Development of a screening test for APD

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Abstract

The present study focussed upon development of a screening test for APD, that taps multiple auditory processes, and is quick to administer. A few APD screening tests are reported to be available in the literature. However, these tests are noted to take longer than the recommended duration for administration and do not tap adequate number of auditory processes. In order to overcome these disadvantages, the 'Screening Test for Auditory Processing' (STAP) was developed that contained four subsections: speech-in-noise (SPIN), dichotic CV (DCV), gap detection (GD) and auditory memory (AM).

The STAP was administered on 500 children selected from 2400 children who were screened using the Screening Checklist for Auditory Processing (SCAP; Yathiraj & Mascarenhas, 2003, 2004). Diagnostic APD tests (speech-in-noise, dichotic CV, gap detection and auditory memory) were administered on 152 of the children referred and/or passed on the screening procedures. The time taken for the administration and scoring of the test on an average was 12 minutes.

The results from the STAP indicated that the auditory memory subsection of the STAP was the most affected followed by dichotic CV and speech-in-noise. Gap detection was the least affected among the four subsections. A high and significant correlation was noted between the subsections of the STAP and the APD diagnostic tests. The sensitivity and specificity of the STAP on comparison with the diagnostic tests was found to be 76.6% and 72%, respectively. It was found that when a combination of SCAP and STAP was used for screening, the sensitivity and specificity were higher. Based on the findings of the study, it is recommended that both SCAP and STAP be administered. Further, there was also a good test-retest reliability of the SCAP, STAP and the APD diagnostic tests.

Introduction

It has been demonstrated that 2-3% of the population has auditory processing disorders (APD). This has been observed in the western population by Chermak and Musiek (1997). Likewise, a study by Muthuselvi and Yathiraj (2009) revealed that a similar number of children are affected with APD in India. They found that among the 3120 school-going children studied by them, 3.2% of them were at-risk for APD. Researchers (Bellis, 1996; Chermak & Musiek, 2007; Muthuselvi & Yathiraj, 2009) have reported of the deleterious impact of this condition on the school performance of children, making it necessary to identify the condition early.

To ensure early identification of APD, screening has been found to play a very important role. Lessler (1972) described screening as a means to acquire preliminary information about the characteristics of individuals, particularly those that may significantly impact their health, education or wellbeing. In addition, the author emphasized that screening tests result in economy of finance, time and other resources. Musiek, Gollegely, Lamb and Lamb (1990) listed several reasons in support of screening program for APD. According to them, accurate screening and identification of APD would help identify conditions that may require medical attention; improve the awareness of APD among educators and parents; prevent unnecessary over-referrals; reduce the psychological stress on the child; and also provide an insightful educational planning for these children. Further, Bellis (2003) opined that the cost involved in a screening program for APD was justified as it would reduce over-referral.

Jerger and Musiek (2000) reported of the consensus of the 'Conference on the Diagnosis of Auditory Processing Disorders in School-Aged Children', which in addition to putting forth a consensus on diagnosis, also arrived at the requirements for screening questionnaires and screening instruments. The group of 14 senior scientists and clinicians agreed that an APD screening procedure should include the following: Tasks to tap processing of complex auditory stimuli such as temporal processing and spatial resolution; provide information on the sensitivity, and specificity, inter-observer reliability, inter-test consistency, and validity. Further, they emphasised that any new screening test should consider the number of items/trials required to obtain reliable information, the stimulus intensity and the type of response; address aspects that can affect the screening results such as examiner training, hearing loss, middle ear dysfunction, equipment quality control and maintenance, and test environment; be minimally influenced by cognitive, attention, and linguistic demands; and be brief (ideally 8-12 minutes). As a cautionary remark, they warn against using screening instruments for the purpose of diagnosis.

Schow and Seikel (2007) also opined that a screening instrument for APD should have a high sensitivity and specificity and it should not be influenced by hearing loss, language, cognition, cultural or other non-auditory factors. They recommended the use of screening tests along with behavioural tests having good sensitivity and specificity.

According to the American Speech Language Hearing Association (ASHA; 2005), the sensitivity of a test should be determined by comparing it with gold standard. Several researchers (Chermak & Musiek, 1997; Keith, 1995; Bellis, 1996, 2003; Ferre & Wilber, 1986) and organisations (ASHA, 1996, 2005) have recommended a test-battery approach to evaluate the efficiency of screening tests since no single test or procedure produces acceptable results in terms of sensitivity and specificity. Due to varying profiles of APD, it has been reported that it is difficult to define the gold standard to measure the sensitivity and specificity of tests of central auditory dysfunction (ASHA, 2005; Schow, Seikel, Chermak & Berent, 2000; Schow & Chermak, 1999). On account of the absence of an absolute gold standard, Chermak and Musiek (1997) recommended the use of a quasi gold standard where outliers from a normative data (i.e., those falling 2 SD below the mean) are identified as APD.

Though there is no gold standard test battery for APD, researchers have made recommendations to use groups of tests, which they suggest could serve as a gold standard. Willeford and Burleigh (1985) provided a test battery approach for diagnosing APD. Originally, he recommended three diagnostic tests consisting of filtered speech test, binaural fusion test and dichotic listening test. Later, time compressed test and synthetic sentence identification were added to the Willeford battery.

Musiek, Guerkink and Kietel (1982) utilized seven diagnostic tests as a part of their test battery for APD. These tests consisted of the frequency pattern test, binaural fusion, rapidly alternating speech perception, competing sentences, low pass filtered speech, dichotic digits and staggered spondaic word (SSW) test. They found that the most sensitive test was the competing sentence test followed by the frequency pattern test, dichotic digits and SSW. Later, Chermak and Musiek (1992) recommended the use of an APD battery with at least one test of temporal processing, one of dichotic listening and one monaural redundancy test.

Ferre and Wilber (1996), based on their findings on children with APD, recommended the use of a test battery consisting of time compressed, dichotic CV, binaural fusion and low pass filtered speech. They found that the results of the participants were heterogenous on the various subtests and hence, they advocated the use of the test-battery.

According to the ASHA technical report (2005), APD is associated with language and academic problems and children associated with APD have a higher likelihood of emotional, social difficulties and low self-esteem. According to ASHA, early identification and intervention may lessen the impact of these secondary problems in school-aged children.

Considering the importance of early identification of APD, numerous authors (Fisher, 1976; Van Dyke, 1985; Keith, 1986; Smoski, Brunt & Tannahill, 1992; Jerger & Musiek, 2000; Schow & Seikel, 2007; Shiffman, 1999; Muthuselvi & Yathiraj, 2009) have suggested the use of screening procedures for quick identification of children with the condition. The screening procedures have utilized questionnaires (Fisher, 1976; Van Dyke, 1985; Smoski et al., 1992; Muthuselvi & Yathiraj, 2009) or behavioural tests (Keith, 1986; Schow & Seikel, 2007). The use of a combination of a questionnaire and screening test has also been recommended (Shiffman, 1999). Additionally, Bellis (2003) advocated the use of an inter-disciplinary method of screening that include both audiological and non-audiological methods of screening.

Screening checklists or questionnaires

In the literature, a number of checklists to screen for APD have been described (Fisher, 1976; Simpson, 1981; Willeford & Burleigh, 1985; Smoski et al., 1992; Anderson & Smaldino, 2000; Summers, 2003; Yathiraj & Mascarenhas, 2003, 2004). The checklists have listed symptoms of APD in order to detect the condition. A few of the commonly reported symptoms in the checklists include difficulty in the comprehension of speech in the presence of noise, reduced auditory attention, inconsistent awareness for auditory stimuli, poor concentration, and lower academic achievement.

Fisher (1976) developed the 'Fisher's Auditory Problems Checklist' to identify children with APD. The checklist consists of 25 questions on the academic performance of the children which are to be answered by the teachers. The checklist has normative values established for children from kindergarten to sixth grade. The questions included in the checklist tap behaviours such as failure to attend oral instructions, the need for repeated instructions, and easy distraction by auditory stimuli. The questions encompass language deficits as well as auditory deficits such as auditory discrimination and degraded processing in a competing acoustic environment. However, Willeford and Burleigh (1985) reported that it resulted in high false-positive responses.

Willeford and Burleigh (1985) developed a checklist which ranked the behaviours associated with APD. Behaviours related to auditory, academic and social profiles were ranked on a 5-point rating scale. However, the authors did not report of the sensitivity, reliability, and validity of the checklist. Smoski et al. (1992) found that the checklists developed by Fisher (1976) and Willeford and Burleigh (1985) did not focus on specific observed listening behaviours of children with APD and that the listed behaviours were based on a limited number of subjects. Keith (2007) also reported that these two checklists were not validated.

The Children's Auditory Processing Performance Scale (CHAPPS), developed by Smoski et al. (1992), assesses six listening conditions and functions. The listening conditions and functions included listening behaviour in noise, quiet, ideal, multiple inputs, auditory memory/sequencing and auditory attention span. The checklist has 36 questions that are rated from +1 to -5 by a teacher or a parent. The higher rating (+1) indicated less difficulty while the lower rating (-5) indicated more difficulty. The total score ranged from +36 to -180. The parent or the teacher had to assess a child's listening ability by comparing his/her scores with that of other similar aged children. Earlier, Smoski (1990) also recommended the CHAPPS as a tool to determine the effectiveness of therapy.

The CHAPPS has been utilised in several studies to identify APD. Studies reported in the literature have compared the CHAPPS scores to the results of diagnostic tests. Smoski et al. (1992) administered CHAPPS on 64 children identified to have APD. These children were classified as having APD if they obtained low scores in two of the four tests that they considered as the gold standard. These four tests consisted of the staggered spondaic word (SSW) test, dichotic digit test, competing sentence test and pitch pattern test. The CHAPPS findings revealed that the most common symptom exhibited by these children was difficulty in hearing in a noisy situation. Other symptoms reported were auditory memory problems, auditory attention and integration of multiple modality inputs.

Purdy and Johnstone (2000) found a significant correlation between the dichotic digit test and memory rating with the CHAPPS. However, Cameron, Dillon and Newall (2005) found no correlation between the CHAPPS and a battery of diagnostic tests that included pitch pattern sequencing test, duration pattern test, masking level differences, Bamford-Knowal-Bench sentences and random gap detection test. The limited utility of the CHAPPS was also noted by Drake et al. (2006) who found that it led to either over or under referral. They found that the CHAPPS over-referred 15 out of 20 children with no APD and under-referred 5 out of 20 children with APD. They found that there existed no relation between the results of the CHAPPS and the diagnostic tests used by them. Based on the outcome of their study, they recommended not using it as a single tool for referral.

The Screening Checklist for Auditory Processing (SCAP; Yathiraj & Mascarenhas, 2003, 2004), was developed based on the feedback from speech and hearing professionals as well as symptoms suggested in the earlier checklists. The SCAP was designed to be administered by parents or class teachers. It comprises of 12 questions regarding symptoms of APD that includes auditory perceptual processing, auditory memory and other miscellaneous symptoms. The checklist is scored on a two point rating as ‘Yes’ or ‘No’. Each answer marked ‘Yes’ is scored as ‘1’ and each ‘No’ is scored ‘0’. Children who obtained scores of more than 50% (6/12) were considered to be ‘at-risk’ for APD. Yathiraj and Mascarenhas (2004) found a significant correlation between the results of the SCAP and the diagnostic tests used by them. The diagnostic tests included Dichotic CV (DCV), Speech-in-Noise Test (SPIN), Duration Pattern Test (DPT), Auditory memory and sequencing test (AMST). This correlation was used to substantiate the utility of their checklist. Further, Muthuselvi and Yathiraj (2009) found that the checklist had a sensitivity of 71% and specificity of 68% when a cut-off criterion of '6' was employed. The sensitivity and specificity were obtained by comparing the results of the SCAP with the diagnostic tests used by them (SPIN, Gap detection, DCV, AMST &, masking level difference). In India, various studies (Yathiraj & Mascarenhas, 2003; Devi, Nair & Yathiraj, 2006; Priya & Yathiraj, 2007; Maggu & Yathiraj, 2011) have utilized the SCAP to detect children who are at-risk for APD. These studies confirmed the presence of APD in their participants using different diagnostic tests.

The Scale of Auditory Behaviours (SAB) is a questionnaire developed out of the Teacher's Scale of Auditory Behaviours and the Parent's Scale of Auditory Behaviours checklists (Simpson, 1981). The SAB consists of 12 items that were selected and refined based on the results of a series of studies conducted at the Idaho State University (Conlin, 2003; Shiffman, 1999; Simpson, 1981; Summers, 2003). According to Schow et al. (2007), these items provided information about the impact of the deficit in everyday life. These items were congruent with the recommendations of the consensus report on the diagnosis of APD in school-going children (Jerger & Musiek, 2000). The norms for the checklists were obtained on 96 children in the age range of 4 to 6 years (Conlin, 2003).

The Children's Home Inventory for Listening Difficulty was developed by Anderson and Smaldino (2000) for children in the age range of 3 to 12 years. This family-centred parent survey focused on hearing and understanding difficulties in quiet and noisy conditions. According to Chermak and Musiek (2007), such a survey may help in broadly screening for processing deficits. However, data on the sensitivity and specificity data were not reported.

Similarly, there are other checklists such as the Evaluation of Classroom Listening Behaviours VanDyke (1985) and the Screening Instrument for Targeting Educational Risk (Anderson, 1989). These checklists focussed on targeting the problems faced by children at school and are were to be administered by the parents or teachers. However, like most checklists developed for APD, their sensitivity and specificity were not reported.

The consensus report on the diagnosis of APD in school-going children by Jerger and Musiek (2000) promoted the use of questionnaires to screen for APD. They recommended that such a questionnaire should include behaviours that would lead to the suspension of APD. The consensus report only provided examples of what could be included in a questionnaire, but not its actual content. However, they emphasized that any questionnaire for APD should specify its pass / refer criteria. They also warned against the use of questionnaires that primarily tap memory and language deficits as these non-auditory aspects could lead to over referral.

The use of screening questionnaires has been criticized by several authors (Schow & Seikel, 2007; Maxwell & Satake, 2006) primarily due to them being subjective. The biases of the clinician (Delgado-Rodriquez and Llorca, 2004) as well as the respondent (Hartman, Forsen, Wallace & Neely, 2002; Hoher, Bach, Munster, Bouillon & Tiling, 1997) have been reported to contaminate the results.

Screening tests

Tests to screen for the presence of APD have been in advocated / developed by several researchers (Cherry, 1992; Jerger & Musiek, 2000; Bellis, 2003). The use of screening tests that indirectly identified APD have been utilised since the early 1980's (Cherry, 1992). The 'Selective Auditory Attention test' (SAAT) developed by Cherry in

1992 for children in the age range of 4 to 8 years, targeted children with selective attention deficits. This was thought to interfere with academic achievement. The SAAT, a closed-set word-identification test, used the commercial recordings of the Word Intelligibility by Picture Identification (WIPI) test developed by Ross and Lerman (1971). Of the two lists of the test that were used, one was presented in quiet and other in the presence of background noise. This was done to check the impact of background noise in children's perception of speech.

In order to determine the validity of the SAAT, Cherry (1992) administered it on 321 children aged between 4 to 8 years. The SAAT correctly identified 90% of the children with learning disability and 40% of the children judged by teacher as being 'at-risk' for learning problem. However, 13% of normally achieving children were incorrectly identified as being 'at-risk' for learning problems. They however did not make any mention of the number of children at-risk for APD that could be identified.

The SCAN developed by Keith (1986) was one of earliest screening test batteries that was specifically developed to detect APD. It was designed for children aged 3 to 11 years. The SCAN consists of three sub tests, auditory figure ground (AFG), filtered words (FW), and competing words (CW). The screening test was standardized on a sample of 1034 children from a variety of geographic regions and racial and economic groups. Keith reported that SCAN could be used conveniently in school situations, since it required only a portable cassette player with headphones. However, it was necessary to administer the test in a quiet environment and took around 20 minutes.

Keith, Rudy, Donahue and Katbamma (1989) studied the auditory processing abilities of 155 children in the age range of 6 to 15 years using the SCAN. They found that the sub-tests of the SCAN, except for the auditory figure-ground and filtered words, had a significant correlation with the SSW test and competing sentence tests. In addition, there was a poor correlation between measures of language and SCAN. The authors reported this as evidence that the SCAN was a valid measure of auditory processing due to the absence of a high correlation with general measures of language. This was considered to indicate that the SCAN was focused on detecting specific auditory processing ability. However, they also reported that the SCAN was sensitive to the presence of an Attention Deficit Hyperactive Disorder (ADHD).

The SCAN has been criticized by Stach (1992) who reported that it was uncertainly sensitive to APD. The SCAN was found to be more sensitive to the presence of attention deficits and language problems. Further, SCAN was criticized by Bellis (1996, 2003) and Schow and Seikel (2007) for the tests included in it. Although, the SCAN used a battery of tests, it included only two of the auditory processes listed by ASHA (2005). The two processes included were binaural / dichotic tests and monaural low redundancy tests. Bellis (1996, 2003) remarked that the SCAN as it did not include a temporal processing measure, which is a process that should have been tapped. Additionally, issues regarding the scoring procedure, the environment and the test-retest reliability of SCAN have also been raised. The test-retest reliability of the SCAN was noted to be relatively low when the test was administered after a 6 to 7 week interval as reported by Amos and Humes (1998). They found that the highest test-retest correlation was moderately strong for the competing word subtest and composite scores ($0.70 < r < 0.78$).

Humes, Amos and Wynne (1998) found fault with the scoring procedure used in the SCAN, noting that it did not provide equal weighting for each subtest while computing the composite score. In a group of 6 children, Emerson, Crandall, Schow and Chermak (1997) found that SCAN scores obtained in a school situation were considerably poorer than those obtained in audiometric test conditions, questioning its ability for use in school/noisy situations. To overcome all the above criticism, the SCAN test was revised and two separate tests were developed, SCAN-A (Keith, 1995) for adults and SCAN-C (Keith, 2000) for children.

Keith (1995) developed the SCAN-A for adults and adolescents above the age of 12 years. The standardized version of SCAN-A included six sub tests: two filtered words, two auditory figure ground tests and competing words and sentences. Keith (1995) reported that the test-retest reliability of SCAN-A was found to be 0.69, indicating good reliability. The SCAN-C for children (Keith, 2000) was recorded in a compact disc version with competing sentences included in them. Equal weightage was provided to all the sub-tests and it was standardized on children ages between 5 to 12 years.

The two screening tests, SCAN and SAAT, were compared by Chermak, Styers and Seikel (1995). They found that the composite score of the SCAN and the SAAT had equivalent group means. However, the SAAT was found to be more sensitive than SCAN in identifying the children as 'at-risk' for APD. They also observed that SAAT and SCAN measured different but overlapping aspects of auditory processing and hence, the two screening tests did not consistently identify the same children as 'at-risk' for APD.

In 2009, Keith released two additional versions of the SCAN, SCAN-3:A (Keith, 2009a) for adolescents and adults and SCAN-3:C (Keith, 2009b) for children. While SCAN-3:A was developed for those above the age of 13 to 50;11 years, SCAN-3:C was designed for children aged 5 to 12 years. Both versions of SCAN-3 were reported to have screening and diagnostic tests. The screening tests consisted of gap detection, competing words and auditory figure-ground. The diagnostic tests included filtered words, competing words and competing sentences. This test was reported to be an improvement over the previous versions of SCAN, as a task of temporal resolution was also included. In a product report regarding the test, Keith reported that the adolescent /adult or children version of the screener took 10 to 15 minutes to administer while the diagnostic tests required 30 to 40 minutes in adults and 20 to 30 minutes in children. Keith (2009a) reported that the sensitivity of SCAN 3 was 66% and its specificity 74% in adults. However, according to a recent technical report of SCAN 3:A by Keith (2012), the sensitivity was noted to be 93% and specificity 49% when a cut-off score of less than 8 was used. However, details regarding the method used to establish the sensitivity and specificity were not provided. While the sensitivity and specificity was provided for adults, it has not been reported specifically for children.

In addition to the SCAN, earlier Keith (1994) also developed a screening tool called the Auditory Continuous Performance Test (ACPT). This screening test assessed only attention related auditory behaviours. The test assessed auditory vigilance, which required listeners to attend to strings of monosyllabic words and raise their thumbs whenever those particular words occurred. Both impulsivity and omissions errors were scored, and performance at the beginning and end of the test were compared to provide an indicator of auditory vigilance over time. This provided information about the child's ability to sustain attention to auditory stimuli.

In the consensus report on diagnosis of APD, Jerger and Musiek (2000) also reported of what a screening test should contain. They recommended the use of a dichotic digit test with two digits in each ear and with the responses obtained through free-recall. Digits were selected since it was opined that such stimuli reduced the linguistic load unlike what occurs with less well-learned speech tokens. Additionally, they promoted the use of a gap detection test with short silent gaps introduced in burst of broad-band noise. This was recommended as it was considered to be an important aspect of speech perception. Thus, they promoted the use of behavioural tests that evaluated three domains: auditory patterning / temporal ordering, monaural separation / closure and binaural integration / separation. These screening procedures were not suggested to be used on children under the age of 6 years due to lack of adequate empirical evidence regarding the ability to carry out diagnosis in this age group. Hence, for children under the age of 6 years, it was felt that screening questionnaires were more appropriate.

Domitz and Schow (2000) employed the Multiple Auditory Processing Abilities (MAPA) and SCAN on 81 children studying in third grade. It was found that the sub-tests of the MAPA had a low sensitivity ranging from 30 to 40% while the specificity was 100%. They also reported that the SCAN had a low sensitivity of 45% with a specificity of 95%. They evaluated the efficacy of a combination of sub-tests and found that the SAAT, pitch pattern test and dichotic digit test led to a sensitivity of 90% with a 100% specificity. The authors claimed that the administration duration of the MAPA screening tests was around 30 minutes. Further, the test-retest reliability of the MAPA, checked on 7 children in the age range 8 to 11 years, was found to be good (r = 0.89). Similarly, Summers (2003) also reported of MAPA having a fairly high test-retest correlation with it ranging from 0.67 to 0.91, depending on the subtest. These findings confirm that the MAPA tests met the generally accepted standard of reliability, which is $r > 0.7$.

Using an exploratory factor analysis, Domitz and Schow (2000) found that only two auditory processes were tapped by SCAN. These processes included monaural separation / closure and binaural separation. On the other hand, they noted that MAPA tapped four processes auditory patterning / temporal ordering, monaural separation closure, binaural integration and binaural separation.

Based on the findings of Domitz and Schow (2000) and Shiffman (1999), Schow and Seikel (2007) recommended the use of a combination of a screening questionnaire and a screening test to increase the sensitivity and specificity of the screening procedure. Shiffman (1999) had reported that the combination resulted in a sensitivity of 83% and specificity of

85%. Additionally, Schow and Seikel (2007) also suggested that a combination of MAPA and SAB could help study the comorbidity of APD with Attention Deficit Hyperactivity Disorder (ADHD), Learning Disability (LD) and autism disorder.

In the literature it is reported that a requirement for a screening procedure is that it should be quick to administer, should tap several auditory processes, and have a high sensitivity and specificity. However, from the review of literature on screening tests for APD, it can be observed that the sensitivity of various APD screening tests varies from 30 % to 93% and the specificity varies from 49% to 100% (Domitz & Schow, 2000; Keith, 2009; Shiffman, 1999); the test-retest reliability ranges from 0.69 to 0.89 (Amos & Humes, 1998; Domitz & Schow, 2000; Keith, 1995; Summers, 2003); the time taken to administer the procedure is found to be 20 to 30 minutes (Domitz & Schow, 2000). From the review of literature, it can be observed that a screening test that taps a larger number of processes has been reported to take more than the recommended time for administration as well as have a poor sensitivity when used in isolation (Domitz & Schow, 2000). Furthermore, the screening tests that reported of a high sensitivity, either based their findings on non-APD tests, or reported their findings on adults. Due to the lack of availability of a screening APD test for children that are reliable yet time efficient, the need to develop one was felt. Hence, the present study aimed to developing a quick, efficient, easy to administer and auditory process-specific screening test to detect auditory processing disorders. The current study also aimed at determining the sensitivity and specificity of the screening test by comparing its scores with a battery of four APD diagnostic tests. The sensitivity and specificity of the screening test when used alone and in conjunction with a screening checklist was also proposed to be determined.

Method

The study was carried out in three stages. In the first stage, the screening test for testing auditory processing (STAP) was developed. The second stage involved administering a screening checklist (SCAP; Yathiraj & Mascarenhas, 2003, 2004) and the newly developed screening test, STAP, on school-going children aged 8 to 13 years. In the third stage, three groups of children, categorized based on the findings of the screening checklist and / or screening test, were tested on a diagnostic test battery.

Stage I: Development of the screening test

The STAP was developed to consist of four subsections: speech-in-noise (SPIN), dichotic CV (DCV), gap detection (GD) and auditory memory (AM). These subsections were selected based on the auditory processes / higher cognitive functions that were reported in the literature to be frequently affected in children with APD. Monaural auditory separation was reported to be commonly deviant in children by Welsh, Welsh and Healy (1980), Katz et al. (1992) and Muthuselvi and Yathiraj (2009). The other auditory processes / higher cognitive functions noted to be often affected in children with APD were binaural integration (Musiek et al., 1982; Katz et al., 1992; Muthuselvi & Yathiraj, 2009), temporal resolution (Musiek et al., 1982; Muthuselvi & Yathiraj, 2009) and auditory memory (Muthuselvi & Yathiraj, 2009). Thus, the STAP was constructed with three verbal subsections (SPIN, DCV and AM) and one non-verbal subsection (GD). The details of the four subsections of the STAP are provided in Table 1.

The material for the three verbal subsections was recorded by a female who spoke Indian-English with a neutral accent. A uni-directional microphone, placed 6 cm from the mouth of the speaker was used for the recording. Using Adobe Audition version 3.0, the stimuli were recorded with a 44.1 kHz sampling rate and 16-bit quantization. The recorded material were scaled to ensure that the intensity level of the stimuli were similar. Prior to the test stimuli in each subsection, recorded instructions and practice items were provided. To ensure that the quality of recording was clear, a goodness test was carried out on 5 adults and 10 children. The goodness test was done with the test stimuli presented in isolation. Any stimulus that did not have 100% intelligibility was rerecorded.

Table 1. *Details of the sub-sections of the STAP*

	STAP Subsections			
	Speech-in-noise (SPIN)	**Dichotic CV (DCV)**	**Gap detection (GD)**	**Auditory memory (AM)**
Stimuli	Monosyllabic words	Consonants-Vowels (/pa/, ta/, /ka/, /ba/, /da/, /ga/)	300 ms white noise	Monosyllabic words
No. of practice items	2 words per ear	2 CV pairs	1 token for each ear	1 token of 4 words
No. of test items	10 words per ear	6 CV pairs	6 tokens for each ear	4 tokens of 4 words
Mode of presentation	Monaural	Dichotic	Monaural	Binaural
Processes Tested	Auditory separation	Binaural integration	Temporal resolution	Auditory memory

Each subsection commenced with instructions regarding what the child would hear and how he/she should respond. This was followed with one / two practice items and the test items. While the GD and AM subsections had one practice item, the DCV and SPIN subsections had two practice items. For the DCV and SPIN subsections additional practice items were introduced as it was found that all 10 children, on whom the goodness test was carried out, had difficulty in following the task with just one practice item on the former and 5 had difficulty in the latter. Hence, for the DCV subsection, the first practice item had a recorded response given by a child in order to make the task clear. The second practice item, similar to the practice items of the other three subsections was followed with a period of silence for the children to respond. The SPIN subsection had two practice items, both with silences for the children to respond. Additionally, a 1 kHz calibration tone was inserted prior to the entire screening test, to be used in case the test is run through an audiometer.

The SPIN subsection consisted of 10 words along with an 8-talker speech babble recorded. Using Adobe Audition (version 3.0), the words and babble were monaurally mixed on a single track for monaural presentation. The speech stimuli and the noise were scaled so that the signal to noise ratio (SNR) was zero. The 8-talker English speech babble, developed by Yathiraj, Vanaja and Muthuselvi (2010) was used as the noise. A silence of 5 sec was inserted between two words to obtain responses from the participants. The instruction recorded prior to the SPIN subsection stated, "You will hear words spoken by a lady in a noisy room. Please repeat what you hear in your right ear". After the presentation of the test items to the right ear, the instructions in the left ear stated, "Please repeat what you hear in your left ear". The material for the SPIN were recorded in different tracks such that stimuli were heard automatically in the right and left ears, one after the other, without having to manipulate any further setting. Each correctly repeated word was awarded a score of one while an incorrect was given a a score of zero. For each ear, the maximum possible score was ten.

The DCV subsection consisted of 6 stops (/pa/, /ta/, /ka/, /ba/, /da/ and /ga/). Each stimulus of a pairs of stops was recorded two separate audio tracks with a 0 ms lag. Between the pairs of stimuli, a gap of 6 sec was provided to acquire responses. The instructions to the children for the DCV subsection were, "You will hear two sounds together, one in your right ear and another in your left ear. Please repeat both of them". Only when the responses were correct in both ears (double correct) was a score of one given. However, an incorrect response in any one ear (single correct) or a incorrect response in both ears was assigned a score of zero. The maximum attainable score was six.

The GD subsection consisted of 12 test items, with 6 for each ear. Each item consisted of a triad of 300 ms white noise, generated using Adobe Audition version 3.0 at a sampling rate of 44.1 kHz, with a silence of 6 ms interspersed in one of the stimuli. The position of the stimulus with the gap was randomised within the triad. A silence of 5 sec was inserted between the triads to obtain responses. For the GD subsection, the direction given to the children was, “You will hear three sounds. Which one of them is different? Is it the first, second or third?” The recording for the GD was done in two tracks such that the stimuli shifted automatically from the right ear to the left ear, without manipulation of any settings. Each correctly response was awarded a score of one while an incorrect response led to a score of zero. For each ear, the maximum possible score was six.

The AM subsection consisted of four 4-word sequences. The words consisted of English monosyllables that were familiar to children aged 8 to 10 years. The familiarity was determined on 30 children in the above age range. The silence within a sequence was 100 ms. Between the sequences an interval of 8 sec was introduced for the children to respond. The information provided before the AM subsection directed the children as follows, “You will hear a few words. Please repeat them together”. Each correctly repeated word was awarded a score of one while an incorrectly response was given a zero. The maximum score that could be attained was 16.

The pass criteria for the various subsections of the STAP were adapted from the earlier existing diagnostic tests. The details of the score for each subsection and the pass criteria are provided in Table 2. For the DCV, it is recommended that the double correct scores be valued. However, the single correct scores could also be used as a guideline, if required.

Table 2. *Details of the scoring and pass criteria of the four subsections of the STAP*

Subsections	**Maximum scores**			**Pass scores**		
	Right Ear	**Left Ear**	**Double Correct**	**Right Ear**	**Left Ear**	**Double correct**
SPIN[a]	10	10	----	6	6	----
DCV[b]	6	6	6	4	4	2
GD[c]	6	6	----	4	4	----
AM[d]	16		-----	12		----

SPIN: Speech-in-Noise; DCV: Dichotic Consonant Vowel; GD: Gap Detection; AM: Auditory Memory
Pass criteria adapted from: a, Olsen et al, 1975; b, Krishna (2001); c, Shinn et al (2009); d,Yathiraj and Vijayalakshmi (2006)

Participants

Children studying in regular schools in the age range of 8 to 13 years were recruited for the study. All the children studied in grades III to VIII. None of the 2400 children selected were reported to have a complaint or history of hearing loss, ear discharge, communication problems or any psychological problems. It had been established by psychologists visiting the schools that the child had average to above average intelligent quotients. The SCAP was administered by 35 school teachers who had taught the children for at least one year. All the teachers taught curricular subjects other than second language. These teachers were selected so that they had a good idea about the pedagogic performance of the children that was not compromised by a lack of exposure to a regional language. In addition to being evaluated by the SCAP, 500 children were also evaluated using the STAP. These 500 children included all the children that the teachers suspected to have APD as well as those children without symptoms of APD.

For the third stage of the study, 152 children were evaluated. These children were selected from the 500 children who were tested on both the SCAP and the STAP. These 152 children represented three groups based on their performance on the SCAP only (Group 1), STAP only (Group 2) and SCAP as well as STAP (Group 3). Thus, Group 1 included those who were referred (N = 30) and passed (N = 15) the SCAP but were not referred on the STAP; Group 2 included those who were referred (N = 30) or passed (N = 25) the STAP but were not referred on the SCAP; and Group 3 included those who were referred (N = 31) and passed (N = 21) both SCAP and STAP.

Instrumentation and environment

The STAP stimuli were played through a laptop loaded with Adobe Audition version 3.0 and was routed to a TDH-39 headphone. The volume controls of the audio software as well as the laptop were manipulated to ensure that the output from the TDH-39 headphones was 65 dB SPL. This was measured using an SLM (Larson Davis systems 824) with a ½ inch 2540 microphone connected to a NBS 9A 6cc coupler. The participants were tested in a quiet room, within the school premises. The room was free from audio and visual distractions. It was ensured that with the TDH-39 headphone on, the audibility of the noise in the environment was much lower than the signal.

The diagnostic testing was carried out in a sound-treated audiometric test suite. A calibrated dual channel diagnostic audiometer (Madsen OB 922 -version 2) with air conduction (TDH-39) and bone conduction (B-71) transducers was used to carry out pure-tone audiometry, speech audiometry and the APD tests. A calibrated immittance meter (GSI Tympstar) was used to ensure the presence of normal middle ear function. Compact disc (CD) versions of the diagnostic tests were played through a CD player of a laptop connected to the audiometer.

Stage 2: Administration of screening tools

In stage 2 of the study, the two screening tools were administered on the children. The SCAP was chosen as it had been found to have a high sensitivity and specificity of 71% and 68%, respectively, as evaluated by Muthuselvi and Yathiraj (2009). The screening checklist that consisted of 12 questions, tapped auditory memory and speech perception in noise difficulties of the children. A cut-off score of 6 (one per positive symptom) had been found to differentiate children at-risk for APD and with no APD by Muthuselvi and Yathiraj (2009).

While the SCAP was administered on all 2400 children who met the subject selection criteria, the STAP was administered on 500 of them. These 500 children were randomly selected from the 2400 children. Half of these 500 children were initially tested with the SCAP and the other half with the STAP. The SCAP was administered by the school teachers who met the requirements to administer the checklist. On the other hand, the children were evaluated on the STAP by an audiologist. A double blind approach was used wherein neither the teachers nor the audiologist knew the results of the tests. The teachers were instructed to refer all the children they suspected to have APD as per the scores of the SCAP, besides referring those without symptoms of APD. The teachers were also told not to reveal the SCAP scores when referring the children.

Procedure for administration of SCAP

The school teachers who administered the SCAP were instructed to mark on the checklist that was provided to them as to whether each child had any of the symptoms listed. Each child was evaluated only by one teacher. The teachers were informed not to reveal the scores obtained by the children. Among the 2400 children, 250 were randomly evaluated on the STAP prior to being evaluated by the teachers on the SCAP. This was done to avoid any test order effect.

Procedure for administration of STAP

The STAP was administered on each child independently in a quiet room. The stimuli were played using Adobe Audition version 3.0. The children were seated comfortable in front of the audiologist. Prior to placing the headphone on a child, he/she was instructed to listen to the recorded instructions and respond verbally. Their responses to the test items were noted by the audiologist who administered the test. It was observed that despite the DCV subsection having an extra practice item, approximately 40% of the children required additional instructions from the audiologist to carry out this task. For these children, the screening test was paused and verbal instruction, similar to what was provided in the recording, was given again by the audiologist. The children were then made to undergo the practice items of the DCV once again before proceeding with the test.

The time taken by each child for the administration of the STAP was also noted. The duration taken was noted from the time child entered the test room and settled down till the complete administration of the test. For thirty randomly selected participants, the time for the administration of the test as well the time for scoring the responses just after the completion of the screening test was also noted. It was found that it took approximately 12 minutes for the administration of the test and scoring of the responses of each child. Without the time taken for scoring, the test took approximately 10 ½ minutes.

For all four subsections, each correct response was assigned a score of one while an incorrect response a score of zero. Using the cut-off criteria provided in Table 2, the children were categorized as having passed or referred for each of the four subsections.

It was found that among the 500 children who were tested on the STAP, 141 children obtained scores of six or more on the SCAP, based on which they were referred. On the other hand, 359 children had scored less than six on the SCAP and hence were passed. Further, it was found that on the STAP, 91 of them were referred on one or more of the subsections and 409 of them passed all the four subsections. On both SCAP and STAP, 77 children were referred.

Test retest reliability

The test-retest reliability of the SCAP and STAP was also done after an interval of 2 month on approximately 10% of the children who were tested on both screening procedures. For the checklist it was done on 63 children and on the screening test it was done on 50 children. It was ensured that none of these children had undergone any form of rehabilitation for auditory processing problems during this period.

Stage 3: Administration of the diagnostic tests

Among the 500 children who were tested on both the screening procedures, 152 children who were selected in a semi-random manner for complete diagnostic testing. These children underwent routine audiological evaluation in addition to being tested on a battery of APD tests. The routine audiological evaluation included pure-tone audiometry, immittance evaluation and speech audiometry. From the pure-tone test results it was ascertained that they had AC and BC thresholds within 15 dB HL in the frequencies 250 Hz to 8 kHz and 250 Hz to 4 kHz respectively. Normal middle ear functioning was confirmed from the immittance evaluation, wherein the participants obtained ‘A’-type tympanograms and acoustic reflexes present at 500 Hz, 1 kHz, 2 kHz. All the children had speech reception thresholds (SRT) of less than 25 dB HL, as measured using the modified PAL material developed by Chandrasekhara (1972). Further, their speech identification score in quiet, determined using the 'Monosyllable Speech Identification test in English for Indian children' (Rout, 1996), was greater than 90%.

All the children were evaluated individually on four different diagnostic APD tests. Tests were selected to evaluate monaural auditory separation / closure, binaural auditory integration, temporal resolution, and auditory memory. The children were evaluated on these auditory processes / higher cognitive factors as it has been reported in the literature that they are often affected in children with APD. Auditory separation / closure was found to be deviant in individuals with APD by Welsh, Welsh, and Healy (1980), Katz et al., (1992) and Muthuselvi and Yathiraj (2009). Likewise, binaural auditory integration was reported to be deviant by Musiek et al, (1982), Katz et al, (1992) and Muthuselvi and Yathiraj (2009); temporal resolution by Musiek et al, (1982) and Muthuselvi and Yathiraj (2009); and Muthuselvi and Yathiraj (2009) found that auditory memory was affected in a high percentage of children (82.3%) studied by them.

To evaluate the above auditory processes / higher cognitive factors, the tests used included Speech-in-noise test in Indian-English (SPIN-IE) developed by Yathiraj, Vanaja and Muthuselvi (2010), Dichotic CV test (Yathiraj, 1999), Gap Detection test (GDT) by Shivaprakash & Manjula, 2003) and the Revised Auditory Memory and Sequencing Test in Indian-English (RAMST-IE) developed by Yathiraj, Vanaja and Muthuselvi (2010). The order in which the participants were tested on these four tests was randomized to avoid any test order effect. For the two monaural tests (SPIN-IE & GDT) half the participants were tested in right ear first and the other half in the left ear first, to eliminate any ear-order effect.

The CD versions of all the diagnostic tests were played on a computer, the output of which was routed to the transducer via the diagnostic audiometer (Madsen OB 922). The 1 kHz calibration tone, recorded in the CD of each test, was used to calibrate the VU meter deflection, prior to the appraisal of each child. This calibration was done for each of the four diagnostic APD tests.

Procedure for administration of the Speech-in-noise test in Indian English (SPIN-IE)

The SPIN-IE test, developed by Yathiraj, Vanaja & Muthuselvi (2010) was administered using the two lists of 25 monosyllabic English words. These stimuli were presented monaurally at 0 dB SNR at 40 dB SL (ref. SRT) via headphones. The children were instructed that they would hear a lady talking in a crowd and they should listen to the words spoken by the lady while ignoring other sounds. The verbal responses of the participants were noted. A correct response was given a score of '1' and an incorrect response a score of '0'. The scores obtained were compared with the age appropriate norms reported by Yathiraj, Vanaja & Muthuselvi (2012).

Procedure for administration of the Dichotic CV test (DCV)

The Dichotic CV test was evaluated using the CD version of the test, recorded by Yathiraj (1999) at 40 dB SL (ref. SRT). The list containing a 0 ms lag was utilized. The children were informed that they would hear two syllables simultaneously, one in each ear. They were asked to repeat both the syllables they heard through headphones. The verbal responses of the participants, were noted. A score of 1 was given if the child repeated both the syllables presented in the two ears correctly. Their double correct responses were noted and compared with age suitable norms given by Yathiraj, Vanaja and Muthuselvi (2012).

Procedure for administration of the Gap detection test (GDT)

Gap detection test (GDT) was carried out using the CD version of the test developed by Shivaprakash and Manjula (2003). The signals were presented monaurally to each ear at 40 dB SL (ref. PTA) through head phones. The participants were required to indicate as to which set of noise bursts in a triad contained a gap. The minimum gap duration that the participants were able to detect was compared with normative given by Shinn, Chermak and Musiek (2009).

Procedure for administration of the Revised Auditory Memory and Sequencing Test in Indian English (RAMST-IE)

The CD version of Revised-Auditory Memory and Sequencing Test (RAMST-IE) developed by Yathiraj, Vanaja and Muthuselvi (2010) was presented at 40 SL (ref. SRT) through two sound-field loudspeakers. The loudspeakers were placed at a distance of one meter at 45^0 azimuth on either side of the head of a participant. 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. The responses were compared with age appropriate norms developed by Yathiraj, Vanaja and Muthuselvi (2012).

The criteria to diagnose a child as having APD or not was done using the recommendations of Yathiraj, Vanaja and Muthuselvi (2012). According to them, children who failed on only one diagnostic test, a -2 SD criteria was recommended to be used and when children failed more than one diagnostic test, a -1 SD criteria was advocated.

Fourteen of the children were administered the diagnostic tests after a period of two months. These children were selected randomly from those who had been evaluated earlier on the diagnostic tests. None of these 14 children had undergone any form of rehabilitation following the earlier evaluation. The children were retested to establish the test-retest reliability of the diagnostic APD tests.

Analyses:

The scores of the screening procedures and diagnostic tests were processed using SPSS 16.0 software. Descriptive and inferential analyses were carried out and are reported in the results section.

Results

To check the sensitivity and specificity of the STAP, the data collected using the same were compared with that of the four diagnostic tests that were administered. Similarly, a comparison of the SCAP with the diagnostic tests was also determined. This was done with SCAP in isolation as well as in combination with the STAP. The data obtained were analysed using the SPSS software (version 16.0) and the R software (version 2.14.2). In addition to descriptive statistics, the data were analysed using Spearman's correlation coefficient, Pearson's product moment correlation coefficient and Kappa's measure of agreement. The results obtained are provided under the following sub-headings.

1. Results of the APD screening procedures
2. Results of the APD diagnostic tests
3. Relation between the STAP and diagnostic tests
4. Sensitivity and specificity of the screening procedures
5. Cut-off criteria for referral with STAP
6. Test-retest reliability of SCAP, STAP and the diagnostic APD tests

1. Results of the APD screening procedures

The data of the *SCAP* from the 2400 children, on whom it was administered, revealed that 141 of them had scores greater than or equal to six. This indicates that 5.9% of the children were at-risk for APD as per the scores of the SCAP.

On the other hand, from the data of the *STAP* obtained from the 500 children tested with it, 18.2 % (91) were found to be affected in one or more of its subsections. Further, 77 children were found to be at-risk on a combination of *STAP* and *SCAP*. Details of those who were referred on each subsection of the STAP are given in Table 3.

Table 3: *Percentage (number) of children referred on the subsections of the STAP*

STAP subsections	**% of children referred on each subsection of STAP**	
	All children tested on STAP (N = 500)	**Children found to be at-risk for APD on STAP (N = 91)**
SPIN	9.6% (48)	52.7% (48)
DCV	9.6% (48)	52.7% (48)
GD	8% (40)	43.9% (40)
AM	12% (56)	61.5% (56)

The data in Figure 1 depicts the number of participants who were affected in each subsection as well as combination of subsections of the STAP. The number of times a participant is represented depended on the number of subsections he/she obtained low scores. It can be observed from Figure 1 and Table 3 that among the 91 children with scores below the cut-off values given in Table 2, the auditory memory subsection had the maximum number of children (56). When pairs of subsections were considered, the combination of SPIN and AM had a larger number (38) of children at-risk for APD, compared to the other combinations. Further, the combination of SPIN, DCV and AM had the maximum number (13) of children at-risk, when a combination of three subsections was considered.

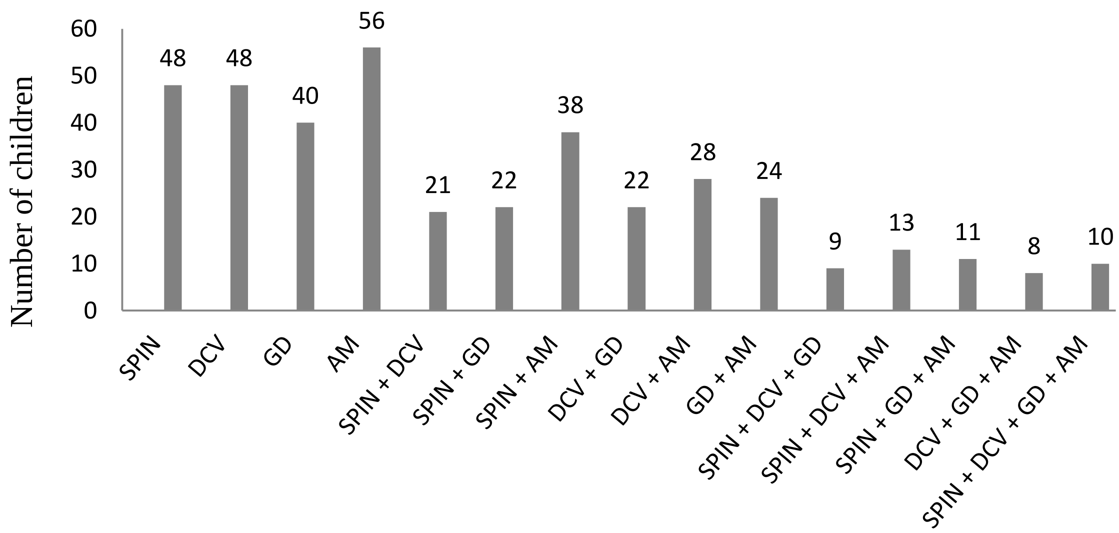

Figure 1. Number of children among the 91 with scores below the cut-off values on each subsection and combination of subsection of the STAP

Figure 2 depicts the number of children (N = 91) affected on one, two, three or all four subsections of the STAP. Each participant is represented only once in the figure. In the 91 children referred based on the scores of the STAP, one subsection of the screening test was affected in 24 children (26.4%), two subsections were affected in 43 children (47.3%), three subsections in 14 children (15.4%) and 10 children (10.9%) had all four subsections affected. As can be seen in Figure 2, among those affected only in one subsection, AM (N = 9) and DCV (N = 8), were affected more when compared to SPIN (N = 3) and GD (N = 4). Additionally, the combination of SPIN and AM had the maximum number (13) of children who were at-risk, when compared to the other combination of subsections.

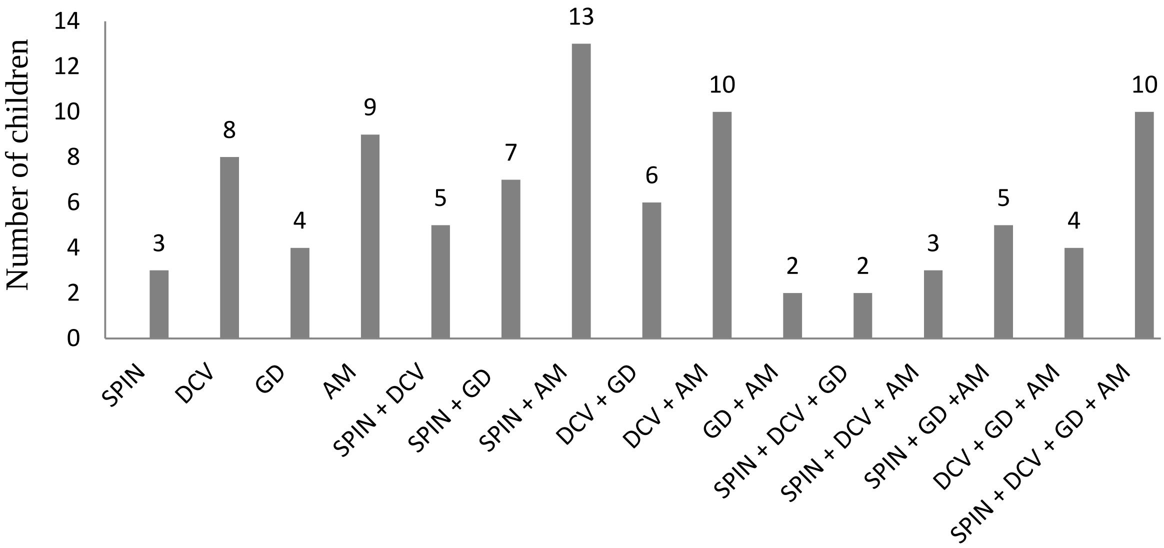

Figure 2. Distribution of the 91 participants with scores below the cut-off values on individual subsection and combinations of subsections of the STAP

Results of the APD diagnostic tests

On analysing the scores of the 152 children who were tested on the four diagnostic tests (SPIN, DCV, GDT, & AMT), it was found that 92 (60.5%) of them were found to have APD. The diagnosis was based on the criteria recommended by Yathiraj, Vanaja and

Muthuselvi (2012). The number of children who failed each of the four diagnostic APD tests as well as the total number of those diagnosed to have APD is provided in Table 4.

Table 4*: Number (%) of participants who failed each diagnostic APD test and were diagnosed to have APD.*

SPIN		**DCV**	**GDT**		**AMT**	**Number diagnosed to have APD**
Rt ear	**Lt ear**		**Rt ear**	**Lt ear**		
39 (25.6%)	37 (24.3%)	25 (16.4%)	29 (19.1%)	44 (28.9%)	49 (32.2%)	92 (60.5%)

Note. *N = 152*

Among the diagnostic tests, the test with the maximum failures was AMT (32.2%) followed by DCV (28.9%), SPIN (average of left and right ears = 24.9%) and the GDT (average of left and right ears = 17.7%). Using the criteria recommended by Yathiraj, Vanaja and Muthuselvi (2012), out of the 152 children evaluated on the diagnostic tests, 60.5% (92) were found to have APD (Table 4 & Figure 3).

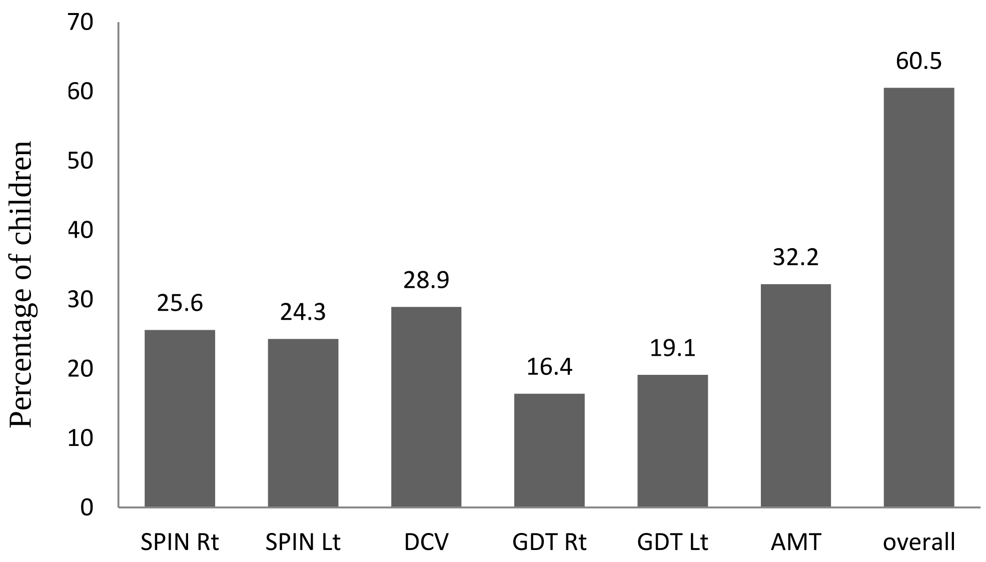

Figure 3: Percentage of children found to have APD on the various tests and diagnosed to have the condition

3. Relationship between STAP and diagnostic tests

The relation between the STAP and the diagnostic tests was determined using Spearman's rank relation coefficient. A high correlation (r = 0.82) between the STAP and diagnostic tests that was significant at the 0.001 level was obtained. Further, the relation between each subsection of the STAP and their diagnostic counterparts was tested using Pearson's Product Moment Correlation coefficient. The results of this correlation (Figure 4 & Table 5) indicated a positive correlation between STAP and each of the diagnostic tests except for the GDT. The GDT was the only test where there was a negative correlation, indicating that as the scores of the GD subsection of the STAP improved, gap detection thresholds decreased and thus, smaller gaps could be detected on the diagnostic GDT. Table 5 provides the correlation coefficient (r values) and their level of significance between the subsections of the STAP and the diagnostic APD tests.

Table 5. *Correlation coefficients of diagnostic APD tests and subsections of STAP*

Diagnostic tests → / **STAP ↓**	**SPIN Right**	**SPIN Left**	**DCV**	**GDT Right**	**GDT Left**	**AMT**
SPIN Right	**0.90****	0.60	-0.07	-0.05	-0.09	0.24
SPIN Left	0.61	**0.92****	-0.05	-0.27	-0.27	0.47
DCV	-0.08	0.00	**0.92****	-0.13	-0.18	0.28
GD Right	0.24	0.34	0.15	**-0.84****	-0.72	0.32
GD Left	0.15	0.23	0.10	-0.79	**-0.88****	0.16
AM	0.20	0.41	0.26	-0.17	-0.17	**0.93****

** = Significant at $p < 0.001$

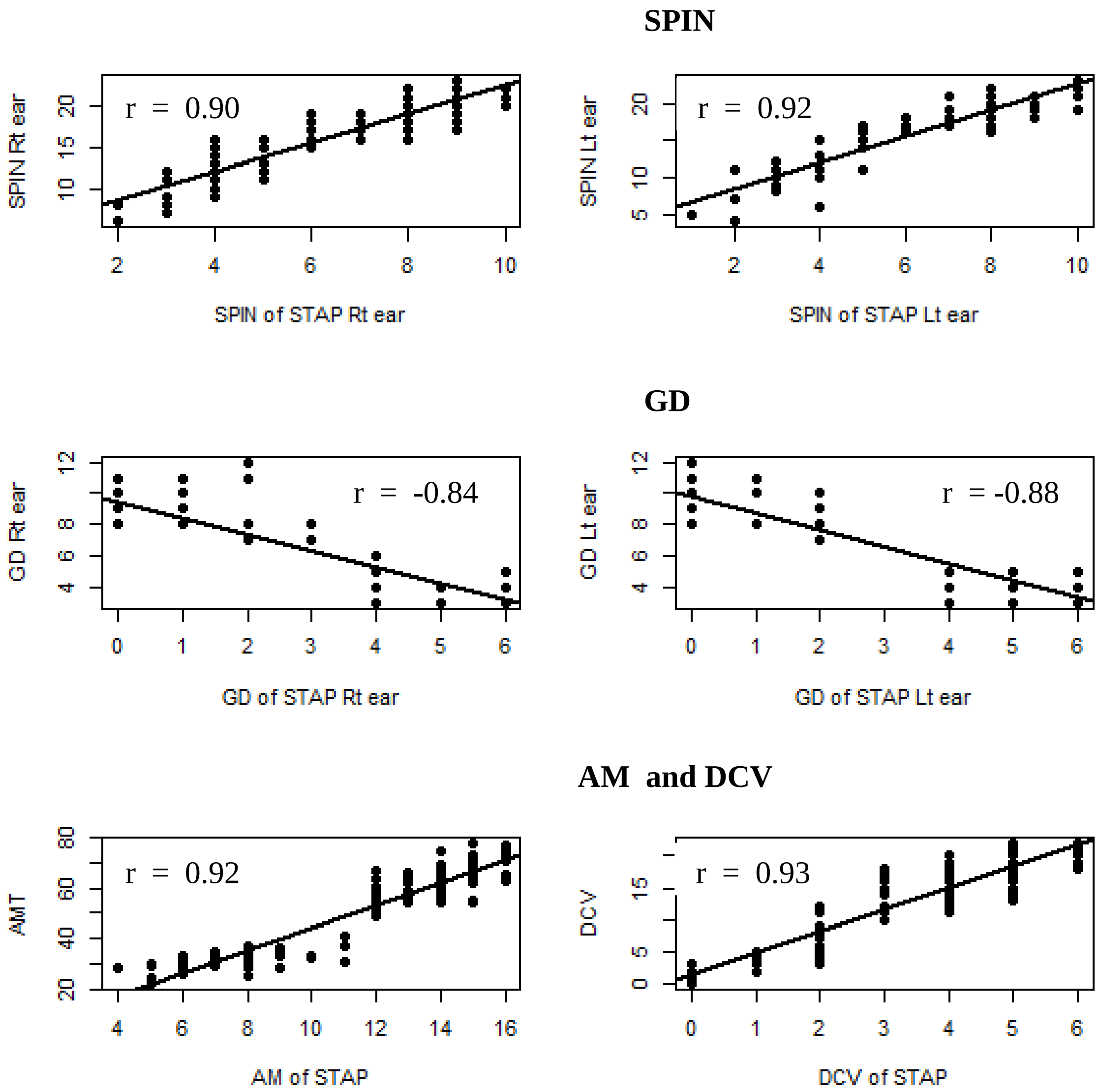

Figure 4. Scatter plots reflecting the distribution of scores across the subsections of the STAP (X axis) and their diagnostic counterparts (Y axis).

4. Sensitivity and specificity of STAP and SCAP

To determine the sensitivity and specificity of the SCAP and STAP, the pass / refer details of each of the screening procedures as well as the combination (SCAP + STAP) were compared with diagnosis of the children. This was done using the data of the three groups (Group 1: refer / pass on SCAP; Group 2: refer / pass on STAP & Group 3: refer / pass on SCAP + STAP) of children formed from those who were referred / passed on SCAP, STAP and SCAP + STAP. The information regarding the diagnosis was based on the final diagnosis made from the findings of the four diagnostic tests using the criteria given by Yathiraj et al. (2012). A 2 x 2 decision matrix was used to obtain information about the true positives and true negatives of the SCAP (Table 6a), the STAP (Table 6b) and the combination of SCAP + STAP (Table 6c).

Table 6. *True positives, false positives, false negative and true negatives of:*
(a) SCAP - Group 1; (b) STAP - Group 2; and (c) SCAP + STAP combined - Group 3

(a) Group 1

SCAP	**Diagnostic APD tests results**		**Total**
	Present	**Absent**	
Refer	**23 (74.1%)**	7 (50%)	30
Pass	8 (25.8%)	**7 (50%)**	15
Total	31	14	45

(b) Group 2

STAP	**Diagnostic APD tests results**		**Total**
	Present	**Absent**	
Refer	**23 (76.6%)**	7 (28%)	30
Pass	7 (23.3%)	**18 (72%)**	25
Total	30	25	55

(c) Group 3

SCAP + STAP	**Diagnostic APD tests results**		**Total**
	Present	**Absent**	
Refer	**26 (83.8%)**	5 (23.8%)	31
Pass	5 (16.1%)	**16 (76.2%)**	21
Total	31	21	52

Using equations 1 and 2, given below, the sensitivity and specificity respectively, were calculated. The outcomes of these calculations are provided in Table 7.

$$\text{Sensitivity} = \frac{\text{True positive}}{\text{True positive + False negative}} \times 100 \qquad \text{Equation 1}$$

$$\text{Specificity} = \frac{\text{True negative}}{\text{True negative + False positive}} \times 100 \qquad \text{Equation 2}$$

Table 7. *Sensitivity and specificity of SCAP, STAP and SCAP + STAP.*

Tests	**Sensitivity**	**Specificity**
SCAP	74.1%	50%
STAP	76.6%	72%
SCAP + STAP	83.8%	76.2%

5. Cut-off criterion for referral

Analysis was done to decide the number of subsections of STAP a child needed to get scores below the recommended cut-off criterion, in order to be referred for diagnostic APD evaluation. To establish this, the sensitivity and specificity of the STAP with different number of affected subsections was determined (Table 8). Thus, those with low scores on one and more, two and more, three and more and all four subsections of the STAP were calculated.

Table 8. *Sensitivity and specificity of STAP at different cut-offs of affected subsections*

No. of subsections affected on STAP	**Pass**	**Refer**	**Sensitivity (%)**	**Specificity (%)**
> = 1	25	30	**76.6**	**72**
> = 2	32	23	66.6	77.4
> = 3	47	8	35.2	94.7
4	52	3	14.2	97.4

The sensitivity was the highest when one affected subsection of the STAP was considered as a cut-off for deciding whether to pass or refer a child for diagnostic evaluation to confirm the presence of APD (Table 8 & Figure 5). However, the specificity of the STAP was the lowest when one affected subsection was considered as a cut-off to make a pass/refer criteria. It was the highest when all four subsections were considered. With increase in the number of affected subsections to make a pass / refer criteria, the sensitivity dropped considerably. In contrast, the increase in the specificity was more gradual.

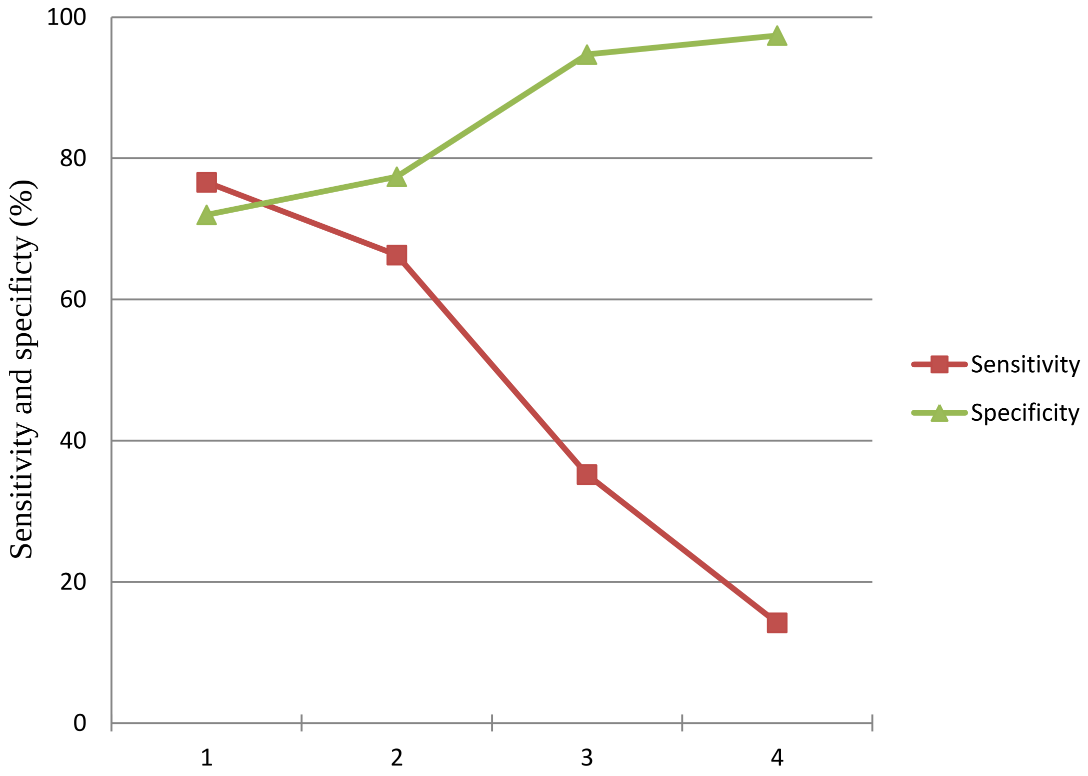

Figure 5. Sensitivity and specificity of the STAP with different number of subsections of the screening tests

Additionally, a Kappa measure of agreement was carried out between the number of individuals identified at different cut-off criteria of the STAP and the number of individuals identified on the diagnostic tests. It revealed a moderate (k = 0.52) and significant agreement ($p < 0.001$) with the cut-off of greater than or equal to one (Table 9).

Table 9. *Agreement between STAP and the diagnostic tests with different cut-off scores of STAP*

Cut-offs values of STAP	**Kappa measure of agreement (k)**	**Significance level**
> = 1	**0.52**	**p < 0.001**
> = 2	0.13	p > 0.05
> = 3	0.25	p > 0.05
4	0.13	p > 0.05

6. Test-retest reliability of the screening procedures and diagnostic APD tests

The test-retest reliability was established for each of the screening procedures (SCAP & STAP) as well as the four diagnostic tests. This reliability was done on approximately 10% of the children who were tested on each of the above procedures.

Test-retest reliability of SCAP

The test-retest reliability for the SCAP was determined on 63 (12.6%) of the 500 children who were tested on both screening procedures. The teachers' responses that were obtained after a gap of 2 months were compared with their earlier responses using the Pearson's Product Moment Correlation coefficient. A high correlation ($r = 0.91$) that was significant at the 0.001 was obtained between the two evaluations (Figure 6).

Test-retest reliability of STAP

In order to determine the reliability of the STAP, the screening test was administered again on 50 children (10%) after an interval of 2 months. The correlation between the scores obtained on the 1st and 2nd evaluation of STAP was checked using Pearson's Product Moment correlation coefficient (Figure 7). Figure 7 reveals that there was a strong correlation ranging from 0.82 to 0.93 between the two evaluations done after a gap of 2 months. These correlation coefficients were significant at the 0.01 level. This indicates that the subsections of STAP had good test-retest reliability.

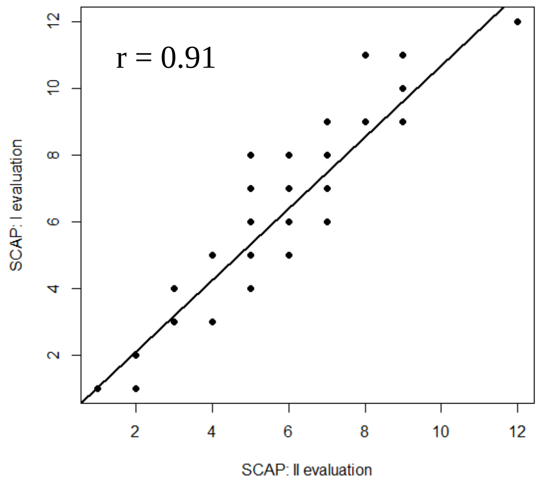

Figure 6. Scatter plot depicting the correlation in the responses obtained during the two evaluations of the SCAP

Test-retest reliability of diagnostic APD tests

For the diagnostic APD tests, the test-retest reliability was also checked for approximately 10% (14) of the 152 children on whom the test had been done earlier. The diagnostic APD testing was again carried out after a gap of 2 months after the first evaluation. The relation between the scores obtained in the first and second evaluation were tested with the Pearson's product moment correlation.

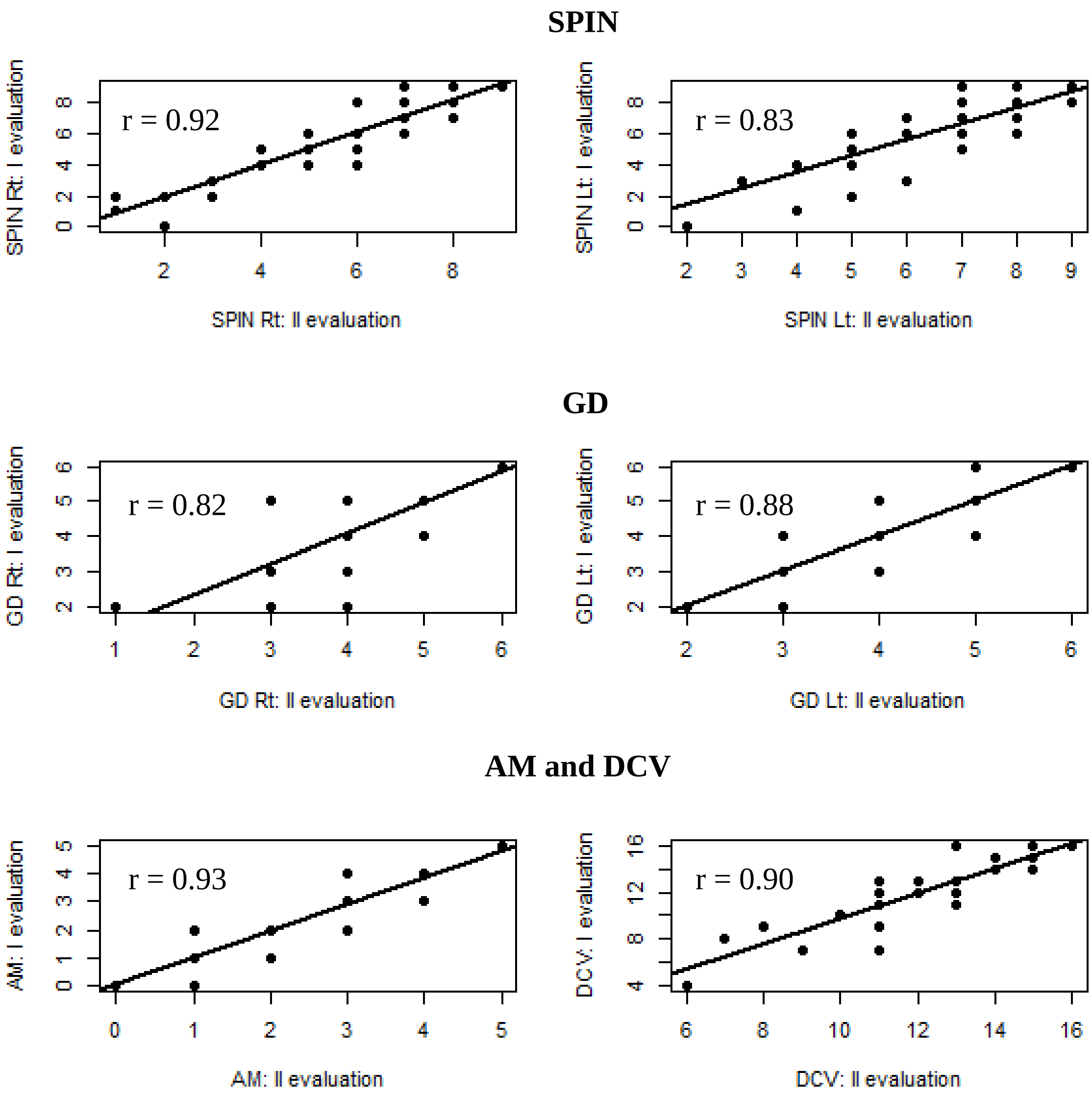

Figure 7. Scatter plot depicting the correlation of evaluation I and II for different subsections of STAP.

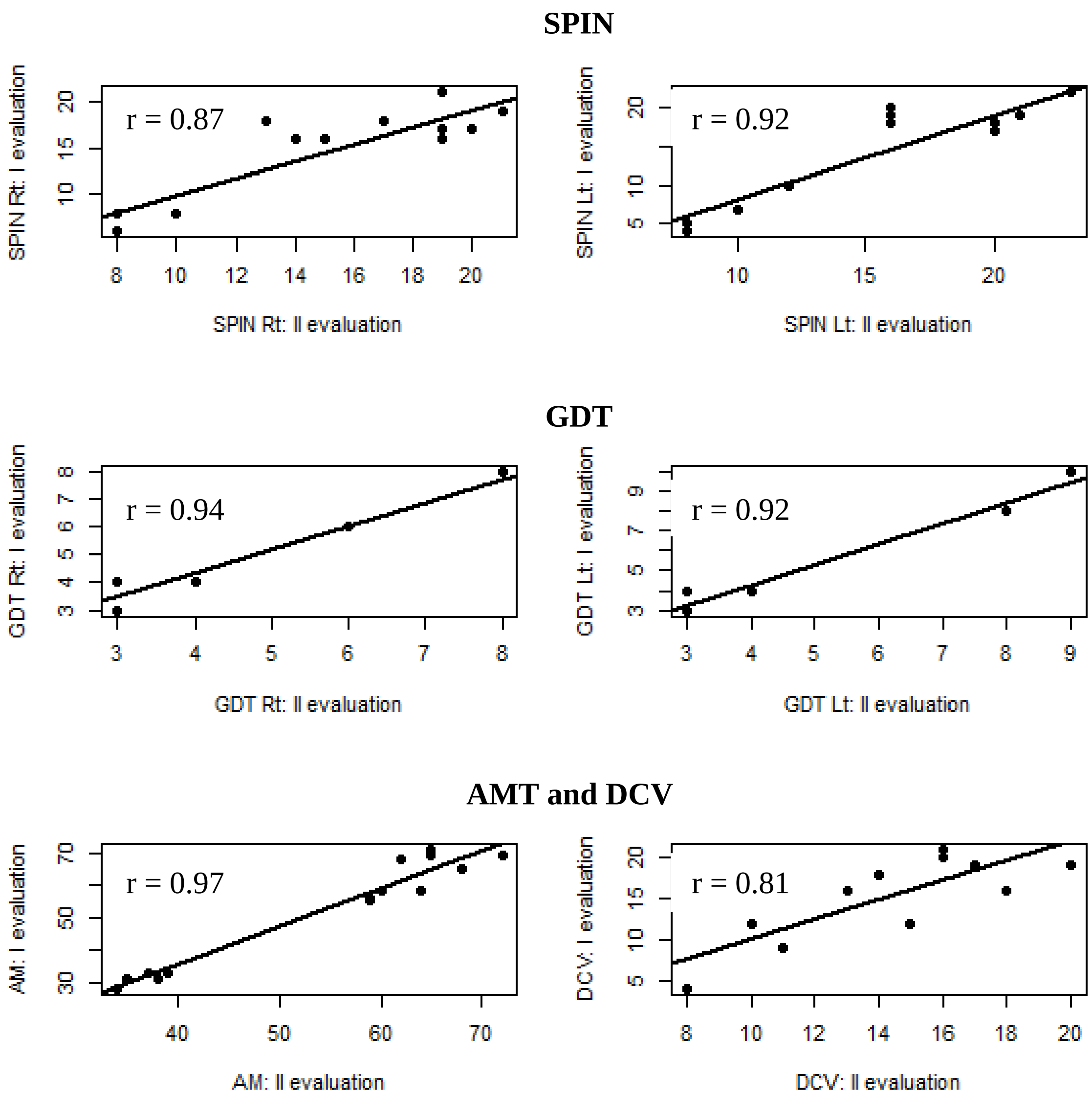

Figure 8. Scatter plots depicting the distribution of responses across the two evaluations of the various diagnostic APD tests

The scores of the two evaluations of the diagnostic APD tests were highly correlated with the coefficient ranging from 0.81 to 0.97 ($p < 00.1$) across the various diagnostic APD tests (Figure 8). These findings established that a good test-retest reliability existed between these APD diagnostic tests.

Discussion

Outcome of the SCAP

The results of the screening checklist (SCAP) revealed that 5.9% were at-risk for APD in the present study. This value was considerably higher than that obtained by Muthuselvi and Yathiraj (2009), who noted that just 2.6% of the children were at-risk for APD. Although the same questionnaire with the same cut-off criteria were utilised in both the studies, difference in findings were obtained. This reflects the subjectivity of the screening checklist, wherein the bias of the teachers influenced the results.

When the two studies were compared with reference to the *sensitivity of the SCAP,* it was found that comparable results were obtained. In the current study, the SCAP had a sensitivity of 74.1% which was similar to that obtained by Muthuselvi and Yathiraj (2009). They obtained a sensitivity of 71%. This reveals that even when different sets of teachers are used to evaluate a different group of children, the sensitive to detecting the presence of APD using a checklist continues to be similar.

When the *specificity of the SCAP* was examined, it was found that in the current study, a large over-referral occurred (50% of the 14 children). This indicates that the teachers tended to unnecessarily refer children for diagnostic evaluation, despite them not having a problem. In contrast, in the study by Muthuselvi and Yathiraj, this over-referral rate was much lesser. The earlier study reported of a specificity of 68%, which is considerably higher than what was obtained in the current study (50%). However, in both the studies, the test-retest reliability of the SCAP was high. This reflects that when the questionnaire is administered by the same set of teachers, even after a gap of 2 months, reliable results are obtained. On the other hand, considerable variability occurs in the specificity of the test when a different set of teachers administer the checklist. Thus, it can be concluded that the variation in the under-referral rate when different sets of teachers are used is considerably less when compared to the variation in the over-referral rate.

The subjective nature of questionnaires has been reported in several studies (Schow & Seikel, 2007; Maxwell & Satake, 2006; Delgado-Rodriquez, 2004; Hartman,et al., 2009; Hoher et al., 1997). Schow and Seikel (2007) recommended that questionnaires to detect the presence of any condition should be used only in the absence of tests that are less subjective.

Despite, checklists being considered as being subjective, it was observed in the current study, that *the test-retest reliability of the SCAP* was high (r = 0.91). This confirms that when the same set of teachers is used to administer the checklist even after a gap of two months, there are minimal variations in their responses. They are consistent in their ability to pass and refer children in a similar manner.

Based on the findings of the present study and that of Muthuselvi and Yathiraj (2009), it can be inferred that when using checklists like the SCAP, teachers are likely to correctly identify with fairly high accuracy, the presence of APD in children. However, depending on the caution used by the teachers, they are likely to over refer them. Additionally, close to 30% of the children with APD are likely to be missed if only checklists are used. Hence, if these drawbacks of checklists are to be overcome, either modification of the same should be done or the use of an alternate mode of screening, such as the use of a screening test should be utilised.

In the literature, the sensitivity for a screening APD checklist has been reported to be similar to that obtained using the SCAP. Extrapolating the information provided by Drake et al. (2006), the sensitivity and specificity of CHAPPS is found to be 75% and 25% respectively. While the sensitivity of CHAPPS was found to be similar to that of the STAP, the specificity was much lower than that observed in the present study as well as by

Muthuselvi and Yathiraj (2009). This substantiates that screening checklists for APD do have fairly high sensitivity, but have questionable specificity.

Schow and Seikel (2007) opined that when considering the sensitivity and specificity of screening procedures, "---- high sensitivity is good even if specificity suffers a bit because if one uses a diagnostic test follow-up, the false positives will be detected and not passed on" (pp 139). Although Schow and Seikel have remarked that the specificity could be low, having a very low specificity, such as that established with the CHAPPS by Drake et al. (2006) would defeat the purpose of a screening procedure due to the very high over-referral rate. In comparison, the SCAP can be considered to be a more useful checklist to screen for the presence of APD.

Outcome of the STAP

The number of children found to be affected on the STAP was 18.2%. The percentage of children suspected to have APD was higher than that obtained with the SCAP. This occurred since the 500 children on whom the STAP was measured group included those who were suspected to have APD on the SCAP. However, the group on whom the SCAP was administered included the general population. The variation in the number of individuals suspected to have APD in the two screening procedures can be ascribed to the difference in population on whom the percentage of affected persons was calculated.

Among the four subsections of the STAP, it was observed that AM was the most affected and GD the least. SPIN and DCV were equally affected. This was seen when all 91 participants who were referred on the STAP were considered (Figure 1). However, when the data of the 24 participants who obtained low scores on only one of the subsections of STAP were considered, the order of subsections in which more difficulty occurred differed. Within these 24 participants, it was seen that the AM and DCV subsections were affected in more children (9 & 8 respectively). In contrast on the GD and SPIN it was 4 and 3 respectively (Figure 2). This difference existed as poor performance in SPIN mainly occurred along with low scores in other subsections and not isolation. It largely occurred along with AM. However, DCV and AM tended to be affected in isolation and along with other subsections of the STAP as can be seen in Figure 2.

Report of AM and DCV being more adversely affected compared to other diagnostic APD tests, has also been noted by Muthuselvi and Yathiraj (2009). They reported this finding on children suspected to have APD, who were evaluated on a battery of five diagnostic tests (DCV, SPIN, GDT, AMST, & MLD). Thus, the trend that was observed on the diagnostic APD tests by Muthuselvi and Yathiraj was also reflected in the subsections of the STAP. Thus, it can be construed that the STAP did provide a representation of the auditory processing difficulties that are found when children are tested on diagnostic APD tests.

In the current study, when combinations of affected subsections were considered, the grouping of SPIN and AM cropped up most often followed by DCV and AM (Figure 2). The number of children having problems with both SPIN and AM was the highest (N = 13). These children exceeded the number having low scores in any isolated subsection or any other combination of the subsections of the STAP. Additionally, from the findings of the STAP, it can be seen that if AM was removed as a subsection, 9 (9.9%) of the children would have been missed. However, if SPIN subsection was removed, only 3 (3.3%) of the children would have been missed.

The finding that SPIN and AM are closely linked has been substantiated in a recent publication by Yathiraj and Maggu (2012). From a principle component analysis carried out on the data of 267 children aged 8 to 13 years, it was found that the third component was shared by the SPIN and AM subsections of the STAP. The link between speech perception in noise and auditory memory has been emphasised by Katz (1992) while describing the 'tolerance fading memory deficit', mentioned in the Buffalo model. The relation between speech perception in noise and auditory working memory has also been observed by Brannstrom, Zunic, Borovac and Ibertsson (2012). They observed this association on 21 normal hearing adults, who were evaluated using auditory evoked potentials.

Outcome of the diagnostic tests

Among the children diagnosed to have APD (N = 92), the tests that the children failed more frequently was the AMT followed by the DCV and SPIN. Relatively lesser children failed the GDT diagnostic tests (Table 4 & Figure 3). This pattern is in consonance with that found with the subsections of the STAP with reference to the former two tests. It also is in line with the findings of Muthuselvi and Yathiraj (2009). The fact that repeatedly it is established that auditory memory is affected predominately in children with APD, corroborates the need to include it in an APD test battery.

In the literature, the use of auditory memory has not been considered as an important component of any 'gold standard' test battery. The tests that have been used as 'gold standard' include dichotic tests (Musiek et al, 1982; Katz et al., 1992; Muthuselvi & Yathiraj, 2009; Jerger & Musiek, 2000), tests for gap detection (Musiek et al, 1982; Muthuselvi & Yathiraj, 2009), tests for speech perception in noise (Musiek et al., 1982; Muthuselvi & Yathiraj, 2009; Welsh et al., 1980) and temporal patterning (Chermak & Musiek, 2007; Bellis, 2003; Jerger & Musiek, 2000).

Relation between STAP and diagnostic tests

The high *correlation between each subsection of the STAP and the diagnostic APD tests* that evaluated similar auditory processes indicates the utility of the test. This high correlation reveals that the screening test provides a good indication of the performance of children on different auditory processes. Thus, it can be inferred that high or low scores on each of the subsections of the STAP would result with a corresponding increase or decrease in performance on related diagnostic APD tests.

The *sensitivity and specificity of the STAP* (Table 6b) indicated that both aspects were high. The sensitivity was similar to that obtained on the SCAP, but the specificity was higher. However, on addition of the SCAP and STAP performance (Table 6c), the sensitivity and the specificity of the screening procedures increased and the false positives and false negatives decreased. This indicates that the two screening procedures do not tap identical aspects of APD. This increase in sensitivity and specificity can be ascribed to the additional associated information related to APD that are obtained from the SCAP. The SCAP provides additional information regarding speech, language and academic performance. As the sensitivity and specificity were higher when both screening procedures were used, it is recommended that the combination should be used in an APD screening programme.

The *cut-off criterion of the STAP for referring the children for diagnostic evaluation* was found to be similar with both the statistical techniques that were used. It was found that the sensitivity of the STAP was the highest with a cut-off criterion of one (i.e. low scores in one and more subsections of STAP). The sensitivity reduced by 52.4% when the cut-off criteria was increased from one to four (i.e. low scores on one subsection to low scores on all four subsections of STAP). The specificity of the STAP was lowered by 25.4% when the cut-off criterion was changed from four to one. Further, the Kappa measure of agreement also indicated that the maximum agreement with the diagnostic tests was observed with the cut-off criteria of one. In view of the drastic reduction of the sensitivity yet marginal increase in specificity with higher cut-off criteria (Table 7), as well as the findings of the Kappa measure of agreement, it is recommended that a cut-off criterion of one be used. Thus, if a child obtains lower than the recommended cut-off scores on any one of the subsections of the STAP, they should be referred for evaluation on a diagnostic APD test battery.

According to Chermak and Musiek (1992) an APD battery should contain at least one test of temporal processing, one of dichotic listening and one monaural redundancy test. Similarly, ASHA (2005) advocated the used of both speech and non-verbal tests in an APD battery that should assess sound localization and lateralization, auditory discrimination, auditory temporal processing, auditory pattern processing, dichotic listening auditory performance in competing acoustic signals, and auditory performance with degraded acoustic signals. In the current study, the diagnostic tests used to determine the sensitivity, specificity and the cut-off criterion for referral of the STAP, met the requirements of Chermak and Musiek as well as most of the requirements of ASHA. Hence, the diagnostic tests used to validate the STAP can be considered as a representation of what an APD test battery typically should contain. It can be concluded that since the STAP has been validated with a representation of a typical gold standard test-battery, its sensitivity, specificity and referral criterion are also valid. Further, the fact the SCAP, STAP and the four diagnostic tests had a good test-retest reliability, indicate that all the measures used in the study provide stable information.

Conclusion

From the findings of the present study it can be inferred that teachers are able the SCAP to correctly identify children with suspected APD. However, they are tend to over-refer children, despite them not having adequate number of symptoms of the condition in order to refer them. Approximately 30% of the children with APD are likely to be missed if only the SCAP is used. The STAP was developed to tap four different auditory processes / higher cognitive functions (monaural auditory separation / closure; binaural auditory integration; temporal resolution; and auditory memory). These were evaluated using four subsections (SPIN, DCV, GD, & AM) containing a limited number of test items. The time taken to administer the screening test along with the scoring took approximately 12 minutes.

Among the four subsections of the STAP, it was observed that AM was the most affected and GD the least. SPIN and DCV were equally affected. Low scores in the SPIN subsection mainly occurred along with low scores in other the subsections and not isolation. It largely occurred along with AM. However, DCV and AM tended to be affected in isolation and along with other subsections of the STAP. The sensitivity and specificity of the STAP was found to be 76.6% and 72% respectively. These values increased when the STAP was used along with the SCAP to 83.8% and 76.2% respectively. As the sensitivity and specificity were higher when the combination of SCAP and STAP were used, it is recommended that an APD screening programme should include both procedures. The sensitivity of the STAP and its agreement with the diagnostic tests was the highest when a cut-off criterion of one was used. Hence, it is recommended that if a child obtained low scores on even one of the subsections of the STAP, they should be referred for detailed APD evaluation.

Acknowledgement

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Appendix 1, 2, 3, and 4

Appendix 1

Manual for administration and scoring the Screening Test for Auditory Processing

MANUAL

Screening test for Auditory Processing (STAP)

Ref: SH/CDN/ARF/4.02/2011-2012

Developed by:

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Submitted in 2012

Manual

Screening test for Auditory Processing (STAP)

Asha Yathiraj & Akshay Raj Maggu (2011)

Developed in the Department of Audiology,
All India Institute of Speech and Hearing, Mysore, India

Background information

The 'Screening Test for Auditory Processing' (STAP) was developed by Yathiraj and Maggu (2011) as a part of a project funded by the AIISH research fund. The screening test is designed to be administered by any professional / personnel with minimal training in administering auditory based tests and minimal knowledge in operating computers. The screening test is designed to be used on children aged 8 years and above with normal peripheral hearing and average intelligence. Although the screening test has been evaluated on children aged 8 years and above, it can be used with caution on children aged 7 years.

Description of the screening test:

The STAP consists of four subsections that tap different aspects of auditory processing. The four subsections include (a) Speech in noise, (b) Dichotic Consonant-Vowels, (c) Gap detection, and (d) Auditory memory. The details of these subsections of the screening test are provided in Table 1. The test takes approximately 12 minutes for administration and scoring.

Table 1. Description of the subsections of STAP

	STAP Subsections			
	Speech-in-noise (SPIN)	**Dichotic CV (DCV)**	**Gap detection (GD)**	**Auditory memory (AM)**
Stimuli	Monosyllabic words	Consonants-Vowels (/pa/, ta/, /ka/, /ba/, /da/, /ga/)	300 ms white noise	Monosyllabic words
No. of practice items	2 words per ear	2 CV pairs	1 token for each ear	1 token of 4 words
No. of test items	10 words per ear	6 CV pairs	6 tokens for each ear	4 tokens of 4 words
Mode of presentation	Monaural	Dichotic	Monaural	Binaural
Processes Tested	Auditory separation	Binaural integration	Temporal resolution	Auditory memory

The instructions for the child, which are recorded in the CD, vary for each subsection. The instructions for each subsection, which are given just before the practice items are as follows:

a. Speech-in-noise: "You will hear words spoken by a lady in a noisy room. Please repeat what you hear in your right ear". After the participant completes the right ear, left ear is to be tested and the instructions are "Please repeat what you hear in your left ear".
b. Dichotic CV: "You will hear two sounds together, one in your right ear and another in your left ear. Please repeat both of them"
c. Gap detection: "You will hear three sounds. Which one of them is different? Is it the first, second or third?
d. Auditory memory: "You will hear a few words. Please repeat them together".

Pre-requirements for the administration of the screening test:

(i) Instrumentation / material:

a. Compact Disc with the STAP software loaded is required. The STAP CD contains a calibration tone, instructions to the child prior to each subsection of the screening test, practice items and the actual test material with adequate inter-stimuli interval to obtain the response of a child.
b. A desktop computer or a laptop with any software to run an audio CD with the output intensity level calibrated is required.
c. Good quality, noise excluding headphones (preferably TDH-39) are necessary for the presentation of the signals. To connect the headphone to the computer, adapters are required to connect the mono J1-J2 jacks to a stereo EP jack.
d. To ensure that the output from the computer is at the required level (65 dB SPL), a sound level meter with an artificial ear should be used. The volume control of the computer and / or the audio software should be manipulated to get the required intensity.

(ii) Test Environment

Each participant should be seated and tested individually in a quiet room free from audio and visual distraction. Headphones are placed on the participant. Following this, the STAP CD is played which consists of instructions for all the subsections, practice items and the test items. Only the test items are to be scored by the tester using the scoring instructions given below.

(iii) *Instructions to be given by the tester*:

The individual administering the test should initially instruct the child that he/she should listen and follow the instructions they hear through the headphones. The tester should specifically instruct the child that he/she will hear four different instructions. The oral responses of the child to the test items should be noted down by the tester on the scoring sheet that is provided.

(iv) Scoring and referral :

The responses to the test items for each subsection should be scored separately by the tester. For each subsection, the scoring is as follows:

a. **Speech-in-noise:** Each correctly repeated word is awarded a score of one while an incorrect response is given a score of zero. For each ear, the maximum possible score is ten.
b. **Dichotic CV:** Only when the responses are correct in both ears (double correct) is a score of one given. However, if the response is incorrect in any one ear (single correct) or a incorrect in both ears, a score of zero is given. The maximum attainable score is six. The cut-off score of the single correct responses may be used as a guideline regarding the performance of a child but not to refer for further testing.
c. **Gap detection:** Each correctly repeated response is awarded a score of one while an incorrect response is given a zero. For each ear, the maximum possible score is six.
d. **Auditory memory:** Each correctly repeated word is awarded a score of one while an incorrectly repeated word is given a zero. The maximum score that can be attained is sixteen.

Details on the pass criteria for the four subsections are given in Table 2. A child should be referred for diagnostic testing if he/she obtains scores below the cut-off criteria even on one subsection.

Table 2. Pass criteria of various subsections of STAP.

Subsections	**Maximum scores**			**Pass scores**		
	Right Ear	**Left Ear**	**Double Correct**	**Right Ear**	**Left Ear**	**Double correct**
SPIN	10	10	----	6	6	----
DCV	6	6	6	4	4	2
GD	6	6	----	4	4	----
AM	16		-----	12		----

Note: *SPIN = Speech in noise; DCV = Dichotic consonant vowel; GD = Gap detection; AM = Auditory memory*

Response sheet

Screening Test for Auditory Processing (STAP)

Asha Yathiraj & Akshay Raj Maggu (2011)

Name: Date:

Class / Section: Age / gender:

Case No.: Contact No.:

School: Address:

(Note the responses of the child in the space provided for each subsection. Indicate the scores for the test items for each subsection in the space provided.)

1. **Speech-in-noise subsection** (***Score****: One for each correct response; Maximum score per ear = 10)*

	S. No.	Right ear	Left ear
Practice items	1.		
	2.		
Test items	1.		
	2.		
	3.		
	4.		
	5.		
	6.		
	7.		
	8.		
	9.		
	10.		
		Right ear score =	**Left ear score =**

2. Dichotic subsection (***Score:*** *One for each correct response; Maximum score = 6)*

	S. No.	Response
Practice items	1.	
	2.	
Test items	1.	
	2.	
	3.	
	4.	
	5.	
	6.	

Score =

3. Gap detection sub-section (***Score****: One for each correct response; Maximum score per ear = 6)*

	S. No.	Right ear	Left ear
Practice item	1.		
Test items	1.		
	2.		
	3.		
	4.		
	5.		
	6.		

Right ear score = **Left ear score =**

4. **Auditory memory subsection** (***Score****: One for each correct response; Maximum score per ear = 16)*

	Sl. No.	Responses			
Practice items	1.				
Test items	1.				
	2.				
	3.				
	4.				

Score =

Answer Key

Screening Test for Auditory Processing (STAP)

Asha Yathiraj & Akshay Raj Maggu (2011)

1. Answer key for the Speech-in-noise subsection of STAP

	S.No.	Right ear	Left ear
Practice Items	1.	Tie	Hat
	2.	See	Rope
Test items	1	Tap	Gate
	2	Get	Fish
	3	Map	Pit
	4	Mice	Can
	5	Pot	Pin
	6	Rat	Zip
	7	Back	Pet
	8	Sat	Hide
	9	Hot	Pup
	10	Take	Fat

2. Answer key for the Dichotic CV subsection of STAP

	S.No.	Stimuli
Practice items	1.	/tha/-/dha/ 90 msec lag
	2.	/tha-dha/ 0 msec lag
Test items	1	/pa/-/da/
	2	/da/-/ka/
	3	/pa/-/ga/
	4	/ta/-/ba/
	5	/ga/-/ta/
	6	/ba/-/ka/

3. Answer key for the Gap detection subsection of STAP

	S.No.	Right	Left
Practice items	1.	3	3
Test items	1.	2	1
	2.	1	1
	3.	3	3
	4.	1	2
	5.	2	3
	6.	3	2

4. Answer key for the Auditory memory subsection of STAP

	S.No.	Test words			
Practice items	1.	Fair	Saw	Knife	Neck
Test items	1.	Hit	Knee	Put	Ate
	2.	Nut	Bank	Seed	One
	3.	Wall	Rain	Bull	Mad
	4.	Zoo	Fall	Shut	Bad

Appendix 2

Abstract of the research paper submitted for platform presentation at the 2nd Newborn Hearing Screening Conference

Yathiraj & Maggu (2012). 'Screening Test for Auditory Processing (STAP): A Preliminary Report'. Platform research presentation at the 2nd Newborn Hearing Screening Conference held at Lake Como, Italy, in June 2012.

Screening Test for Auditory Processing - A Preliminary Report

Yathiraj A, Maggu A R

Abstract of the platform research presentation at the 2nd Newborn Hearing Screening Conference held at Lake Como, Italy, in June 2012

The prevalence of auditory processing disorder (APD) has been found to be 2-3% in school-going children (Chermak & Musiek, 1997; Muthuselvi & Yathiraj, 2009). This indicates the necessity to carryout screening tests in order to make appropriate referrals. The existing screening tests for APD have been noted to be time consuming (Muthuselvi & Yathiraj, 2009) and evaluate limited auditory processes (Bellis, 1996). Hence, when screening large groups of school-going children, it is essential for a screening test to be quick and tap several processes. The present study evaluated a newly developed screening test for auditory processing (STAP) on 267 school-going children in the age range of 8 to 13 years. The developed test consisted of 4 sub-sections [Speech-in-noise (SPIN), dichotic CV (DCV), gap detection (GD) and auditory memory (AM)] that tapped auditory separation, binaural integration, temporal resolution and auditory memory. Each sub-section had limited number of stimuli enabling the test to be carried out within 12 minutes. The test, played through a laptop loaded with Adobe Audition (version 3.0) was heard by the children through TDH-39 headphones. The responses of the children were scored and subjected to statistical analysis. Principal component analysis revealed the presence of 3 distinct components. The DCV sub-section scores obtained the highest rotated factor loadings (right ear = 0.82, left ear = 0.88, double correct = 0.95) in component 1. The GD sub-section scores had the highest rotated factor loadings (right ear = 0.95, left ear = 0.94) in component 2. However, component 3 consisted of both the SPIN sub-section (right ear and left ear) and the AM sub-section with rotated factor loadings of 0.87, 0.85 and 0.48, respectively. In total, the three components accounted for a total variance of 75.9% which is higher than what has been reported by Schow and Chermak (1999) for SCAN.

Appendix 3

Yathiraj, A. & Maggu, A. R. (2012). Screening test for auditory processing (STAP): revelations from principal component analysis. SSW reports, 34 (3), 16-24.

SSW Reports

• Screening Test for Auditory Processing (STAP)
[A Contribution from Mysore, India]

Vol. 34 No. 3 **August 2012**

Editorial Introduction

I was most excited to read this STAP article and pleased to share the excellent work of Professor Yathiraj and Research Officer Maggu in SSW Reports. I think you will find it most interesting because they have developed an impressive screening test and because in the process of studying their test they have uncovered information pertinent to the Buffalo Model. In addition, I must admit I envy of the sample sizes in their studies.

As you will see the authors came upon a relationship between auditory memory and speech-in-noise scores. But instead of working with data from children with APD, as we did 25 years ago when we developed the Buffalo Model, they studied an essentially normal group of children who were then screened for the purposes of checking their STAP. In studying correlational-type data they found that Speech-in-Noise and Auditory Working Memory were lumped together.

This work is particularly timely because recently an audiologist has indicated that the Tolerance-Fading Memory category should be divided into the speech-in-noise component and the memory component. Well just this week in the July-August, 2012 issue of JAAA there is an article by Brannstrom et al. that found the very same thing. In their study dealing with noise issues for the hard-of-hearing they showed the very same relationship of speech-in-noise (i.e., background noise level) to load on the same characteristic as Working Memory in a group of essentially normal hearing adults.

When three such different studies, in three different languages all looking at different objectives with different populations and yet have the same improbable result; it adds considerable strength to the joint findings. I think I can speak for those who use and benefit from the Buffalo Model that we are grateful that you brought your work to our attention.

* * * * *

Screening Test for Auditory Processing (STAP): Revelations from Principal Component Analysis

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In India, screening for the presence of auditory processing disorders (APD) is currently carried out using a screening checklist. Muthuselvi and Yathiraj (2009), using their screening checklist on 3120 school-going children, found that it had a sensitivity of 71% and specificity of 68%. In general, it is believed that screening tests, which reflect the actual auditory processes have higher sensitivity and specificity compared to screening checklists (Schow & Seikel, 2007). Hence, there is a need for a screening test for APD. In order to screen the children at school for APD, certain audiological screening tests such as SCAN-C developed by Keith (2000) and Multiple Auditory Processing Assessment (MAPA) developed by Domitz and Schow (2000) have been devised. These tests take approximately 20 minutes (Lampe, 2011) to 30 minutes (Schow & Chermak, 2009) to screen a child. This defeats the purpose of a screening tool. Lessler (1972) reported that one of requirements of a screening test is that it should be economical in terms of time.

Keeping these issues in mind, we have developed a 'Screening Test for Auditory Processing' (STAP) as a part of an ongoing research project. This test incorporates the most frequently occurring auditory processing deficits mentioned in the earlier studies (Welsh, Welsh & Healy, 1980; Musiek, Guerkink & Kietel, 1982; Katz, Kurpita, Smith & Brandner, 1992; Muthuselvi & Yathiraj, 2009). The criteria for inclusion of a particular process in the screening test also depended upon the high prevalence of that deficient process in a particular study. According to the literature, the processes that are more frequently affected are auditory separation (Welsh, Welsh & Healy, 1980; Katz et al., 1992; Muthuselvi & Yathiraj, 2009), binaural integration (Musiek et al., 1982; Katz et al., 1992; Muthuselvi & Yathiraj, 2009), temporal resolution (Musiek et al., 1982; Muthuselvi & Yathiraj, 2009) and auditory memory (Muthuselvi & Yathiraj, 2009). Hence, our screening test consists of four sub-sections which tap the above processes. The sub-sections included are speech-in-noise, dichotic CV, gap detection (GD) and auditory memory (AM). Table 1 provides details regarding these sub-sections.

Table 1. Details of the sub-sections included in the screening test

Sub-Sections	Number of Items	Mode	Processes Tested
Speech in Noise (SPIN)	10 words per ear	Monaural	Auditory Separation
Dichotic CV (DCV)	6 pairs (/pa/, ta/, /ka/, /ba/, /da/, /ga/)	Dichotic	Binaural Integration
Gap Detection (GD)	6 tokens for each ear	Monaural	Temporal Resolution
Auditory Memory (AM)	16 words	Binaural	Auditory Memory

Participants

Two hundred and sixty-seven children in the age range of 8 (grade III) to 13 years (grade VIII) were screened in a public school by an audiologist. The screening was carried out using the compact disc (CD) version of the STAP. In addition to the test items, the CD also contained instructions for carrying out each sub-section. Prior to testing each child, it was ensured that he/she had no observable speech and hearing problems, based on the reports of the class-teacher and the child.

Procedure

The participants were asked to follow the recorded instructions and respond verbally. Their responses were noted down by the audiologist. Each correct response was awarded a score of one while an incorrect response was given a score of zero. The pass criteria of the various sub-sections were adapted from the earlier existing diagnostic tests. Details of the scoring are provided in Table 2.

Table 2: Maximum scores and pass criteria of the sub-sections STAP

Subsections	**Maximum scores**			**Pass scores**		
	Right Ear	**Left Ear**	**Double Correct**	**Right Ear**	**Left Ear**	**Double correct**
SPIN[a]	10	10	----	6	6	----
DCV[b]	6	6	6	4	4	2
GD[c]	6	6	----	4	4	----
AM[d]	16		-----	12		----

SPIN: Speech-in-Noise; DCV: Dichotic Consonant Vowel; GD: Gap Detection; AM: Auditory Memory Pass criteria adapted from: a, Kalikow et al. 1977; b, Yathiraj (1999); c, Shinn, Chermak & Musiek (2009); d,Yathiraj & Vijayalakshmi (2005)

Statistical Analysis

Since our aim was to check the independence of the four auditory processes from each other as well as to determine their interaction with each other, Principal Component Analysis (PCA) was chosen for data reduction. The analysis was carried out using SPSS 16.0 software.

Results

As a part of the PCA procedure, correlational values among the sub-sections were obtained. Overall, it was found that the within sub-sections correlations were greater than the between sub-sections. For instance, the left ear speech-in-noise scores had a higher correlation with the right ear scores than with any other sub-section. This reflected the independence of auditory separation from the other processes. Likewise, the binaural integration and temporal resolution were independent from the other processes. This can be observed in Table 3.

From the PCA, 8 different components emerged. However, there were only 3 components which had Eigen values greater than 1 (Figure 1).

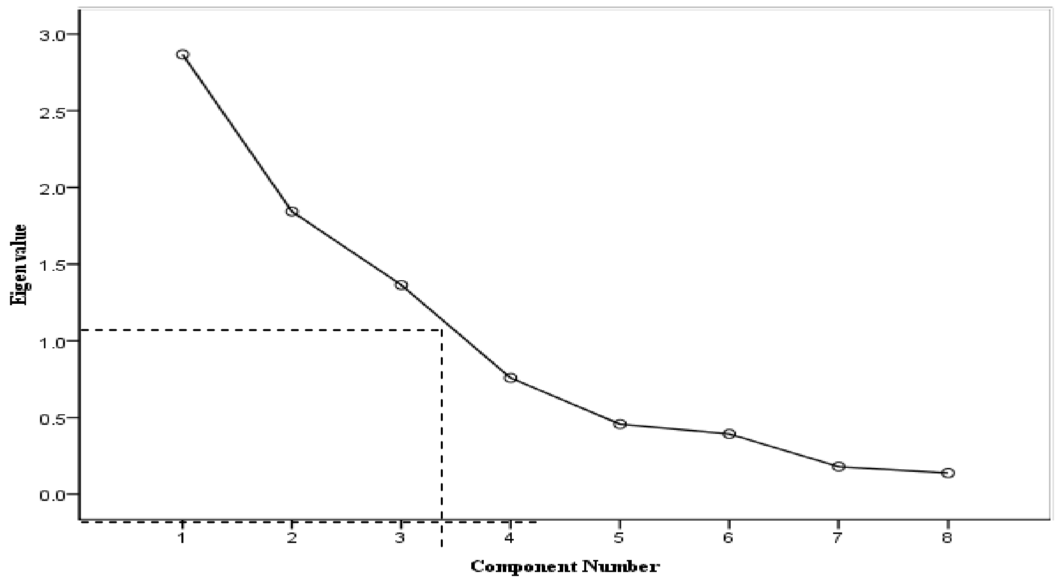

Figure 1. Scree plot showing the various components with their Eigen values.

Orthogonal rotation of these components led to a better representation in space and it was found that the variables within the dichotic CV sub-section were maximally loaded on component 1, gap detection sub-section had most loading on component 2 while the component 3 was shared by both speech-in-noise sub-section and auditory memory sub-section. This can be observed in Table 4. We found that the three components which emerged in our study accounted for a total variance of 75.9%.

Table 3. Depicting the rotated component loadings of the various sub-sections.

Sub-sections	**Components**		
	1	**2**	**3**
SPIN Rt	-0.114	0.076	**0.871**
SPIN Lt	0.144	0.070	**0.853**
DCV Rt	**0.824**	0.047	0.114
DCV Lt	**0.879**	0.098	0.012
DCV DC	**0.942**	0.011	0.091
GD Rt	0.049	**0.947**	0.102
GD Lt	0.084	**0.937**	0.125
AM	0.333	0.153	**0.478**

Rt, Right ear; Lt:, Left ear; DC, Double correct; SPIN, Speech-in-Noise; DCV, Dichotic Consonant Vowel; GD, gap detection; AM, auditory memory

Discussion

There are some important points that emerged in this study that are worth discussing here. First, we were concerned about the time taken by the screening procedure. We found that STAP took a total of 12 minutes per child. This included the time taken from seating, placement of headphones, instructions to the child, administration of the test to tabulation of the responses. The total duration taken by STAP is markedly less than the time reported to be taken by other available tests such as SCAN which takes approximately 20 minutes (Lampe, 2011) and MAPA which takes approximately 30 minutes (Domitz & Schow, 2000). Second, our analysis of 267 subjects revealed that the three major components which accounted for variance of 75.9%, was higher than the already existing tests such as SCAN which could account for a variance of 61.9% (Schow & Chermak, 1999).

Third, based on the rotated component loadings, two auditory processes i.e., binaural integration and temporal resolution were identified as component 1 and component 2, respectively. Fourth, and an important finding of the study was that the component 3 was shared by speech-in-noise and the auditory memory sub-sections. This indicates that there is some relationship between the two. Such findings may be obtained when fewer subjects are studied. However, this was not the case in the present study. We looked at the literature and found that our findings were in consonance with the findings of Katz (1992). The Buffalo Model proposed by Katz (1992) has a sub-type of deficits called the Tolerance Fading Memory (TFM) deficits. According to Katz (1992), this is the second most common sub-type in the general population. In this deficit, a person has problems in speech perception in noise along with reduced short-term memory. According to Katz and Smith (1991), there is a close association between frontal and anterior temporal lobe and if there is a lesion in this association, there are chances of a person to exhibiting TFM deficit. We believe that existence of TFM sub-type accounts for component 3 of our results, which was shared by speech-in-noise and auditory memory sub-section.

The developed screening test, STAP, seems to be a promising tool because it accounts for a large proportion of the variance. Currently, its sensitivity and specificity are being determined on a larger sample.

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Appendix 4

Yathiraj & Maggu (2013). Comparison of A Screening Test and Screening Checklist for Auditory Processing Disorders. Platform research presentation at the 45th ISHACON held at Chennai, Tamil Nadu, in February 2013.

(Abstract given in the ISHACON format)

COMPARISON OF A SCREENING TEST AND SCREENING CHECKLIST FOR AUDITORY PROCESSING DISORDERS

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COMPARISON OF A SCREENING TEST AND SCREENING CHECKLIST FOR AUDITORY PROCESSING DISORDERS

Abstract

Introduction

The diagnosis and management of auditory processing disorders (APD) has been a challenge for clinicians (Lucker, 2007). According to Chermak and Musiek (1997), 2 to 3% of school-going children have APD. Similar findings have been reported in India by Muthuselvi and Yathiraj (2009) who found APD to have a prevalence of 3.2% in school-going children.

Screening for APD has been considered mandatory for several reasons. These reasons include spreading awareness among parents and educators (Musiek, Gollegly, Lamb & Lamb, 1990); providing directions to professionals dealing with APD (Bellis, 2003); offering timely intervention (Chermak, 1996); planning effective management strategies (Musiek et al., 1990; Bellis, 2003); and make appropriate educational recommendations (Musiek et al, 1990).

In India, screening for APD has been mostly carried out using the ‘Screening checklist for auditory processing’ (SCAP) developed by Yathiraj and Mascarenhas (2003, 2004). Muthuselvi and Yathiraj (2009), using the SCAP on 3120 school-going children, found it to have a sensitivity of 71% and specificity of 68%. In addition, they also found a good correlation between SCAP and diagnostic APD tests. However, screening tests that directly tap auditory processes, have been noted to have higher sensitivity and specificity compared to screening checklists (Schow & Seikel, 2007).

Screening tests, reported in literature to detect children at-risk for APD, include SCAN-C (Keith, 2000) and Multiple Auditory Processing Assessment (MAPA) (Domitz & Schow, 2000). These tests have been found to take approximately 20 minutes (Lampe, 2011) to 30 minutes (Schow & Chermak, 1999) for administration. Thus, these tests are not time-efficient, a requirement for a screening test, according to Lessler (1972). In contrast, the Screening Test for Auditory Processing (STAP) developed by Yathiraj and

Maggu (2012) is reported to take approximately 12 minutes for administration and scoring.

Need for the study

Katz (2012), in an editorial comment, remarked about STAP (Yathiraj & Maggu, 2012) being an “impressive screening test” (pp 16) for APD. The test noted to be a promising screening tool for APD due to its time-effectiveness. However, its utility in actually identifying children with APD has yet to be established. Hence, its correlation with a procedure that has been found to have a fairly high sensitivity and specificity such as SCAP (Muthuselvi & Yathiraj, 2009) is necessary. Further, the relation between the two screening tools would shed light as to whether the tests could be administered independently or together.

Aim and Objective

The present study aims at determining the relationship between two screening tools for APD, SCAP and STAP.

Method

Four hundred school-going children (218 males, 182 females) studying in grade III to VII in 3 schools were randomly selected for the study. These children, aged 8 to 13 years, were screened using SCAP and STAP. While SCAP had 12 questions regarding symptoms of APD, STAP had 4 subsections that tapped different auditory processes [speech-in-noise (SPIN), dichotic CV (DCV), gap detection (GD) and auditory memory (AM)]. SCAP was administered by teachers who had taught the children for at least one year and STAP was administered by an audiologist. The order of administration of SCAP and STAP was counterbalanced with half being tested first with SCAP and half being tested with STAP first. This was done to avoid any test order effect. A double-blind approach was used wherein the teachers and the audiologist were unaware of each other’s test results.

The children who obtained scores below the cut-off criteria recommended for SCAP (Yathiraj & Mascarenhas, 2003, 2004) or STAP (Yathiraj & Maggu, 2012) were considered at-risk and were referred for detailed diagnostic APD evaluation. The current study, a part of an ongoing study, however only analysed the data obtained from SCAP and STAP to determine if there was any relation between the two screening tools.

Results

Among the 400 randomly selected children, 49 (12.3%) children were found to be at-risk for APD on SCAP and 64 (16%) were found to be at-risk on STAP. Using data of the children who passed and were referred on each of the screening tools (SCAP & STAP), a Chi square test of association was carried out. A significant association ($\chi 2 = 2.93$, df = 1, $p < 0.001$) was found between the two screening tools. In order to confirm the relationship between the two screening procedures, Spearman's rank correlation coefficient was carried out. It revealed a significant correlation ($r = 0.86$, $p < 0.001$) between SCAP and STAP.

Thirty-one children were found to be at-risk for APD on both SCAP and STAP. Using their test scores, further analyses was done in order to derive a relationship between SCAP and the subsections of STAP. Pearson's Product Moment Correlation coefficient indicated the presence of a significant correlation between SCAP and auditory memory ($r = -0.46$, $p < 0.01$) subsection of the STAP. However, no significant correlation was seen for other three subsections.

Discussion

The findings of the present study suggest a strong and significant correlation between SCAP and STAP. This indicates that STAP would have a sensitivity and specificity as good as that of SCAP, if not better. Earlier research has shown a good correlation between SCAP and diagnostic APD tests (Muthuselvi & Yathiraj, 2009). Thus, it can be construed that there could be a high correlation between STAP and diagnostic APD tests. Confirmation of this speculation is underway as a part of this ongoing study. It is anticipated that the sensitivity and specificity of STAP would be better than that of SCAP since a larger number of children were detected to be at-risk based on the former compared to the latter.

Further, the results suggest that more children would be detected to be at-risk for APD if the results of STAP were used instead of SCAP. Had only SCAP been used, 33 (51.5%) of the children would have been missed out and had only STAP been used, 18 (36.7%) both screening procedures were used. Hence, it is recommended that both SCAP and STAP should be used to identify children who are at-risk for APD.

The significant moderate correlation between SCAP and the auditory memory subsection of STAP confirm that the former taps this process. The lack of correlation between SCAP and the Dichotic CV and gap detection subsections could be attributed to the non-availability of questions in SCAP that tap binaural integration and temporal resolution, auditory processes that are difficult to assess from day-to-day observation of children. Thus, it is anticipated that STAP would detect children with binaural integration and temporal resolution problems who might have been missed when screened with SCAP.

Summary and Conclusion

The study indicates a high correlation between two screening tools for auditory processing disorders, a screening checklist (SCAP) and a screening test (STAP). It is recommended that both SCAP and STAP be administered in order to detect more children 'at-risk' for APD. Both tools are able to detect children with difficulties with auditory separation and auditory memory. However, additionally the STAP is able to detect those with auditory binaural integration and temporal resolution problems.

Introduction

The diagnosis and management of auditory processing disorders (APD) has been a challenge for clinicians (Lucker, 2007). According to Chermak and Musiek (1997), 2 to 3% of school-going children have APD. Similar findings have been reported in India by Muthuselvi and Yathiraj (2009) who found APD to have a prevalence of 3.2% in school-aged children. In order to identify these children, screening for APD has been considered necessary by Musiek, Gollegly, Lamb and Lamb (1990), Bellis (2003), and Chermak (1996). Screening was reported by them to spread awareness among parents and educators; enable planning effective management strategies; and make appropriate educational recommendations.

Screening for APD has been carried out using questionnaires or checklists (Anderson, 1989; Muthuselvi & Yathiraj, 2009; Smoski, Brunt & Tannahill, 1992; Yathiraj & Mascarenhas, 2003, 2004) and screening tests (Bellis, 1996; Chermak & Musiek, 1997; Gardner, 1997; Keith, 1986, 1995, 2000). Some of the checklists reported in literature include the 'Children's Home Inventory for Listening Difficulty' (Anderson & Smaldino, 2000), 'Children's Auditory Processing Performance Scale' (CHAPS; Smoski et al., 1992), 'Screening Instrument for Targeting Educational Risk' (SIFTER; Anderson, 1989), 'Screening Checklist for Auditory Processing' (SCAP; Yathiraj & Mascarenhas, 2003, 2004) and 'Scales of Auditory Behaviours' (Summers, 2003). Although a number of checklists have been described in literature, limited information is available regarding their usefulness.

The CHAPS (Smoski et al., 1992) was designed to be administered on parents and teachers to assess the listening ability of a child. Parents / teachers were required to compare a child with other children of same age group. The questions in CHAPS were based on the perception in the presence of noise, quiet, multiple inputs, auditory memory/sequencing and auditory attention span. Purdy and Johnstone (2000) had found a significant correlation between the dichotic digit test and memory rating of CHAPS. On the other hand, Drake et al. (2006) reported that there is no relation between CHAPS and diagnostic APD tests. Their findings were based on their study of 40 children in the age range of 8 to 15 years, who were administered CHAPS along with diagnostic tests. Like Drake et al., the lack of correlation between the CHAPS and diagnostic APD tests was demonstrated by Cameron, Dillon and Newall (2005). They compared CHAPS with a battery of diagnostic APD tests consisting of the pitch pattern sequencing test, duration pattern test, masking level differences, Bamford-Knowal-Bench sentences and random gap detection test. They found no significant correlation between CHAPS and the diagnostic APD tests.

Similarly, Muthuselvi and Yathiraj (2009) check the relation between the SCAP and five diagnostic APD tests on 42 school-aged children. The diagnostic tests included a speech-in-noise, dichotic CV, masking level difference, gap detection test, and auditory memory and sequencing test. They found a significant correlation between SCAP and speech-in-noise test as well as the auditory memory test. SCAP was also found to have a sensitivity of 71% and specificity of 68%.

Emerson, Crandell, Seikel and Chermak (1997) reported that screening checklists may lead to over-referrals. In support of the use of screening tests, Schow and Seikel (2007) observed that such tests had better sensitivity and specificity than screening checklists. Chermak and Musiek (1997) recommended the use of a battery of tests to screen for APD. A few of the screening tests reported in the literature are the 'Screening test for central auditory processing disorders' (SCAN) developed by Keith (1986), SCAN-A for adults (Keith, 1995), SCAN-C for children (Keith, 2000), 'Selective Auditory Attention Test' (SAAT; Cherry, 1992), TAPS-R (Gardner, 1997), Multiple Auditory Processing Assessment (MAPA; Domitz & Schow, 2000), Bamford-Kowal-Bench Speech-in-Noise test (BKB-SIN; Etymotic research, 2005) and screening test for auditory processing (STAP; Yathiraj & Maggu, 2012).

Wilson et al. (2011) studied the relationship between screening procedures (checklists & tests), with diagnostic APD tests. They used two checklists (CHAPS, SIFTER) and a screening test (TAPS-R). They found a weak correlation between these screening procedures with the diagnostic tests used by them (competing sentences test, low-pass filtered speech test, frequency pattern test and dichotic digit test).

Besides the sensitivity and specificity of any screening tool, the efficiency of the same has also been determined based on the time taken for its administration. The total duration to conduct a screening task has been considered an important factor by Lessler (1972). The time taken to administer the SCAN and MAPA has been reported to be 20 minutes (Lampe, 2011) and 30 minutes (Domitz & Schow, 2000), respectively. In contrast, the STAP has been found to require just 12 minutes for it to be run which included the time for scoring.

In the literature on APD screening tools, most of the studies have been restricted to evaluate the relation between screening procedures with the diagnostic APD tests. However, there is a dearth of literature pertaining to the relationship across different screening procedures i.e. screening checklists and screening tests. Such information would shed light on whether different APD screening procedures can be used independent of each other or in conjunction with each other. Hence, there is a need to compare the relationship between screening procedures.

The present study focussed on evaluating the relationship between STAP (Yathiraj & Maggu, 2012) and SCAP (Yathiraj & Mascarenhas, 2003, 2004). The results of the study would also help determine whether one screening technique can be used in lieu of the other or whether both screening tools should be utilized. If the two are to be used together, the study would provide information regarding the effectiveness of a hybrid screening protocol consisting of the two procedures.

Method

Participants

The participants included 400 children (218 males, 182 females), aged 8 years to 13 years. These children were randomly selected from among 2400 children from three different schools. The participants studied in grades III to VIII in schools where the medium of instruction was English. All the children had undergone educational instruction in English for at least three years. Prior to testing each child, it was ensured that he / she had no developmental as well as speech and hearing problems, as reported by the class-teacher and the child. A letter of consent was obtained from the teachers and caregivers before testing the children. This complied with the recommendations of the Ethical Guidelines for Bio-Behavioural Research Involving Human Subjects (2004) of the All India Institute of Speech and Hearing.

Material

The present study was conducted using the STAP developed by Yathiraj and Maggu (2012) and the SCAP developed by Yathiraj and Macarenhas (2003, 2004). As described earlier by Yathiraj and Maggu (2012), the STAP was developed based on the auditory processes that were reported to be predominately affected in children with APD (Welsh, Welsh & Healy, 1980; Katz, Kurpitha, Smith & Brandner, 1992; Muthuselvi and Yathiraj, 2009; Musiek et al, 1982). The STAP was constructed to include four subsections (Speech in noise, Dichotic CV, Gap detection and Auditory Memory) that tapped auditory separation / closure, binaural integration, temporal resolution and auditory memory, respectively. Table 1 provides a description of the contents of the four subsections of the STAP.

Table 1. *Details of the subsections of STAP.*

	Subsections			
	Speech-in-noise (SPIN)	**Dichotic CV (DCV)**	**Gap detection (GD)**	**Auditory memory (AM)**
Stimuli	Monosyllabic words	Consonants-Vowels (/pa/, ta/, /ka/, /ba/, /da/, /ga/)	300 ms white noise	Monosyllabic words
No. of practice items	2 words per ear	2 CV pairs	1 token for each ear	1 token of 4 words
No. of test items	10 words per ear	6 CV pairs	6 tokens for each ear	4 tokens of 4 words
Mode of presentation	Monaural	Dichotic	Monaural	Binaural
Processes Tested	Auditory separation	Binaural integration	Temporal resolution	Auditory memory

The pass criteria for the various subsections of STAP were adapted from the existing diagnostic tests (Table 2). These criteria were used to determine the children at-risk for APD.

Subsections	**Maximum scores**			**Pass scores**		
	Right Ear	**Left Ear**	**Double Correct**	**Right Ear**	**Left Ear**	**Double correct**
SPIN[a]	10	10	----	6	6	----
DCV[b]	6	6	6	4	4	2
GD[c]	6	6	----	4	4	----
AM[d]	16		-----	12		----

SPIN: Speech-in-Noise; DCV: Dichotic Consonant Vowel; GD: Gap Detection; AM: Auditory Memory Pass criteria adapted from: a, Olsen et al, (1975); b, Krishna (2001); c, Shinn et al (2009); d,Yathiraj and Vijayalakshmi (2006)

The SCAP, developed by Yathiraj and Mascarenhas (2003, 2004), consists of 12 symptoms that were found to be affected in children with APD (Muthuselvi & Yathiraj, 2009; Yathiraj, Vanaja & Muthuselvi, 2012). A score of six or more was reported to be an indicator of risk for APD (Muthuselvi & Yathiraj, 2009).

Table 2. *Scoring and pass criteria for the four subsections of the STAP*

Instrumentation and environment

The recorded version of the developed screening test, STAP was loaded onto a laptop with a Celeron processor and was presented to the participants using the Adobe Audition 3.0 software. The volume control of the computer as well as the Adobe Audition software was adjusted such that the output through a TDH-39 headphone was 65 dB SPL. This intensity level was selected since it represented the typical normal conversational level. The level was ascertained using a 'Larson Davis systems 824' sound level meter equipped with a ½ inch microphone and a NBS 9A coupler. The noise attenuation characteristics of the headphones lead to minimal interference of extraneous noise.

Procedure

Half the children were evaluated first on the STAP and then on SCAP while the other half were tested vice versa. A double blind approach was used wherein those who evaluated the children on the SCAP / STAP did not know the results of the other test / checklist. This was done to avoid any tester bias.

The SCAP was administered by teachers who had taught the children for over a year. The teachers taught curricular subjects other than the second language. The teachers were instructed to mark the presence of a symptom on the SCAP as ‘yes’ or ‘no’ based upon their observation of the children in their class. These responses were not revealed until the screening evaluation was completed in all respects.

The STAP was administered by an audiologist in a quiet room within the school premises that was free from audio and visual distractions. The participants were initially informed that they would have to carry out four different tasks under headphones. The children were instructed to listen carefully to the recorded instructions and complete the practice items that they heard prior to attempting the test items. The responses obtained from the children varied depending on the subsections. For the SPIN subsection, the children had to identify the word in the presence of noise and repeat them; for the dichotic CV subsection, the children were required to repeat both the CVs that were presented to their two different ears; for the GD subsection, the participants had to locate the stimulus containing a gap among the triad of noise bursts that were presented; and for the AM subsection, the children had to repeat each 4-word sequence, after the presentation of the string of four words. The responses for all four subsections were noted down by the audiologist. In order to avoid tester-related bias, the responses were scored by another audiologist. Each correct response was given a score of 1 while an incorrect response was given a score of 0.

Analyses

The raw scores obtained from the participants were tabulated and analysed using SPSS 16.0 software. The data from the children, who were found to be at-risk on SCAP and STAP, were analysed further. A χ^2 test was used to determine the association between the two screening procedures from the scores obtained on children who were at-risk for APD on the SCAP & / or the STAP. Spearman’s rank correlation coefficient was employed on the data of 400 children constituting of passed and referred participants of both the screening tests. Paired samples t-test was used to evaluate the differences between the right and left ear scores. Further, Pearson's Product Moment Correlation coefficient was also used for determining the relationship between SCAP and STAP in referred participants.

Results

Out of the 400 children tested with SCAP and STAP, 82 (20.5%) children were considered at-risk for APD either on the SCAP, STAP or both. Of these children, it was found that 49 (12.3%) children were considered to be 'at-risk' for APD on SCAP and 64 (16.0%) children were 'at-risk' on STAP. Of these children, 31 were found to be 'at-risk' on both the screening tools. The number of children who passed and who were referred on the two screening procedures is given in Table 3.

Table 3. *The number of participants who passed and who were referred on the two screening procedures*

Screening procedure	Passed	Referred	Total
SCAP	351 (87.7%)	49 (12.3%)	400
STAP	336 (84%)	64 (16%)	400
SCAP + STAP	369 (92.3 %)	31 (7.8%)	400

The association between the two screening tools (SCAP & STAP) was checked with the χ^2 test of association using the data of all 400 participants. The χ^2 test revealed a significant association ($\chi^2 = 2.93$, df = 1, $p < 0.001$) between the two screening procedures. Similarly, Spearman's rank correlation coefficient, reflected a significant high correlation ($r = 0.86$, $p < 0.001$) between the two screening procedures. Additionally, McNemar test for repeated measures was done to check the significance of difference between the two screening procedures. A highly significant difference was observed between the two procedures ($N = 400$, $p < 0.0001$).

The scores of the left and right ears were compared for the SPIN as well the GD subsections of the STAP. Using a paired samples t-test, it was found that there was no significant difference between the scores of the right and the left ear for the SPIN subsection ($t(30) = 1.5$, $p > 0.05$) and the GD subsection ($t(30) = 0.19$, $p > 0.05$). As no significant difference was seen between the ears, the average scores of the left and right ears were considered for further analyses.

Additionally, the relation between the SCAP and four subsections of the STAP was determined using the Pearson's Product Moment Correlation. This relation was checked using the 31 children who were suspected to have APD on both the SCAP and the STAP. The analysis revealed that a significant correlation existed between SCAP and only one of the four subsections of STAP.

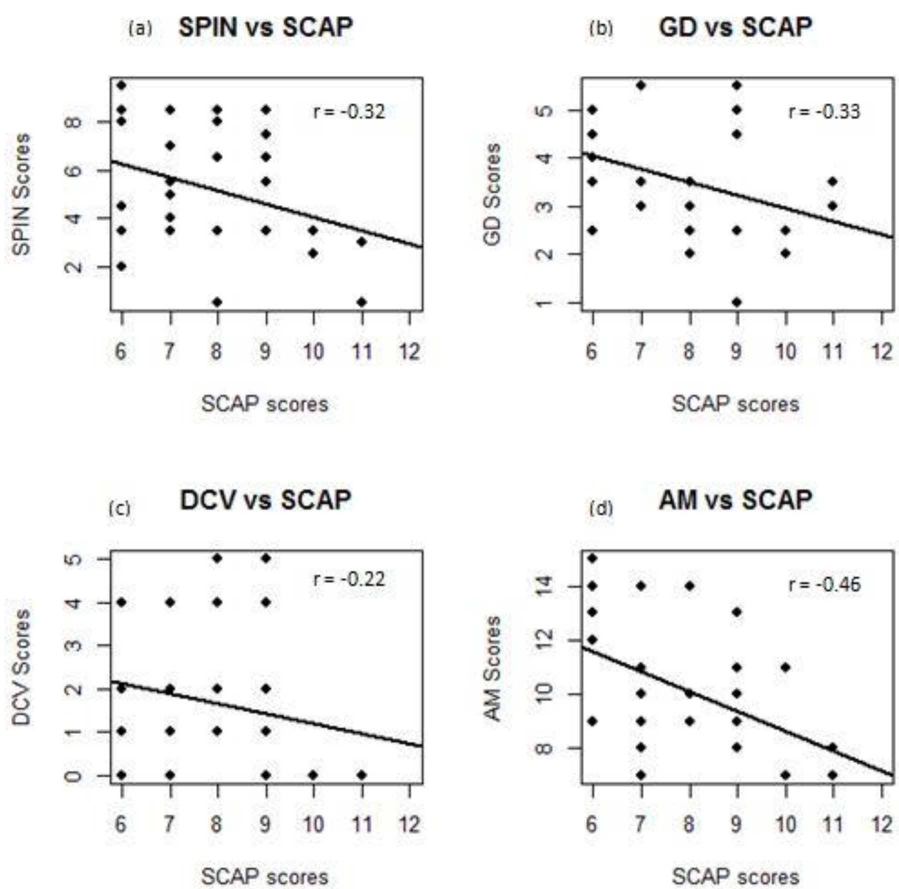

Figure 1. Depicting the relation between SCAP and the four subsections of STAP: (a) SPIN subsection and SCAP, (b) GD subsection and SCAP, (c) DCV subsection and SCAP, and (d) AM subsection and SCAP.

A significant but moderate correlation was seen only for the auditory memory subsection scores ($r = -0.46$, $p < 0.01$). However, there was no significant correlation with the SPIN subsection ($r = -0.32$, $p > 0.05$), GD subsection ($r = -0.33$, $p > 0.05$) and the DCV subsection ($r = -0.22$, $p > 0.05$). This is evident from Figure 1 where the regression line was steeper for the AM subsection compared to the other three subsections.

Discussion

The findings of the present study revealed that the number of children who were considered at-risk for APD varied depending on the screening procedure used. Only 7.8% of the total number of children studied were at-risk on both the screening procedures and 12.7% were considered at-risk based on either one of the screening procedures. Thus, among those at-risk on any one of the screening tools (82 children), only 37.8% were at-risk based on both tools and the majority (62.2%) were at-risk on either one of the screening procedures. From Table 3, it is evident that the STAP detected a larger number of children to be at-risk for APD when compared to the SCAP. Had only SCAP been used, 33 (51.5%) of the children would have been missed out. Hence, it is recommended that both SCAP and STAP be used to identify children who are at-risk for APD.

The association and correlation, calculated to determine the relationship between the overall scores of the SCAP and the STAP, revealed a highly significant association as well as a high correlation that was significant. This reveals that both screening procedures were able to detect children at-risk for APD in a similar manner. This finding confirms that better performance in one screening procedure is reflected with similar better performance in the other procedure. Likewise, a poorer performance in one procedure resulted in a similar poorer performance in the other. However, there was a significant difference between the two screening procedures. Thus, it can be construed that although the two screening tools provided similar information regarding the increase or decrease in overall performance, they measured different dimensions of the problem.

The relation between the SCAP and four subsections of the STAP revealed a moderate correlation of SCAP with auditory memory subsection of the STAP. However, there was no significant correlation with other subsections of the STAP. This indicates that teachers judge whether a child is at-risk for APD primarily based on the memory scores rather than based on other symptoms. The link between auditory memory and auditory processing has been proposed in the Buffalo's model as tolerance fading memory (Katz, 1992). The findings of the current study substantiate this link that was advocated by Katz.

Additionally, the absence of a correlation between the SCAP and the three of the subsections of the STAP confirm that they both tap different aspects of auditory processing. The lack of correlation between the SCAP and the Dichotic CV as well as the gap detection subsections could be attributed to the non-availability of questions in the SCAP that tap binaural integration and temporal resolution. These attributes of auditory processing are difficult to assess from day-to-day observation of children and hence are not included in the SCAP. Thus, it is anticipated that STAP would detect children having problems with binaural integration or temporal resolution who might have been missed when screened with the SCAP.

Yathiraj and Maggu (2012) noted that the speech-in-noise subsection and auditory memory subsection of the STAP were grouped as a single component in the principle component analysis done by them. This indicated the relation between the two subsections. It is possible that though a direct relation between the SCAP and the speech-in-noise subsection was not observed, there could be an indirect relation between the two.

The absence of a relation between the SCAP and a few of the subsection of the STAP could account for the difference in the number of children who were referred on the two screening procedures. Hence, it is reiterated that both screening procedures should be administered in order to detect as many children as possible with suspected auditory processing problems.

Summary and Conclusions

The present study compared the relation between two screening procedures for APD, SCAP and STAP, on school-going children. The study revealed that 16% (64) of children were found to be at-risk on STAP and 49 (12.3%) children on SCAP. It was found that if either one of the screening procedure was used, a number of children would have been missed. Among the subsections, only auditory memory had a significant correlation with the SCAP while other subsections of the STAP did not correlate well with the SCAP. These findings indicate that these two screening procedures tap different aspects of auditory processing. Hence, these two screening procedures should be carried in order to detect a larger number of children with suspected APD.

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