this to the different processes the two tests tapped.

Domitz and Schow (2000) developed a test battery called as Multiple Auditory Processing Assessment (MAPA) which included SAAT (Cherry, 1980), Pitch Patterns (Pinheiro, 1977), Dichotic Digits (Musiek, 1983) and Competing Sentence test (Willeford, 1985). The test was administered along with SCAN on 81 children. A low sensitivity of 30 to 40% and a specificity of 100% were reported. Further, they administered MAPA, SCAN (Keith, 1986) and Auditory Fusion Test-Revised (Keith, 1997) on children studying in the third grade. Also, teachers and guardians were made to administer the Teachers Scale of Auditory Behaviours (Schow, Simpson and Deputy, 1983) and Fisher's Auditory Problems Checklist (Fisher, 1980). The results showed that none of the tests considered in the study could stand alone as a screening tool to identify APD. When a comparison of the sensitivity of SCAN and MAPA was made, it showed SCAN had poorer sensitivity compared to MAPA.

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Yathiraj and Maggu (2012) devised the 'Screening Test for Auditory Processing (STAP)'. It comprised of 4 subsections (Speech-in-noise test, Dichotic consonant vowel test, Gap detection test, & Auditory memory subsection). These subsections were designed to tap auditory separation/closure, binaural integration, temporal processing and memory. The authors administered STAP on 500 children in the age range of 8 to 13 years. The screening test was compared with a battery of with diagnostic tests that evaluated similar processes / higher cognitive functions [SPIN-IE (Yathiraj et al., 2009), DCV (Yathiraj, 1999), Gap Detection Test (Shivaprakash, 2003) and RAMST-IE (Yathiraj et al, 2009)]. The authors reported that sensitivity and specificity of STAP was 76.6% and 72% respectively.

In order to improve the sensitivity and specificity of screening checklists or screening tests for APD, recommendations have been made to use a combination of the two. Shiffman (1999) reported that a combination of a checklist and a screening test yielded a higher sensitivity and specificity in APD screening. Based on the suggestions by Shiffman (1999), Schow and Seikel (2007) also suggested the use of a combination of a questionnaire and a screening test.

Summers (2003) found that the use of the 'Scales of Auditory Behaviours' in conjunction with the MAPA provided a functional means of identification of children with auditory processing problems. The authors reported that MAPA and Scales of Auditory Behaviours could help tap various processes and efficiently help in identification of the condition even in the presence of co-morbid conditions like Attention Deficit Hyperactivity Disorder and Learning Disability.

Wilson et al. (2011) revealed that screening procedures, both checklists and tests, had a weak correlation with diagnostic tests. Their results were based on a comparison of two checklists (CHAPS, SIFTER) and a screening test (Test for Auditory Processing Skills – Revised; TAPS-R; Gardner, 1997) with various diagnostic APD tests.

Yathiraj and Maggu (2013) studied the relationship between Screening Checklist for Auditory Processing (SCAP), given by Yathiraj and Mascarenhas (2003) with that of STAP. The study revealed that out of 400 children aged between 8 and 13 years who were studied, SCAP found 49 children 'at-risk' for APD while STAP found 64 of them as 'at-risk'. The authors also reported that if either of the tests were to be used alone, some children would have been missed out and hence suggested the use of both tools together. The authors also observed that a combination of the screening checklist and screening test gave better sensitivity and specificity ( 83.8% and 76.2% respectively).

From the review, it is evident that several screening tests have been developed to detect problems in auditory processing. Information on their validity, sensitivity and specificity has been reported. A combination of a screening checklist / questionnaire and a screening test has been recommended.

### 2.3 Diagnostic gold standard tests

To validate screening tests, a standard test or battery of tests is necessary to compare the outcomes of the screening tests. It has been emphasised that the utility of any screening tool can be confirmed only with the help of a set of gold standard diagnostic tests (ASHA, 2005). Although ASHA recommended that the results of the screening tests should be comparable to gold standard tests, owing to the heterogeneity of the problem and absence of an absolute gold standard, several researchers have utilised different battery of tests in order to measure the efficacy of the various screening tests to identify those at-risk for APD. Cacace and McFarland (2005) reported the field of CAPD lacked a gold standard against which the tests can be evaluated due to which there have been imprecise attempts to validate various diagnostic tests of APD. However, despite the lack of gold standard tests, attempts to evaluate the utility of the APD tests have been made by several researchers.

Singer, Hurley and Preece (1998) analysed a CAPD test battery (Binaural Fusion Test, Masking Level Difference and Filtered Speech Test on children aged 7 to 13 years with or without the presence of APD. In spite of the children having a confirmed history of learning problems, the test battery failed to indicate whether auditory processing problems existed in the children or if the auditory processing difficulties were the underlying cause for the learning related problems. They also concluded that there is no single test or test battery acts as a 'gold standard'.

Musiek, Bellis and Chermak (2005) reported that although there might not be an absolute gold standard for APD tests due to the heterogeneity of the disorder, there are several individual tests which evaluate the deficits in individuals with defined lesions of the central auditory nervous system. Thus, they suggested using measures that have documented sensitivity and specificity. The same has been promoted by ASHA (2005a, 2005b).

The battery of APD tests reported in literature varies from one study to another. Yathiraj, Vanaja and Muthuselvi (2012) carried out a series of diagnostic tests on 280 typically developing children aged 6 to 10 years. They used a battery of 4 tests which included Speech-in-Noise in Indian-English (SPIN-IE; Yathiraj, Vanaja, & Muthuselvi, 2009), Dichotic CV (DCV) test recorded by Yathiraj (1999), Duration Pattern Test (DPT; Gowri, 2003) and Revised Auditory Memory and Sequencing Test in Indian-English (RAMST-IE) (Yathiraj, Vanaja, & Muthuselvi, 2009). The aim of the study was to establish normative values for the battery of tests that tapped different auditory processes / higher cognitive function (auditory closure, binaural integration, temporal processing abilities, & auditory memory and sequencing). The authors established cut-off criteria for the diagnosis of APD and recommended use of the four tests to effectively identify children with APD.

Thus, researchers in literature emphasize the use of gold standard test battery to validate screening tools. However, the battery used varies from one study to the other. It is recommended that the battery should include tests that tap different processes such as temporal processing, dichotic tasks for integration and monaural low redundancy tests (Chermak & Musiek, 1992; ASHA, 2005). Yathiraj et al (2012) and Yathiraj and Maggu (2012) recommend that in addition to using a typically APD test battery, a test that taps auditory memory should be included in the test battery, viewing the link between auditory memory and performances in noise.

**2.4 Age of identification of APD**

The ASHA technical report (2005) has recommended that audiologists should be aware of age related issues while carrying out various tests for the auditory processing disorder. It suggests that the results of behavioural tests on children below 7 years of age is questionable as there are factors like maturation, task difficulty and performance variability that influence the outcome. American Academy of Audiology (AAA) practice guidelines (2010) suggested that age is the primary factor of consideration in central auditory function evaluation. Their recommendation was based on report by Jerger and Musiek (2000) who emphasised the difficult in testing children under the age of 7 years. AAA also emphasized that the minimum age requirement for behavioural testing is 7 or 8 years, especially for tests that evaluate the corpus callosum. They also recommended labelling individuals as 'at-risk' rather than diagnose them as having 'APD'.

Unlike the recommendation of ASHA (2005) and Schminky and Baran (1999), there have been attempts made by researchers to carry out APD tests in children as young as 4 years of age. Stollman, Neijenhuis, Simkens, and Snik (2004) carried out a test battery comprising of Sustained Auditory Attention Test (SAAT), dichotic word test, binaural masking level difference, auditory word discrimination test, a gap detection test and phonemic awareness test. The results showed that 6 year olds performed significantly better in dichotic and phonemic awareness tests than the 4 year olds and delineated the factor of maturation acting till 12 to 13 years of age. They also observed significant correlations between the subtests in all the age groups. The authors opined that the battery of tests they used could be utilized in testing children 4 years and older. The authors suggested that the battery could further be modified as very young age group was being tested. It was recommended to use only one version of SAAT, increased inter-stimulus interval in the presentation of stimuli in Dichotic Word test. This was to reduce the time the test would consume. They also concluded that the Gap Detection Test in the form that they used would be difficult to administer and score and recommended the use of Random Gap Detection Test (Keith, 2000) instead. However, they suggested that the normative data should be established on a larger number of children.

Similarly, Stollman, Simkens, Snik, and Marie (2004) described the development of various auditory processes in children aged 6 to 12 years. They used speech-in-noise test, filtered speech test, an auditory synthesis test, auditory closure test and a number recall test. The results showed that there were maturational effects on processes extending to 12 years of age.

Yathiraj et al. (2012) evaluated children aged 6 to 10 years to establish normative data for a battery of tests (SPIN-IE, DCV, DPT and RAMST-IE). The authors reported a nonlinear maturational pattern in various auditory processes due to the changes in the performance on the battery of tests. They concluded that although the children in the youngest group had significantly poor scores in all the tests, it was possible to carry out most of the tests. They also emphasized on utilizing age appropriate normative values.

Therefore, the literature shows the existence of two different views on the age at which APD should be diagnosed. While most of the authors recommend that children be labelled as having an APD only above the age of 7 to 8 years; there are few emerging studies which recommend the use of standard tests in children younger than 7 years. However, researchers opine the tests have to be modified according to the age group and it is recommended to have age appropriate normative values.

APD continues to challenge the professionals involved in the task of diagnosis and intervention. However, several researches have emphasized on the impact of APD on an individual's scholastic, emotional and social performance. Hence, they emphasized the need for early identification and intervention of individuals with APD. The functional and behavioural changes brought about in the auditory processing with age due to maturation have been delineated in quite a few studies. In order to effectively identify the presence/ absence of APD, authors suggest that powerful screening tools are required. Several screening checklists / questionnaires have been reported in the literature. However, the validity of some of them have been questioned. Further, to improve the efficiency of screening for APD, screening tests were given. In order to establish the validity of screening tests, authors recommended comparing the tests with a standard set of test batteries known to identify APD. However, due to the heterogeneity of APD and various auditory processes that are to be tapped, there is no absolute gold standard reported. Researchers have contemplated about the age at which children can be labelled as having an APD. Several authors recommended that children should be at least 7 to 8 years in order to rightly label them as having an APD. On the other hand, a few researches have also evidenced that it was possible to identify children at a very young age below 7 years also.

## Chapter 3

## Method

With the aim to determine the performance of children aged 6 to 8 years on the Screening Test for Auditory Processing (STAP) developed by Yathiraj and Maggu (2012), the study was carried out in two stages. The first stage involved screening using two screening tools, Screening Checklist for Auditory Processing (SCAP) by Yathiraj and Mascarenhas (2003) and STAP. In the second stage, an Auditory Processing Disorder test battery that taps auditory closure, binaural auditory integration, temporal resolution and auditory memory was carried out.

### 3. 1. Participants

In Stage I of the study, 426 school-going children aged between 6 years to 8 years were screened using SCAP from schools in Mysuru. From the children tested on SCAP, 43 children at-risk and 57 children not at-risk for auditory processing disorder (APD) were administered STAP using a blind approach. The children who were administered STAP had no scholastic problems, as well as no history of psychological, otologic, developmental or language disorders. Thirty-five of the children who were administered SCAP and STAP were selected for Stage II of the study in a semi-random manner. The 35 children comprised of those who were referred only on SCAP (4 children), only on STAP (10 children), both on SCAP and STAP (11 children) and passed both the screening tools (10 children).

### 3. 2. Instrumentation

For Stage I of the study the STAP stimuli were played through a DELL VOSTRO 14 3000 series laptop loaded with Adobe Audition. The audio output of the laptop was routed through a TDH-39 earphone housed in MX-41AR supra aural cushions, so that each ear could be tested independently. The output through the headphones was maintained at 65 dB SPL by manipulating the volume control of the laptop and audio software. The intensity level of the output from the headphones measured using a Brüel Kjaer sound level meter and a NBS 9A 6cc artificial ear.

For Stage II, a two channel clinical audiometer (GSI-61) was used to carry out pure-tone audiometry, speech audiometry and the diagnostic APD tests. GSI Tympstar impedance meter was used for tympanometry and acoustic reflex thresholds measurements to confirm the presence of normal middle ear function. The CD versions of the diagnostic APD tests were played through a laptop (DELL VOSTRO 14 3000). The output from the laptop was routed to the audiometer and delivered through TDH-39 earphones.

**3. 3. Environment**

The screening tests were administered in 4 different schools in Mysuru. The screening was done in quiet rooms, free from visual and auditory distractions within the premises of each of the schools. The routine audiological and APD diagnostic evaluations were administered in a sound treated double room. The ambient noise in the testing room was within ANSI S3.1-1999 standards.

**3. 4. Material**

Stage I: In Stage I, SCAP (Yathiraj & Mascarenhas, 2003, 2004) and STAP (Yathiraj & Maggu, 2012) were administered. The SCAP, designed to be administered by a school teacher, consisted of 12 questions that extracted information related to auditory perceptual abilities, auditory memory and other miscellaneous related symptoms. It was scored on a 2-point rating scale and the children who obtain more than the 50% scores (≥ 6) were considered ‘at-risk’ for auditory processing deficits.

STAP consisted of four subsections (‘Speech-in-Noise subsection’, ‘Dichotic CV subsection’, ‘Gap detection subsection’, & ‘Auditory memory subsection'). The CD of the test contained a 1 kHz calibration tone, overall instructions to the test, instructions for each subsection prior to the commencement of the stimuli for each subsection, and the stimuli for each subsection. As the stimuli for each ear were recorded on two different tracks, evaluation of the two ears could be done without the tester having to do any further manipulations once the test commenced. Cut-off criteria were provided for each subsection to decide whether a child was ‘at-risk’ or not for APD. Children were considered ‘at-risk’ for APD if they were referred on one or more subsections.

In Stage II, four diagnostic tests were utilised. These included Speech-In-Noise Test in Indian-English (SPIN-IE) developed by Yathiraj, Vanaja and Muthuselvi (2009), Dichotic CV test recorded by Yathiraj (1999), Gap Detection Test (Shivaprakash, 2003) and Revised Auditory Memory and Sequencing Test in Indian English (RAMST-IE) developed by Yathiraj et al., (2009). SPIN-IE consisted of 2 lists with 25 phonemically balanced words each that served as the stimuli and an interrupted eight-talker babble that served as the noise. The average amplitude of the noise and words were matched to ensure a 0 SNR situation. The duration of interruption was kept constant at 75 ms and the duration of noise was varied from 310ms to 620ms semi-randomly. The authors reported that the interruption was not present while the stimulus was presented. The interval between the stimuli was 5 seconds. For the purpose of calibration, each list commenced with a 1 kHz tone. The maximum score for each list was 25.

The Dichotic CV test was carried out using the 'Dichotic CV Test-Revised' recorded by Yathiraj (1999). A list having a 0 ms lag time was used. The material contained 30 pairs of six syllables (/pa/, /ta/, /ka/, /ba/, /da/ & /ga/). To adjust the VU meter of the audiometer, a 1 kHz calibration tone was provided. The responses were scored in two ways (single correct & double correct), with the maximum score for each being 30.

The Gap Detection Test consisted of sixty sets of stimuli that included 4 practice sets and 6 catch trials. Each stimulus set was made up of a triad of noise bursts having a duration of 300 ms, separated by a 750 ms silence. Each burst of noise contained a gap. The duration of the gap progressively decreased in steps of 2 ms from 20 ms to 11 ms and thereafter in steps of 1 ms till 1 ms. A calibration tone of 1 kHz was provided before each list.

RAMST-IE (Yathiraj et al., 2009) contained 3-word and 4-word sequences having 2 tokens each and 5-word and 8-word sequences with 4 tokens each. In total, the test contained 118 words per list. Within each token, a 500 ms inter-stimulus interval was provided. The test contained words that were highly familiar to children aged 6 years. The maximum possible score for the test was 118.

### 3. 5 Procedure

A flow chart of the sequence of activities used in the study is illustrated in Figure 3.1. As can be seen in the figure, the study commenced with screening the children in Stage I. This was followed by administration of diagnostic APD tests in Stage II.

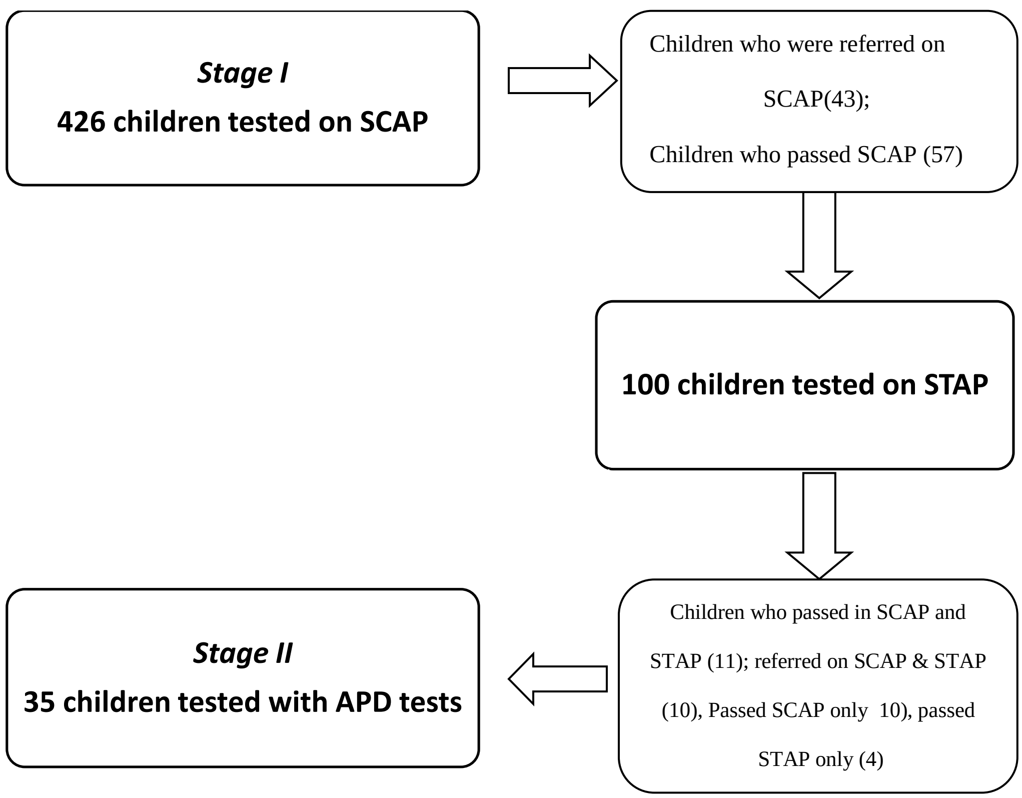



**Figure 3.1: Flowchart of the procedure used in the study.**

*Stage I: Screening*

School-going children aged 6 to 8 years were chosen from 4 schools in Mysore. Initially, SCAP was administered by a teacher who taught curricular subjects to the children for at least 6 months. Each teacher was instructed to identify children with the symptoms listed in the checklist. They were asked to refer to the audiologist, who was present in the school, children 'at-risk' (scores $\geq 6$) as well as those not 'at-risk' (scores $< 6$) for APD, based on the responses obtained on STAP. The audiologist was however not aware as to who among the 100 referred children were 'at-risk' or 'not at-risk' for APD. The teachers were also not informed about the performance of the children on STAP.

The STAP was administered independently on each child by the audiologist in the school premises. Each child was instructed before the test procedure and was reinstructed in case he/she had difficulty following the recorded instructions. For all four subsections, a score of 1 was given for each correct response and a score of 0 for every incorrect response. Using the recommended criteria given in the original test (Yathiraj & Maggu, 2012) the children were categorized as 'pass' or 'refer' for each of the subsections.

On scoring the results of SCAP to categorising the children as 'pass' or 'refer', it was seen that among the 426 children who were screened using the checklist 357 (83%) 'passed' and 69 (16.19%) were 'referred'. Similarly, from the scores of STAP that was administered on 100 children, 55 (55%) 'passed' and 45 (45%) were 'referred'. It was found that 41 (41%) children passed both screening tools and 17 (17%) children were referred on both tools.

*Stage II: Administration of diagnostic test battery*

The diagnostic test battery utilized to validate STAP was the same as that used by Yathiraj and Maggu (2014). They reported that they had included SPIN-IE, DCV, GDT and RAMST-IE in their APD diagnostic test battery as these tests tapped a variety of auditory processes / higher cognitive skills (auditory closure, auditory binaural integration, temporal resolution & auditory memory). They selected these auditory processes / higher cognitive skills as they were found to be frequently affected in children with APD [Welsh et al., (1980), Katz et al., (1992), Muthuselvi and Yathiraj (2009), Musiek et al., (1982)].

Thirty-five children, selected using a semi-random criterion among those screened in Stage I, underwent the diagnostic testing procedure. The children selected for Stage II of the study included those who had not passed STAP but passed SCAP, not passed SCAP but passed STAP, not passed both screening procedures as well as passed both screening procedures.

A routine audiological evaluation was carried out to confirm that the children had no peripheral hearing problems. It was ensured that all the selected children had air conduction thresholds and bone conduction thresholds within 15 dB HL in the frequencies 250 Hz to 8 kHz and 250 Hz to 4 kHz respectively. All the children had speech identification scores of more than 90% in a quiet condition on English PB word test (Rout, 1996). Further, the children had an ‘A’ type tympanogram and presence of ipsilateral and contralateral acoustic reflexes at 500 Hz, 1 kHz and 2 kHz.

The four diagnostic APD tests were carried out in a random order to rule out any order effect. While administering SPIN-IE and GDT, the ears were randomly tested to prevent any ear order effect. The output from the computer was routed to headphones via the diagnostic audiometer. The 1 kHz calibration tone, recorded in the CD of each test, was used to adjust the VU meter deflection prior to administration of each test and appraisal of each child.

The SPIN-IE stimuli were presented monaurally at 40 dB SL (ref. SRT) via headphones. Prior to presentation of the material at 0 dB SNR, the children were instructed to listen to the words spoken by the lady while ignoring other sounds. The verbal responses of the participants were noted. A correct response received a score of ‘1’ and an incorrect response a score of ‘0’. The scores obtained were compared with age appropriate norms given by Yathiraj, Vanaja and Muthuselvi (2012)

The Dichotic CV test stimuli recorded by Yathiraj (1999) were presented at 40 dB SL (ref. SRT). The children were informed that they would hear two syllables simultaneously, one in each ear. They were asked to repeat both the syllables they hear through the headphones. The verbal responses of the participants were noted and scored to obtain both single correct and double correct responses. A score of 1 was assigned for each correct response and 0 for each incorrect response, separately for each ear while calculating the single correct responses. To calculate the double correct response score, 1 was awarded only if both the syllables presented in the two ears were repeated correctly. These scores were compared with age appropriate norms given by Yathiraj, Vanaja and Muthuselvi (2012). For the 6 year old children only the single correct scores were calculated as the authors reported of high variability in the double correct scores, making them not reliable in this age group.

For GDT, the signals were presented monaurally to each ear at 40 dB SL (ref. PTA) through headphones. The participants were asked to indicate as to which set of noise bursts in a triad contained a gap. Before the actual test, the recorded practice sets were played. Following the practice trials, the children were tested using the test items. The lowest gap that could be detected was considered to be the threshold. The scores of were compared with age appropriate normative data (Shivaprakash, 2003) for the 7 to 8 year old children. However due to the non-availability of normative values for children of 6 years, a regression analysis was done using SPSS. Using a linear regression the cut off for the lower age (6 years) was extrapolated.

The CD version of RAMST-IE was presented at 40 SL (ref. SRT) through headphones. The participants were instructed to listen to each word-sequence before repeating the stimuli. They were also informed that the number of stimuli in the word-sequences would gradually increase. A score of ‘1’ was given for each correctly repeated word to calculate the auditory memory score. An additional score of 1 was awarded if the words were repeated in the correct order, when calculating the sequencing scores. The responses were compared with the age appropriate norms developed by Yathiraj, Vanaja and Muthuselvi (2012).

The criteria to diagnose a child as having APD or not was based on the recommendations of Yathiraj et al., (2012) where, for children who failed on only one diagnostic test, a -2 SD criteria was used and -1 SD criteria for those who failed more than one diagnostic test.

On scoring the four diagnostic tests, it was observed that among the 35 children tested, 14 (40%) children were diagnosed as having an APD based on the criteria given by Yathiraj et al., (2012). 9 (25.7%) children failed in SPIN-IE, 10 (28.57 %) children failed in DCV, 9 (25.7%) and 8 (22.8%) children failed GDT and RAMST-IE respectively.

### 3. 6. Statistical Analyses

The data obtained from the administration of SCAP, STAP and the diagnostic test battery were analysed using SPSS (Version 20). Descriptive statistics, Chi-square, Pearson Product Moment correlation, Man-Whitney U test and Kappa’s measure of agreement were done to analyse the obtained data.

# Chapter 4

# Results

To validate STAP, the data obtained from school-going children aged 6 years to 8 years were compared with four diagnostic tests (SPIN-IE, DCV, GDT and RAMST). In similar lines, a comparison of SCAP and the diagnostic tests was carried out. Also, a combination of SCAP and STAP results were compared with the battery of diagnostic tests. The results of the study are provided in the following sections:

4.1. Findings of the screening procedures

4.1.1 Findings of SCAP

4.1.2 Findings of STAP

4.1.3 Comparison of SCAP and STAP

4.2 Findings of APD diagnostic tests (SPIN-IE, DCV, GDT, & RAMST-IE)

4.3. Relationship between the screening tools and the diagnostic tests.

4.4. Sensitivity and specificity of STAP and SCAP

Initially, the normality of all the data obtained was checked using a Shapiro-Wilk test. It revealed that the distribution of data was not normal. Hence, non-parametric tests of statistics were used to compute the relationships between the screening procedures and the diagnostic tests.

## 4.1 Findings of the APD screening procedures

Descriptive and inferential statistics were carried out on the data obtained from the 100 children who were administered both screening procedures (SCAP & STAP). This included the data of 57 children who ‘passed’ SCAP and 43 children who were ‘referred’ on SCAP. These children were randomly selected by the school teachers among the 69 children who they categorised as ‘refer’ and 357 children categorised as ‘pass’, after administration of SCAP. Further, analysis was also carried out on the data of the 55 children who ‘passed’ and the 45 children who were ‘referred’ on STAP, as well as 17 children were found to be ‘at-risk’ for APD on both SCAP and STAP. To check if age of the participants had an influence on the data, analysis was done with the children categorised into two age groups (6 to 7 & 7 to 8 years). Details of the children who ‘passed’ and were ‘referred’ on the screening tools are provided in Table 4.1.

**Table 4.1**: *Number (percentage) of children who passed and were referred on the screening tools*

| **Screening tools** | **N** | **Pass** | **Refer** |
|---|---|---|---|

| | | | |
|---|---|---|---|
| **SCAP** | 426 | 357 (83%) | 69 (16.19%) |
| **STAP** | 100 | 55 (55%) | 45 (45%) |
| **SCAP + STAP** | 100 | 41 (41%) | 17 (17%) |

### *4.1.1 Findings of SCAP*

From the findings of SCAP, 69 of the total children (N = 426) tested were found to be 'at-risk' of APD. This indicated that 16.19% of the children exhibited six or more symptoms of APD listed in SCAP.

When the children were divided into *two age groups (younger and older)* it was observed that 179 (42.01 %) younger children and 178 (41.58% %) older children passed SCAP. Among the 69 children who were 'at-risk' on SCAP, 31 (44.92%) were 6 to 7 years old and 38 (55.07%) were 7 to 8 years old.

### *4.1.2 Findings of STAP*

Table 4.2 gives the details of the scores obtained by the children in each of the subsections of STAP. From Table 4.2 it can be observed that the performance of most of the children was below the cut-off in the DCV test. The scores in GD subsection were the best when compared to the scores of other subsections. However, the variability in the performances was found to high with AM having the maximum variability.

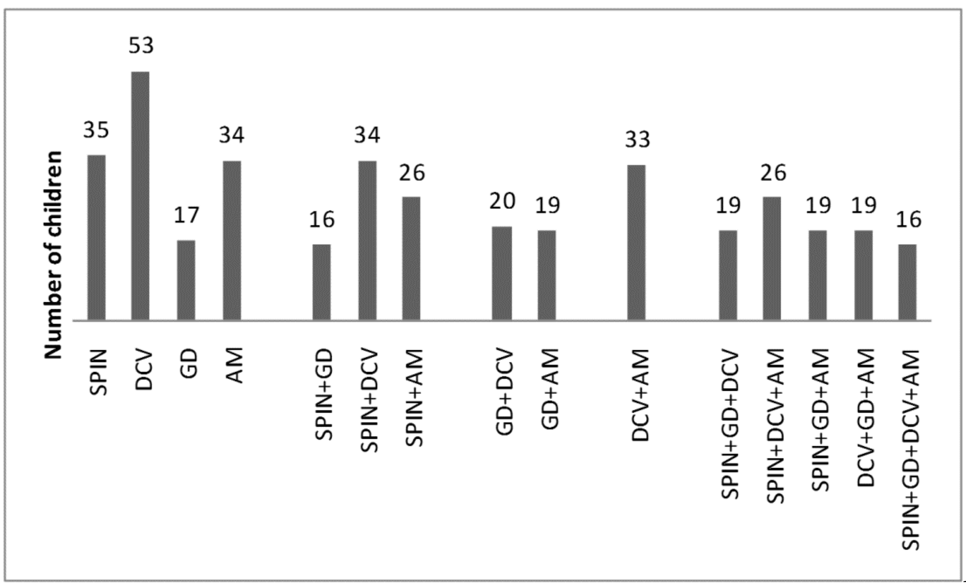
Further, the number of children who were referred in each of the subsections of STAP is represented in Figure 4.1. Besides providing information about the number of children who performed poor in each of the subsections of STAP, the figure depicts the number who performed poorly in combinations of the subsections of STAP. The children were represented multiple times as the same children were referred on isolated subsections as well as in combinations of the subsections. It was observed that most of the children performed poorly in the DCV subsection (53 children) followed by the SPIN subsection (35 children), and AM subsection (34 children) and GD subsection (17 children). Within the combination of subsections where children were referred, 34 performed below the cut-off criteria in the DCV + SPIN subsections, followed by DCV + AM subsections where 33 children were referred. Further, it was observed that 29 children were referred in the combination of DCV + SPIN + AM subsections.

Figure 4.2 represents the number of children who scored below the cut-off in STAP, with the participants being represented only once. For example, a child who was referred on SPIN only, was not represented again in any other subsection or combination of subsections even SPIN was a part of the combination.

**Table 4.2***: Mean, median and standard deviations (SD) of the scores in the subsections of STAP*

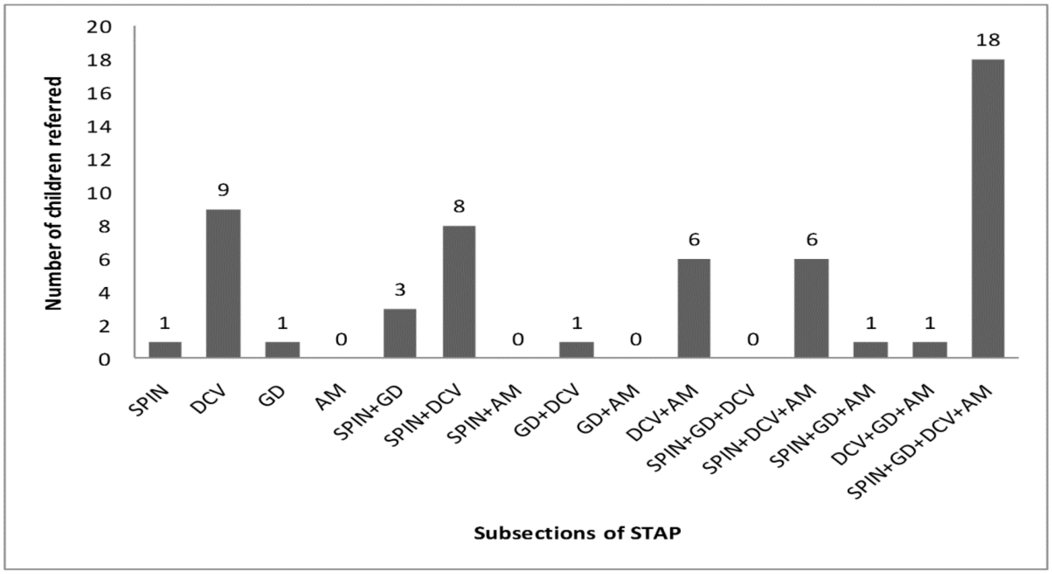
| Subsections of STAP | Cut-off scores * | Mean scores (N = 35) | Median (N = 35) | 1 SD |
|---|---|---|---|---|
| **SPIN (Right)** | 6 | 6.17 | 7.00 | 1.99 |
| **SPIN ( Left)** | 6 | 6.29 | 6.00 | 2.08 |
| **DCV** | 2 | 1.06 | 1.00 | 1.08 |
| **GD (Right)** | 4 | 4.34 | 5.00 | 1.77 |
| **GD (Left)** | 4 | 4.43 | 5.00 | 1.77 |
| **AM** | 12 | 12 | 13.00 | 3.53 |

*Note.** Cut-off scores given by Yathiraj and Maggu (2012)




*Note.* *SPIN* =Speech–In-Noise; DCV =Dichotic Consonant Vowel; GD =Gap Detection; AM = Auditory Memory

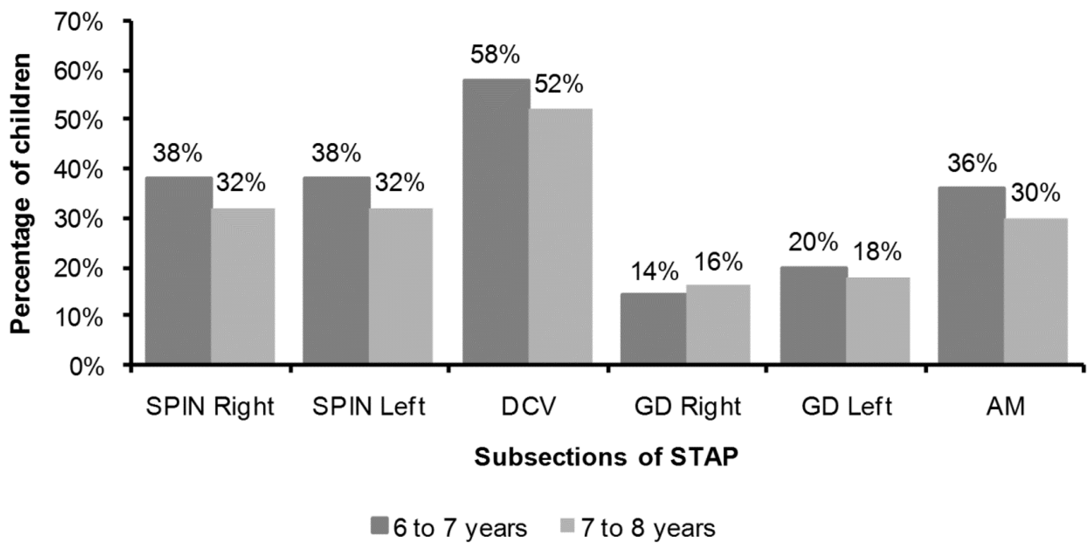
**Figure 4.1:** *Number of children scoring below the cut-off scores given by Yathiraj and Maggu (2012) in each of the subsections of STAP and in combinations of subsections of STAP (each participant represented multiple times)*




*Note. SPIN* =Speech–In-Noise; DCV =Dichotic Consonant Vowel; GD =Gap Detection; AM = Auditory Memory

Figure 4. 2: *Distribution of the 35 participants with scores below the cut-off values on individual subsection or combinations of subsections of the STAP (each participant represented only once)*

Comparing the STAP performance across the *younger and older children*, it was seen that the former were referred more than the latter in most of the subsections of STAP (Figure 4.3). However, the trend in the difficulty across the subsection of the screening test was similar in the two age groups. The children were referred most often on the DCV subsection, followed by SPIN and AM subsections. Despite this, in the GD right ear older group showed a slightly higher percentage of children being referred than the younger group.




*Note*. SPIN = Speech-In-Noise; DCV = Dichotic CV; GD = Gap Detection; AM = Auditory Memory

**Figure 4.3:** *Percentage of children referred on the different subsections of STAP in the two age groups.*

### *4.1.3 Comparison of SCAP and STAP*

Among the 100 children on whom both SCAP and STAP were administered, it was found that 17 children were referred on both the tools and 41 children passed both the tools. However, it was observed that 17 children who were referred on SCAP were not referred in STAP and 7 children were referred on STAP in spite of passing SCAP.

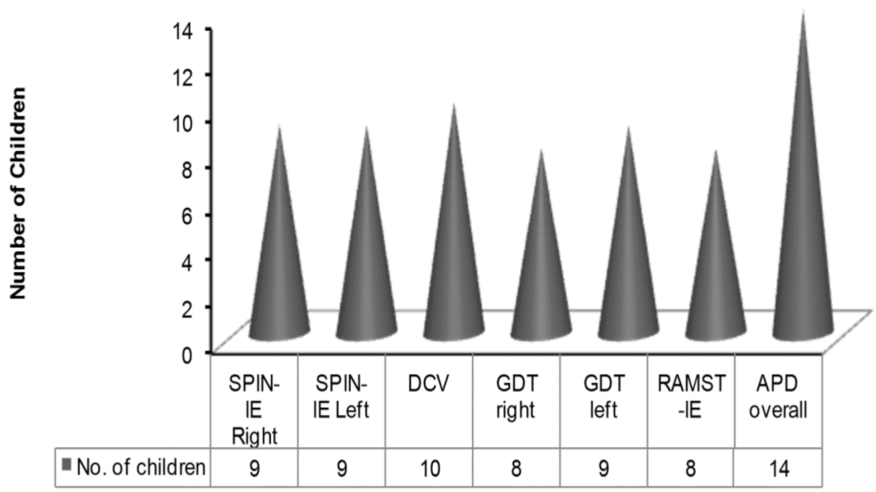
Using a Chi-square test, the relation between SCAP and STAP was established to be significant [$X^2$ (1, N = 35) = 5.84, p = 0.016].

While comparing the SCAP and STAP results between the *younger (N =11) and older (N =24) age groups,* SCAP was found to have no significant relation with STAP in the former [$X^2$ (1, N = 11) = 0.16, p = 0.898]. However, a significant relation [$X^2$ (1, N = 24) = 8.54, p = 0.003] was observed in the latter group of children.

**4.2 Findings of APD diagnostic tests**

In Figure 4.4, the information regarding the number of children who passed and failed the diagnostic APD tests (SPIN-IE, DCV, GDT, & RAMST-IE) has been represented. These results are provided for the 35 children who were selected in a semi-random manner for diagnostic testing. The scores were compared with the cut off scores given for each of the diagnostic APD tests (SPIN-IE, RAMST-IE, DCV & GDT). For DCV in the 6 year olds, 'Single Correct Scores' for the right and left ear were considered for diagnosing rather than 'Double Correct Scores'. This was done based on the report by Yathiraj et al. (2012) that the variability in double correct scores was very high in this age group, indicating that they were not reliable. However, for the older children, the double correct scores were considered. Also, due to the non-availability of normative GDT scores for the younger group (6 to 7 years), it was extrapolated from the given normative values of older children using a regression equation.

From Figure 4.4 it can be observed that among the 35 children subjected to diagnostic testing, 14 (40%) were found to have APD as per the criteria given by Yathiraj, Vanaja, and Muthuselvi (2012). The figure also indicates that the number of children who failed the different diagnostic tests was not very different.




*Note.* SPIN-IE = Speech-In-Noise in Indian English; DCV=Dichotic Consonant Vowel test; GDT= Gap Detection Test, RAMST-IE= Revised Auditory Memory and Sequencing Test in Indian English

**Figure 4.4:** *Number of children who failed the different APD diagnostic tests (N = 35) (each participant has been represented multiple time)*

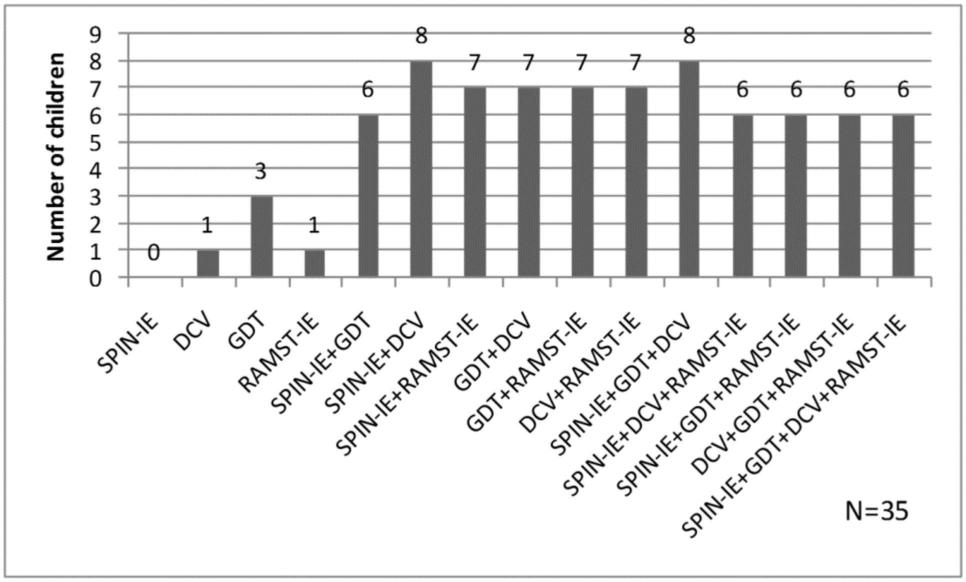
Table 4.3 gives the scores of the children in each of the diagnostic tests administered. The table represents the mean of scores, median scores and their standard deviations separately for the *two age groups* (6 to 7 year olds; N = 11) and (7 to 8 year olds; N = 24). These details indicate the difference in performances in the two age groups for each of tests. It can be observed that the older children performed better in all the tests. It was seen that 6 (60%) children failed in the younger group and 8 (32%) children in the older group.

**Table 4.3:** *Mean, Median and standard deviation (SD) of the scores obtained by the 35 children on the APD diagnostic tests.*

| Subsections of STAP/Diagnostic tests | Max. possible scores | Scores to Pass * | | Mean scores | | Median values | | 1 SD | |
|---|---|---|---|---|---|---|---|---|---|
| | | 6 Yrs | 7 yrs | 6 yrs | 7 yrs | 6 yrs | 7 yrs | 6 yrs | 7 yrs |
| **SPIN-IE Rt** | 30 | 11.40 | 14.77 | 13.63 | 15.96 | 13.00 | 16.00 | 2.01 | 2.80 |
| **SPIN-IE Lt** | 30 | 11.40 | 14.77 | 14.54 | 15.25 | 15.00 | 16.00 | 2.06 | 3.15 |
| **DCV- SCR** | 30 | 12.27 | 13.57 | 7.3 | 15.23 | 7.00 | 14.00 | 2.15 | 2.32 |
| **DCV- SCL** | 30 | 6.39 | 12.24 | 2.36 | 13.04 | 2.00 | 12.00 | 2.20 | 3.02 |
| **DCV- DCS** | 30 | - | 5.2 | - | 7.5 | - | 7.00 | - | 4.41 |
| **GDT Right** | -*** | 6.66** | 5.55 | 6.27 | 5.38 | 6.00 | 5.00 | 1.42 | 1.43 |
| **GDT Left** | -*** | 6.66** | 5.55 | 6.27 | 5.29 | 6.00 | 5.99 | 1.50 | 1.57 |
| **RAMST-IE** | 118 | 42.45 | 44.19 | 36.18 | 45.17 | 37.00 | 46.00 | 4.33 | 8.38 |

*Note*.* Pass scores of SPIN-IE, RAMST-IE and DCV of Yathiraj et al. (2012); GDT cut-off score of Shivaprakash (2003); **extrapolated score using a regression analysis **; ****minimum score same as cut off value

**Figure 4.5** *represents the number of children who failed in the diagnostic APD tests in isolation and in combinations. It can be observed that none of the children failed SPIN-IE in isolation. However, 3 children failed GDT in isolation. Most children were found to be failing in a combination of different tests.*




*Note.* SPIN-IE = Speech-In-Noise in Indian English; DCV = Dichotic Consonant Vowel test; GDT = Gap Detection Test, RAMST-IE = Revised Auditory Memory and Sequencing Test in Indian English

**Figure 4.5:** *Number of children who failed in each of the diagnostic tests and in combinations of the diagnostic tests* **(***each participant has been represented multiple time)*

## 4.3 Relationship between the Screening procedures and the APD diagnostic tests

### *4.3.1 SCAP and APD diagnosis*

The relation between the 2 screening tools and the diagnosis of APD was established. It was found that 19 children were found to have passed SCAP and the APD diagnostic tests. However, 5 children were referred on SCAP but did not have an APD based on the scores in the battery of diagnostic tests. Further, to determine the relation between SCAP and the diagnosis of APD, a Chi-square test was performed. The relation between the screening checklist and the outcome of diagnostic APD tests was found to be significant [$X^2$ (1, N = 35) = 3.98, p = 0.046].

*4.3.2 STAP and the APD diagnostic tests*

STAP was analysed in comparison with the diagnostic tests in three different ways. This included (a) Association between the pass/refer criteria of STAP vs pass/fail criteria of the diagnostic tests (using Kappa's measure of agreement), (b) Association between the raw scores of STAP vs raw scores of the diagnostic tests (using Pearson's product moment correlation), (c) Difference between the raw scores of STAP vs raw scores of the diagnostic tests between the younger and older age groups (using Mann Whitney test).

*a) Association between pass/refer criteria of STAP and pass/fail criteria of the diagnostic tests.*

In order to establish the association between pass/ refer criteria of STAP and pass/fail criteria of diagnostic tests, a Kappa's measure of agreement was carried out. The results revealed a substantial significant agreement (K = 0.638, p < 0.005). Also, Kappa's measure of agreement was calculated for each of the subsections of STAP and the respective diagnostic tests. From Table 4.4 it can be seen that the agreement was highest between the GD subsection of STAP and GDT (substantial agreement) followed by the SPIN subsection and SPIN-IE (substantial agreement), further followed by AM subsection and RAMST-IE (moderate agreement). The least agreement was seen between DCV subsection of STAP and DCV test (fair agreement).

**Table 4.4:** *Agreement between the subsections of STAP and diagnostic APD tests.*

| **SPIN-IE** | | **DCV** | **GDT** | | **AM** |
|---|---|---|---|---|---|
| **Right ear** | **Left ear** | **Binaural** | **Right Ear** | **Left Ear** | **Binaural** |
| 0.608 | 0.660 | 0.238 | 0.746 | 0.679 | 0.478 |

*Note.* Where K= Kappa's co-efficient; p < 0.005; SPIN-IE= Speech In Noise in Indian English; DCV= Dichotic Consonant Vowel; GDT= Gap Detection Test; RAMST-IE= Revised Auditory Memory and Sequencing Test in Indian English

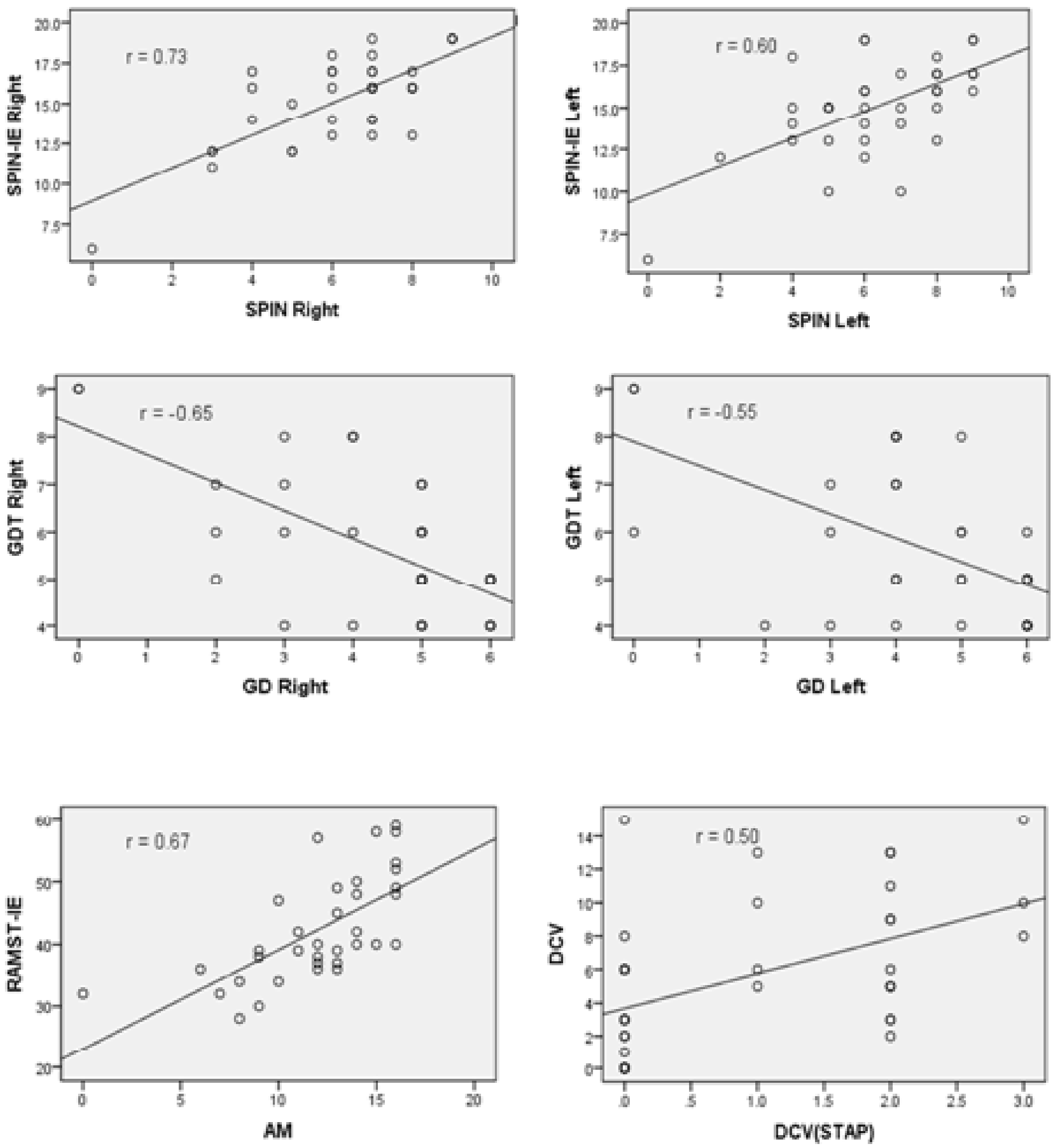
*b) Association between the raw scores of STAP and APD diagnostic tests*

The correlation between the raw scores obtained in the subsections of STAP and the raw scores of the diagnostic APD tests were measured using Pearson's product moment correlation. The results revealed there was a significant strong to moderate correlation between the STAP subsections and the diagnostic tests (Table 4.6). From Table 4.6 it can be observed that only GDT exhibited a negative correlation indicating that the children who got higher scores on the GD subsection of STAP were able to perceive smaller gaps on the diagnostic GDT. Further, the correlation (r) determined using Pearson Product Moment correlation has been represented in a simple scatter plot in Figure 4.5.

**Table 4.5:** *Correlation between STAP subsections and the diagnostic tests*

| APD tests and subsections of STAP | Ear | Correlation Co-efficient (r) |
|---|---|---|
| **SPIN-IE vs SPIN** | Right ear | 0.73 |
| | Left ear | 0.60 |
| **DCV Test vs DCV** | Binaural | 0.50 |
| **GDT vs GD** | Right | -0.65 |
| | Left | -0.55 |
| **RAMST-IE vs AM** | Binaural | 0.67 |

*Note*. p = 0.01; SPIN-IE= Speech In Noise in Indian English; DCV= Dichotic Consonant Vowel; GDT= Gap Detection Test; RAMST-IE= Revised Auditory Memory and Sequencing Test in Indian English; SPIN = Speech-In-Noise; DCV = Dichotic CV; GD = Gap Detection; AM = Auditory Memory




*Note.* SPIN-IE= Speech In Noise in Indian English; DCV= Dichotic Consonant Vowel; GDT= Gap Detection Test; RAMST-IE= Revised Auditory Memory and Sequencing Test in Indian English; SPIN = Speech-In-Noise; DCV = Dichotic CV; GD = Gap Detection; AM = Auditory Memory

**Figure 4.6:** *Scatter plots depicting the scores in each of the subsections of STAP (X-axis) with the diagnostic tests (Y-axis)*

The correlation between each of the STAP subsections and scores on the corresponding diagnostic tests was ascertained in the *younger* and *older age groups* (Table 4.6). The results revealed a moderate correlation between GD vs GDT; AM vs RAMST-IE the corresponding diagnostic tests in the younger age group.The other sections did not reveal a significant correlation. However, a significant correlation was observed between the subsections of STAP and the diagnostic tests in the older age group, except for DCV. In this group, a moderate correlation between GDT and GD, AM and RAMST-IE was observed and a strong correlation between SPIN and SPIN-IE in both the ears was seen. The correlation between the DCV subsection and DCV test was not significant.

**Table 4.6**: *Association between subsections of STAP and APD tests in the two age groups (6 to 7 years; 7 to 8 years)*

| **APD tests and subsections of STAP** | **Ear** | **Correlation Co-efficient (r)** | |
|---|---|---|---|
| | | **6 to 7 years** | **7 to 8 years** |
| **SPIN-IE vs SPIN** | Right ear | 0.37 | 0.77* |
| | Left ear | 0.40 | 0.72* |
| **DCV Test vs DCV** | Binaural | 0.40 | 0.38 |
| **GDT vs GD** | Right ear | -0.55* | -0.66* |
| | Left ear | -0.45* | -0.54* |
| **RAMST-IE vs AM** | Binaural | 0.63* | 0.66* |

Table 4.7 provides information about the children who were referred on each of the subsections of STAP and their performance on the diagnostic tests. In the DCV subsection of STAP and in the DCV test of the APD battery, the maximum number of children did not pass. In STAP, the maximum number of children passed the GD subsection. However, among in the diagnostic tests, the maximum number of children passed RAMST-IE.

**Table 4.7:** *Comparison of outcomes of STAP subsections and the APD diagnostic tests.*

| **Subsections of STAP** | **No. of Children (%) who scored below the cut off* (N = 100)** | **APD Tests** | **No. of children (%) found to have APD (N = 35)** |
|---|---|---|---|
| **SPIN** | 35 (35%) | **SPIN-IE** | 9 (25.7%) |
| **DCV** | 53 (53%) | **DCV** | 10 (28.57%) |
| **GD** | 17 (17%) | **GDT** | 9 (25.7%) |
| **AM** | 34 (34%) | **RAMST-IE** | 8 (22.8%) |

*Note.* *Cut off scores given by Yathiraj and Maggu (2012)

*c) Differences in the performances between the younger and older children*

To establish whether the *younger and the older children* performed differently on the diagnostic tests, non-parametric Mann Whitney U test was performed using their raw scores on various subsections of STAP and the four different diagnostic APD tests. The results showed a significant difference in the performances in SPIN of right ear, DCV subsection and AM of STAP, with the older group performing better than the younger group. Further, in the diagnostic test battery, it was observed that the older children obtained significantly higher scores than the younger group on SPIN-IE right ear, DCV, GDT left ear and RAMST-IE tests (Table 4.8). However, such difference in performance was observed in SPIN of left ear and GD subsections of STAP; and in SPIN-IE scores of left ear and GDT scores of right ear.

**Table 4. 8:** *Comparison of performance in the subsections of STAP and the diagnostic tests across the two age groups (6 to 7 years & 7 to 8 years)*

| Subsections of STAP / Diagnostic Tests | Age groups | Median values | SD | U | P |
|---|---|---|---|---|---|
| **SPIN Right** | 6 to 7 yrs | 5.00 | 1.48 | 55.5 | 0.00* |
| | 7 to 8 yrs | 7.00 | 2.08 | | |
| **SPIN Left** | 6 to 7 yrs | 5.00 | 1.62 | 101.0 | 0.26 |
| | 7 to 8 yrs | 5.00 | 2.22 | | |
| **DCV** | 6 to 7 yrs | 0.00 | 0.82 | 73.5 | 0.02* |
| | 7 to 8 yrs | 2.00 | 1.09 | | |
| **GD-Right** | 6 to 7 yrs | 5.00 | 1.72 | 79.0 | 0.05 |
| | 7 to 8 yrs | 7.00 | 1.55 | | |
| **GD-Left** | 6 to 7 yrs | 5.00 | 1.77 | 72.5 | 0.03* |
| | 7 to 8 yrs | 7.00 | 1.73 | | |

| | | | | | |
|---|---|---|---|---|---|
| **AM** | 6 to 7 yrs | 11.00 | 2.40 | 51.5 | 0.004* |
| | 7 to 8 yrs | 13.50 | 2.40 | | |
| **SPIN-IE Right** | 6 to 7 yrs | 13.00 | 2.01 | 55.5 | 0.00* |
| | 7 to 8 yrs | 16.00 | 2.80 | | |
| **SPIN-IE Left** | 6 to 7 yrs | 15.00 | 2.06 | 101.0 | 0.26 |
| | 7 to 8 yrs | 16.00 | 3.15 | | |
| **DCV** | 6 to 7 yrs | 2.00 | 2.15 | 73.5 | 0.02* |
| | 7 to 8 yrs | 7.00 | 4.413 | | |
| **GDT-Right** | 6 to 7 yrs | 6.00 | 1.42 | 79.0 | 0.05 |
| | 7 to 8 yrs | 5.00 | 1.43 | | |
| **GDT-Left** | 6 to 7 yrs | 6.00 | 1.50 | 72.5 | 0.03* |
| | 7 to 8 yrs | 5.00 | 1.57 | | |
| **RAMST-IE** | 6 to 7 yrs | 37.00 | 8.42 | 51.5 | 0.004* |
| | 7 to 8 yrs | 46.00 | 8.38 | | |

*Note*. U = test statistic of Man Whitney test, $p < 0.05$; SPIN-IE= Speech In Noise in Indian English; DCV= Dichotic Consonant Vowel; GDT= Gap Detection Test; RAMST-IE= Revised Auditory Memory and Sequencing Test in Indian English; SPIN = Speech-In-Noise; DCV = Dichotic CV; GD = Gap Detection; AM= Auditory Memory.

### 4.5 Sensitivity and Specificity

To establish the sensitivity and specificity of STAP, the pass/refer information obtained on the screening test was compared with the outcomes of the four APD diagnostic tests that were administered. The children included 4 groups: Those who passed both SCAP and STAP (N = 11); those who were referred on both SCAP and STAP (N = 10); those who passed SCAP but were referred on STAP (N = 10); and those who were referred on SCAP and passed STAP (N = 4). Three 2 X 2 matrices containing information about the number of children who passed or were referred on the screening tools (SCAP, STAP or SCAP + STAP) and passed / failed the APD tests were formed (Table 4.9a, 4.9b & 4.9c). The diagnosis of APD was done based on the cut-off criteria recommended by Yathiraj et al. (2012).

**Table 4.9a** : *True positives, False positives, False negatives and True negatives of SCAP*

| SCAP ↓ | APD diagnosis | | Total |
|---|---|---|---|
| | **Present** | **Absent** | |
| **Refer** | **7** | 7 | 14 |
| **Pass** | 7 | **14** | 21 |
| **Total** | 14 | 21 | 35 |

**Table 4. 9b:** . *True positives, false positives, false negatives and true negatives of STAP*

| STAP ↓ | APD diagnosis | | Total |
|---|---|---|---|
| | **Present** | **Absent** | |
| **Refer** | **11** | 6 | 17 |
| **Pass** | 6 | **12** | 18 |
| **Total** | 17 | 18 | 35 |

*Table 4.9 c True positives, False positives, False negatives and True negatives of a combination of SCAP and STAP*

| **SCAP & STAP ↓** | **APD diagnosis** | | **Total** |
|---|---|---|---|
| | **Present** | **Absent** | |
| **Refer** | **5** | 4 | 9 |
| **Pass** | 1 | **9** | 10 |
| **Total** | 6 | 13 | 19 |

*Note: The values in bold represent true positives and true negatives.*

Sensitivity and Specificity were calculated using the following formulae:

$$Sensitivity = \frac{True\ positive}{True\ positive + False\ negative}$$

$$Specificity = \frac{True\ negative}{True\ negative + False\ positive}$$

Details of the sensitivity and specificity of the two screening tools (SCAP & STAP) have been provided in Table 4.10. It can be seen from the table that a combination of SCAP and STAP resulted in much higher sensitivity and marginally increased the specificity as opposed to the individual screening tools.

**Table 4. 10:** *Sensitivity and specificity of SCAP, STAP and SCAP + STAP*

| | SCAP | STAP | SCAP + STAP |
|---|---|---|---|
| **Sensitivity** | 50% | 73% | 83% |
| **Specificity** | 66.6% | 66.6% | 69.2% |

From the overall results of the study the following were observed:

- There was a significant relation observed between the outcomes of SCAP and STAP as well as SCAP and the APD diagnostic tests;
- A moderate to strong correlation was obtained between the subsections of STAP and the diagnostic tests;
- The sensitivity of SCAP was found to be 50% while the specificity was 66.6%;
- STAP was found to have a sensitivity of 73% and specificity of 66.6%;
- A combination of the screening checklist (SCAP) and the screening test (STAP) resulted in higher sensitivity (83%) and specificity (69.2%).
- The SCAP results of the younger age group (6 to 7 years) showed no relation with diagnostic results while that of the older group (7 to 8 years) exhibited a significant relation.
- A comparison of performance of children on STAP and the diagnostic tests across the two age groups revealed that there was a significant difference in their

performances in some subsections of STAP as well as some of the diagnostic APD tests, with the older group performing better that the younger children.

- The correlation between the screening subsections and the diagnostic tests varied depending on the subsection / test, the age of the participants as well as the ear being tested.

# Chapter 5

# Discussion

The study involved administering SCAP, STAP and a battery of APD tests on children aged between 6 and 8 years. The SCAP checklist was administered by teachers; the screening test (STAP) and the diagnostic tests were carried out by an audiologist. The data obtained by administering SCAP, STAP and the diagnostic tests were compiled and analysed. The results of the study are discussed in terms of number of children passed / referred using each of the screening tools; the performance of the participants on diagnostic APD tests; comparison of the two screening tools; performance of the two age groups (6 to 7 & 7 to 8); the relation between the screening tools and the diagnostic tests; and sensitivity and specificity of the two screening tools when used on the target age group.

## 5.1. Screening procedures

### *5.1.1 SCAP*

According to the results of SCAP, 16.19% of the total children tested were found to be 'at-risk' of APD. This percentage is considerably higher than the percentage of children 'at-risk for APD reported by Muthuselvi and Yathiraj (2009) which was 2.6%. Values lower than that observed in the current study (5.9%; 141 children out of 2400 children) were also noted by Yathiraj and Maggu (2012) when the same checklist was used on children aged 8 to 13 years. The difference in findings between the current study and that of the earlier ones can be attributed to the fact that the younger age group (6 to 7 years) had been in school for only about 5 months and the teachers may not have had adequate time to interact with the children to make accurate judgement about their behaviour. Further, the children would have not had adequate exposure to English at the time of evaluation, as children in India are majorly exposed to the language only after their admission into formal schooling. Due to the lack of exposure to English, the children probably required repetition of information or quieter environments to listen. It has been reported in literature that children learning unfamiliar information / languages require more favourable signal-to-noise ratio than familiar information / native language (Mayo, Florentine & Buus, 1997) and also would be less tolerant to degradation of the signals (Nabelek & Donohue, 1984). These requirements are also listed as symptoms in SCAP to identify children as having APD. Thus, it could have led to over-referral by the teachers of children when using SCAP in both age groups, with there being 14.7% younger children (31 out of 210 younger children) and 17.5% (38 out of 216 older children) older children who were over-referred.

*5.1.2 STAP*

STAP was administered on 100 children recruited from those who were referred on SCAP (N = 45) and those who did not exhibit any symptoms of APD (N = 55). Among the four subsections of STAP, the performance on DCV was found to be the poorest followed by SPIN and AM. The performance on the GD subsection was found to be the best. In the combinations of subsections, it was observed that DCV and SPIN (Figure 4.1) had the maximum number of children performing poorly followed by DCV and AM. This can be due to the general poor performance of most of the children in the DCV subsection. During the administration of STAP also, it was observed that most of the children required a repetition of instructions for DCV subsection. This task difficulty may also have influenced the outcomes in this section.

**5.2 APD diagnostic tests**

To establish the utility of STAP, 35 children were evaluated on a battery of four APD tests (SPIN-IE, DCV, GDT, & RAMST-IE). The appropriateness of the chosen 4 APD tests had been provided in literature in several earlier studies (Welsh, Welsh & Healy, 1980; Chermak & Musiek, 1992; Katz, Kurpitha, Smith & Brandner, 1992; Jerger & Musiek, 2000; Bellis, 2003; Muthuselvi & Yathiraj, 2009; Yathiraj & Maggu, 2014). Out of the 35 children who were tested on the APD diagnostic battery, 14 (40%) were labelled as having APD when the criteria given by Yathiraj et al. (2012) was utilised (Figure 4.4). In comparison, Yathiraj and Maggu (2014) reported of 60.5% of their participants aged 8 to 13 years as being diagnosed as having APD on a similar battery of diagnostic tests as used in the current study. This discrepancy in the number of children diagnosed as having an APD can be attributed to the difference in the number of children who were ‘at-risk’ for APD in the two studies. In the current study 16 (45.71%) children 'at-risk' were tested, while in the study by Yathiraj and Maggu, 91 (59.86%) children 'at-risk' were tested. Hence, the probability of the children being found to have an APD was naturally higher in the latter study and lesser in the current study.

Among the individual tests used in the diagnostic battery, there was not much difference in the number of children who failed each of the tests (Figure 4.4). While 10 (28.6%) children failed DCV, 9 (25.7%) failed SPIN-IE, 8 / 9 (22.8% / 25.7%) failed GDT in the right and left ears respectively, and 8 (22.8%) failed RAMST-IE. These results were not very different from the trend reported earlier by Yathiraj and Maggu (2014) for all the tests except for RAMST-IE. They reported that of a much larger number of children failed this test. This could be on account of the larger number of 'at-risk' children tested by them compared to the present study.

Researchers have advocated testing only children above 7 years on various diagnostic tests of APD (ASHA, 2005; Schminky & Baran, 1999). Colorado education department (2008) also noted that it is inappropriate to carry out APD assessments in children younger than 7 years. However, Yathiraj et al. (2012) demonstrated that it is possible to carryout APD / higher cognitive diagnostic tests such as SPIN-IE, DCV with single correct scores, as well as memory and sequencing in children as young as 6 years of age. The use of standard tests in young children as young as 4 years have been earlier supported by Stollman, Neijenhuis, Simkens, and Snik (2004), Stollman, Simkens, Snik, and Marie (2004). They provided evidence that children aged 4 years and older were able to perform a battery of diagnostic tests (SAAT, binaural masking level difference, gap detection test and Lindamood Auditory Conceptualization test) although a strong effect of age was noted.

## 5.3 Comparison of screening tools and with APD diagnostic tests

### *5.3.1 SCAP and STAP*

A significant association between the outcomes of SCAP and STAP was observed when all children were grouped together. However, from the raw data it was observed that despite the number of children who passed or who were referred on the two screening tools being similar, the two procedures did not pick out the same children. It was seen that 17 children who were referred on SCAP passed STAP and 7 children referred on STAP passed SCAP. Based on this finding, it is recommended that both STAP and SCAP be administered so as to detect a larger number of children who are at-risk for APD. This recommendation is further substantiated by the findings of the current study where the sensitivity was higher when a combination of screening tools were used (83%) compared to each of the screening tools being used in isolation (50% / 73%) (Table 4.10). This is similar to the recommendation of Yathiraj and Maggu (2014) who also noted that in older children the sensitivity was higher when a combination of tests was used.

On looking at the outcome of SCAP in comparison with STAP within each age groups (6 to 7 & 7 to 8 years), no significant relation was observed for the younger age group, but was present in the older group. The absence of relation between SCAP and STAP in the younger group might be due to over referral / under referral by the teachers and / or on account of the task difficulties seen in STAP. As mentioned earlier, the teachers were probably unable to make accurate judgements about the presence or absence of symptoms of APD in the children for two reasons. While making decisions about the younger age group, the teachers may not have been able to give correct feedback about the problems faced by the children, due to inadequate interaction time. On the other hand, in both age groups due to difficulties faced by any child while learning a non-native language, they may have utilised coping strategies similar to those used by children at-risk for APD. Hence, when SCAP is used with children aged 6 to 8 years, there is a high likelihood of false positives and false negatives.

*5.3.2 SCAP and APD diagnosis*

The outcomes of SCAP were also compared with APD diagnosis. A significant relation displayed on analysis indicates that most of children referred or passed on SCAP were also found to have an APD and not having an APD. On establishing the sensitivity and specificity in the current study, the sensitivity of SCAP was found to be 50% and specificity was 66.66%.

Earlier studies using SCAP on older children above the age of 8 years noted higher sensitivity ranging from 71% (Muthuselvi & Yathiraj, 2009) to 74.1% (Yathiraj & Maggu, 2014). However, the specificity noted by Yathiraj and Maggu (2014) was similar to that seen in the current study, but Muthuselvi and Yathiraj (2009) reported it to be higher (68%). This indicates the subjectivity involved while using checklists. This has also been observed by past researches (Emanuel, 2002; Maxwell & Satake, 2006; Schow & Seikel, 2007; Delgado & Rodriques, 2004; Hartman, Forsen, Wallace & Neely, 2002; Hoher et al., 1997). This substantiates the need to use a screening test instead of only a checklist in order to reduce the subjectivity.

5.3.3 STAP and APD diagnostic tests

In order to test the validity of STAP, the association of STAP and the APD diagnostic test battery were analysed in terms of pass/refer criteria as well as the raw scores. The results showed a substantial significant agreement. When each of the subsections of STAP were compared with the diagnostic tests that evaluated similar processes / higher cognitive function, GD and GDT showed a substantial agreement while the least agreement was observed between DCV subsection and DCV. Similarly, when the raw scores were used to see the association between STAP and the APD diagnostic tests revealed a similar trend wherein a moderate correlation was seen for GDT and GD as well as for RAMST-IE and AM. A strong correlation was seen between SPIN and SPIN-IE (Table 4.6). This one-to-one correlation and agreement revealed the utility of the test and indicated that the subsections of the test are good representatives of all the auditory processes. The high correlation between the screening subsections and the diagnostic tests also indicates that both tapped similar auditory processes / higher cognitive function. Thus, a high or low score on the subsections of STAP would also result in a high or low score on the corresponding diagnostic APD test.

The correlation between the subsections of STAP and the corresponding diagnostic tests *within each of the two age groups* showed that that both groups performed differently. In the younger group, a moderate correlation existed between GD subsection and GDT as well as between AM and RAMST-IE. On the other hand, in the older group a significant correlation was observed between all the subsections of STAP and the diagnostic tests except for DCV. This probably occurred due to the relatively poor performance on this test compared to other tests (Table 4.3) indicating that the task is difficult for children aged 6 to 8 years. This is similar to what was reported by several authors (Lamm & Epstein, 1997; Yathiraj et al., 2012). Lamm and Epstein also opine that the dichotic performance improves within the first year of school. Yathiraj et al., also suggested that the auditory capacity of children aged 6 years to integrate is very low; but scores of both 6 and 7 year old children did not differ in their performance significantly. Roeser, Millay and Morrow (1983) reported of a steady increase in auditory capacities of children with age. Owing to the difficulty level of task for a dichotic test, the scores also showed a high variability in the present study, which was consistent with the reports of Yathiraj et al. (2012).

When the *difference in performance between the two age groups* was checked for each of the subsections of STAP and the 4 diagnostic tests, once again the contrast between the younger and older children was evident. A significant difference in performance between the two groups was seen for the subsections / diagnostic tests that tapped binaural integration (DCV) and auditory memory (AM / RAMST-IE). However, for auditory separation (SPIN / SPIN-IE) and temporal resolution (GD / GDT), they varied depending on the ear being tested (Table 4.8). This trend was seen for the screening subsections and the diagnostic tests. Thus, it can be inferred that age and maturation plays a crucial factor in the choice of tests for screening. It also becomes necessary to consider revising or relaxing the cut-off scores for the younger age group.

In order to establish the validity of STAP on children aged 6 to 8 years, its sensitivity and specificity of STAP were measured. The sensitivity and specificity of STAP in isolation was found to be 73% and 66.6% respectively. However, the sensitivity and specificity increased to 83% and 69.2% respectively when a combination of SCAP and STAP was used. Yathiraj and Maggu (2012) reported a sensitivity of 76% and specificity of 72% in isolation and in combination with SCAP was found to be 83.8% and 76.2% respectively. Thus, both the studies uphold the views of using a screening checklist and a test for efficient screening of individuals with APD as emphasized on by other authors (Shiffman, 1999; Scow & Seikel, 2007). Thus, the sensitivity and specificity of STAP in children aged 6 to 8 years are comparable to the values obtained in older children (Yathiraj & Maggu, 2012).

From the findings of the current study and that of similar studies reported in literature, it can be inferred that the use of screening tools to detect APD in children would help identify the condition early. The outcome of the present study also revealed that it is possible to effectively test children with screening and diagnostic APD tests as young as 6 to 8 years. As recommended in earlier studies, it is suggested to use a combination of a screening checklist and screening test to increase the sensitivity of an APD screening programme. The correlation between the screening subsections and the diagnostic tests varied depending on the subsection / test, the age of the participants as well as the ear being tested. These variables are to be kept in mind while using STAP as a screening tool.

# Chapter 6

## Summary and Conclusion

With studies emphasizing on the impact of APD on the quality of life of individuals, the importance of early identification and intervention has been stressed widely. Owing to the need for powerful tools to screen for the presence or absence of APD, several screening checklists / questionnaires and screening tests have been reported in literature. The sensitivity and specificity of these screening tools have been established to check their validity. However, two schools of thought continue to exist regarding the age of labelling a child as having an APD, one saying children have to be above the age of 7 to 8 and other providing evidence that it was possible to identify APD in young children below 7 years. Hence, the current study was conducted with an aim to establish the validity of an existing APD screening test on young children aged between 6 to 8 years. The 'Screening Test for Auditory Processing' (STAP; Yathiraj and Maggu, 2012), has currently norms established for children above 8 years of age.

Children aged 6 to 8 years were recruited for the study. Initially 426 children studying in 4 different schools were administered 'Screening Checklist for Auditory Processing' (SCAP; Yathiraj & Mascarenhas, 2003) by their teachers. From these children, 100 children, who had either been referred on or had passed SCAP were administered STAP by an audiologist in the school premises. STAP consisted of 4 subsections SPIN, DCV, GD and AM to tap auditory separation, auditory integration, temporal resolution and auditory memory. To check the validity of the outcomes of STAP its outcome was compared with a battery of 4 APD diagnostic tests which included SPIN-IE, DCV, GDT and RAMST-IE. The diagnostic tests were administered on 35 children who had either passed or had been referred by one or both of the screening tools that were used.

The data collected from these children were analysed using statistical analyses in order to establish the relation among SCAP, STAP and the outcomes of diagnostic tests. A relation between SCAP and STAP as well as between SCAP and the APD diagnosis was done using a Chi-square test; The association between pass/refer criteria of STAP with the pass/fail criteria of diagnostic tests was established using Kappa's measure of agreement; The correlation between the STAP raw scores and raw scores of diagnostic tests was arrived at by using Pearson's product moment correlation; and the differences in performance between the two age groups was obtained using Man Whitney test. Also, by comparing the outcomes of the screening procedures with the diagnostic tests, the sensitivity and specificity of the screening procedures were measured using 2 X 2 matrices . The results revealed the following:

- A significant relation was observed between the outcomes of SCAP and STAP as well as SCAP and the APD diagnostic tests;

- A moderate to strong correlation was obtained between the subsections of STAP and the diagnostic tests;
- The sensitivity of SCAP was found to be 50% while the specificity was 66.6%;
- STAP was found to have a sensitivity of 73% and specificity of 66.6%;
- A combination of the screening checklist (SCAP) and the screening test (STAP) resulted in higher sensitivity (83%) and specificity (69.2%).
- When the difference in performances across the two age groups were checked, a significant difference was obtained in some subsections of STAP as well as in some of the diagnostic APD tests, with the older group performing better that the younger children.

Thus, the study established the validity of STAP on children aged 6 to 8 years. The outcome of the present study revealed that it is possible to effectively test children aged 6 to 8 years with screening (STAP) and diagnostic APD tests. As recommended in earlier studies, it is suggested to use a combination of a screening checklist and screening test to increase the sensitivity of an APD screening programme. The correlation between the screening subsections and the diagnostic tests varied depending on the subsection / test, the age of the participants as well as the ear being tested. These variables are to be kept in mind while using STAP as a screening tool.

Clinical implications

- The screening test (STAP) can be used to effectively screen for APD in children 6 years and above.
- The study shows that use of SCAP along with STAP further enhances the efficiency of STAP.
- It can be recommended that an APD screening program should include both the screening tools.
- It can facilitate in early identification and in turn early intervention.
- The study gives an indication of the task difficulty in this age group (6 to 8 years) and hence caution while administering STAP.has to be taken.

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