



# Setting appropriate pass or fail cut-off criteria for tests to reflect real life listening difficulties in children with suspected auditory processing disorder



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## ABSTRACT

**Objective:** This paper explores the pass or fail cut-off criteria, the number of test fails, and the nature of tests that are most appropriate in predicting listening difficulties (LiD) in children with suspected APD (SusAPD).

**Methods:** One hundred and nine English-speaking children (67 males, 42 females) aged between 6 and 11 years with SusAPD were assessed. The Children's Auditory Performance Scale (CHAPS) scores 2 SD below the mean were taken as markers of LiD in different listening conditions. Binary logistic regression analyses were carried out to evaluate the cut-off criterion (2 SD or 1.5 SD or 1 SD below the mean) of failing at least two tests, from the SCAN-C and IMAP test batteries, which significantly predicted LiD. Analyses were also carried out to assess if the group of auditory processing (AP) or cognitive or combination of AP plus cognitive tests were significant in predicting LiD. Receiver Operative Characteristic (ROC) curves were also explored to evaluate how the sensitivity and specificity in confirming LiD varied with the number of test fails.

**Results:** Filtered Words, Competing Words, Competing Sentences, VCV in ICRA noise, Digit Span, Sight Word Reading and the Cued Auditory Attention tests correlated with one or more of the CHAPS domains. Failing at least two of these tests 1.5 SD below the mean significantly predicted ( $p < .05$ ) CHAPS Ideal scores 2 SD below the mean, and failing at least two of the tests 1 SD below the mean significantly predicted ( $p < .05$ ) CHAPS Memory and CHAPS Attention scores 2 SD below the mean. The combination of AP plus cognitive tests had significantly higher ability to predict CHAPS Ideal, Memory and Attention scores, compared to the group of AP or cognitive tests separately. ROC curves showed that failing at least two of the tests was associated with the best sensitivity and specificity in predicting LiD.

**Conclusion:** Of the different CHAPS domains only the CHAPS Ideal, Memory and Attention correlated with the APD tests. Failing at least two APD tests from a combination of AP and cognitive tests 1 SD and 1.5 SD below the mean, but not 2 SD, is more appropriate in confirming LiD.

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## 1. Introduction

It is estimated that about 1% of the childhood population in the United Kingdom attend Ear, Nose and Throat (ENT) or Audiology departments with a hearing difficulty and pure tone audiogram thresholds within normal limits [1]. These children with listening difficulties without any known underlying cause or pathology may have developmental auditory processing disorder (APD) [2,3]. The

American Speech–Language–Hearing Association (ASHA) recommended five different types of behavioural auditory processing (AP) tests that included *auditory discrimination, auditory temporal processing, dichotic listening, monaural low-redundancy speech tests and sound localization* for diagnosing APD [4]. The diagnosis of APD can vary widely, from 24.7% to 96%, in the same group of children using the same AP tests but different pass or fail criteria [5]. Without any information about the sensitivity and specificity of the diagnosis comparison of diagnostic accuracy of different criteria is not possible. Currently there is no consensus as to what constitutes APD [2,6,7] that makes ascertaining a diagnosis difficult. Some researchers consider children with listening difficulties with normal hearing irrespective of their outcomes

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in AP tests to have APD [8], some consider APD as a discrete condition diagnosed using APD tests [4] while others consider APD as a marker of a broader neurodevelopmental syndrome [2]. For children with real life listening difficulties it is irrelevant if they fulfil a diagnostic label of APD or not, it is important that the functional difficulties are recognised and remedial measures taken [6]. It has been proposed that children with real life listening difficulties are initially identified using some form of “screening” or “Listening difficulties test” and subsequently specific diagnosis of APD is confirmed using tests from a APD test battery based on some pass or fail cut-off criterion [4,6]. It has been claimed that the criteria of performance 2 SD below the mean in at least two AP tests and 3 SD below the mean in at least one AP tests [4] commonly used to diagnose of APD are not evidence based [9]. Diagnoses (APD or non-APD) using such cut-off based on “distribution of scores for people with no disorder” may not reflect real life listening ability [6]. There is no published literature to suggest what pass or fail cut-off criteria for APD tests would reflect real life listening difficulties and this information would be very important in accurate diagnosis of APD or confirmation of listening difficulties. In this paper we referred to children with listening difficulties as children with suspected auditory processing disorder (SusAPD) [10] being aware that the terms “Listening Difficulties” [2] as well as APD [2,8] have been in the literature to refer to these children.

The problem of setting appropriate cut-off criterion for tests to reflect real life functional difficulties are not limited to APD tests and listening difficulties. Similar issues are noted with neuropsychological tests assessing Executive Function (EF) [11] and language tests assessing Language Impairment [12]. Cut-off criteria of 1 and 1.5 SD below the mean for neuropsychological tests to assess functional difficulties with EF [11,13] and 1.25 SD below the mean for language tests to assess language impairments [12] are used in clinical practice. APD mostly co-occurs with other neurodevelopmental conditions that include language impairment and attention deficit disorder, which is linked to EF [2,11,13,14]. Therefore, in this paper, we explore if cut-off criteria of 1 or 1.5 SD are more appropriate than 2 SD below the mean for APD tests to identify children with listening difficulties. A number of screening questionnaires are available to evaluate listening difficulties [15]. The Children’s Auditory Performance Scale (CHAPS) [16] is one of the established and commonly used questionnaires to support clinical assessment of children with suspected APD, both in the UK [17] and the USA [18]. CHAPS evaluates children’s listening behaviour in six different listening conditions using either parental or teacher observation (see Methods), and scores children in relation to their peers. A number of studies have looked into the relationship between APD tests and the CHAPS questionnaire [19–21]. However, the weaknesses of these studies are that they use unorthodox CHAPS scores that are not standardized [22]. In this paper, we standardise the CHAPS scores in relation to the normative data obtained from a large population study [23], which allows statistical analyses of standardised outcome of the CHAPS questionnaire and standardised outcome of APD tests to be more reliable. The bottom 5–10% of children from a large population who have the poorest CHAPS scores are likely to have APD or listening difficulties [23]. For the purpose of the paper we considered performance 2 SD below the population means in the different CHAPS [16] domains as evidence of real life difficulties under different listening conditions.

Children with SusAPD may have difficulties in one or more areas of auditory processing and hence a battery consisting of different APD tests are recommended for evaluation [4]. In addition to the five types of recommended behavioural tests [4], there are a number of considerations in choosing a test battery. The British

Society of Audiology suggests that tests using both speech and non-speech stimuli are used [3]. A number of publications show the need of including cognitive tests in addition to auditory processing (AP) tests in an APD test battery [10,22,23], and there are conflicting evidence with suggestion that only cognitive tests are predictive of real life listening difficulties [9]. In this paper we used two test batteries, SCAN-C [24] and the IMAP [23]. The SCAN-C [24] test battery is a commonly used test battery [18] that evaluates auditory processing ability using speech-based stimuli, although the dichotic listening tests (Competing Words and Competing Sentences) have cognitive load. The IMAP [24] is a research battery that assesses both speech and non-speech auditory processing and a number of cognitive abilities such as non-verbal intelligence (NVIQ), memory and attention. Both the SCAN-C and IMAP test batteries have age related normative data. The combination of these two test batteries represented four of the five (auditory discrimination, auditory temporal processing, dichotic listening and monaural low-redundancy speech tests) different types of behavioural auditory processing tests suggested by ASHA [4], provide a good balance of both speech and non-speech auditory stimuli [3] and give the opportunity to assess the contribution of both AP and cognitive tests in the predicting real life listening difficulties [9,10,23,25]. We hypothesise:

- (1) Performance 1 SD below the mean in at least 2 APD (2 AP or 2 cognitive or 1 AP plus 1 cognitive) tests is a better measure than performance 2 SD below the mean in at least 2 APD tests in predicting children who perform 2 SD below the mean in the CHAPS domains.
- (2) Performance 1 SD below the mean in at least 2 APD tests is a better measure than performance 1.5 SD below the mean in at least 2 APD tests in predicting children who perform 2 SD below the mean in the CHAPS domains.
- (3) Performance 1.5 SD below the mean in at least 2 APD tests is a better measure than performance 2 SD below the mean in at least 2 APD tests in predicting children who perform 2 SD below the mean in the CHAPS domains.
- (4) Cognitive tests but not the AP tests can predict listening difficulties.

In addition to our above stated hypotheses, we also aim to evaluate how the sensitivity and specificity of confirmation of significant real life listening difficulties vary with the number of APD test fails based on the most appropriate pass or fail cut-off criterion.

## 2. Material and methods

The data used in this study were collected as a part of a previous research that looked into the factors underlying listening difficulties in children with SusAPD [10]. The participants, inclusion criteria, details of the IMAP [23] and SCAN-C [24] tests, procedures and extraction of the three factors have been described elsewhere [10]. A brief summary is included below.

### 2.1. Participants

Data from 109 participants, 42 females and 67 males, between 6 and 11 years of age (Mean = 9.33 years, SD = 1.40) were included. They were all English-speaking apparently healthy children attending mainstream school who had listening difficulties despite normal middle-ear compliance ( $>0.2 \text{ cm}^3$ ) and pressure ( $\geq -200 \text{ daPa}$  to  $\leq +50 \text{ daPa}$ ), presence of the stapedial reflex and normal pure-tone thresholds ( $\leq 20 \text{ dB HL}$  averaged across octave frequencies between 0.5 and 4 kHz) bilaterally.

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