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Intelligibility of degraded speech and the relationship between symptoms of inattention, hyperactivity/impulsivity and language impairment in children with suspected auditory processing disorder

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ABSTRACT

Objectives: To compare the sensitivity and specificity of Auditory Figure Ground sub-tests of the SCAN-3 battery, using signal to noise ratio (SNR) of +8 dB (AFG+8) and 0 dB (AFG0), in identifying auditory processing disorder (APD). A secondary objective was to evaluate any difference in auditory processing (AP) between children with symptoms of inattention versus combined sub-types of Attention Deficit Hyperactivity Disorder (ADHD).

Methods: Data from 201 children, aged 6 to 16 years (mean: 10 years 6 months, SD: 2 years 8 months), who were assessed for suspected APD were reviewed retrospectively. The outcomes of the SCAN-3 APD test battery, Swanson Nolan and Pelham-IV parental rating (SNAP-IV) and Children's Communication Checklist-2 (CCC-2) were analysed.

Results: AFG0 had a sensitivity of 56.3% and specificity of 100% in identifying children performing poorly in at least two of six SCAN-3 sub-tests or one of the two questionnaires, in contrast to 42.1% and 80% respectively for AFG+8. Impaired AP was mostly associated with symptoms of ADHD and /or language impairment (LI). LI was present in 92.9% of children with ADHD symptoms. Children with symptoms of combined ADHD plus LI performed significantly poorly ($p < 0.05$) compared to inattention ADHD plus LI in Filtered Words (FW) sub-test, but not in the rest of the SCAN-3 sub-tests.

Conclusion: Speech in noise tests using SNR of 0 dB is better than +8 dB in assessing APD. The better FW performance of the inattention ADHD plus LI group can be speculated to be related to known difference in activity in a neural network between different sub-types of ADHD. The findings of the study and existing literature suggest that neural networks connecting the cerebral hemispheres, basal ganglia and cerebellum are involved in APD, ADHD and LI.

1. Introduction

APD is defined as "a disorder characterized by impairment of the auditory processing resulting in deficiencies in the recognition and interpretation of sounds by the brain" in the recent International Classification of Diseases (ICD-10-CM diagnostic code H 93.25). In children APD mostly presents without any known aetiology other than a family history of developmental communication and related disorder, and the term "developmental APD" is used [1]. In this paper, the term APD is used for "developmental APD". Difficulties in listening, especially in the presence of background noise, despite normal pure tone audiometric thresholds is the main characteristics of APD, and APD mostly accompanies other neuro-developmental conditions [2]. Poor classroom acoustics can impact on the educational progress of children [3], especially in children with APD who in addition to listening difficulties may also have poor attention, forgetfulness and language/communication difficulties. These children qualify for additional classroom support if the listening difficulties are confirmed [4]. Therefore, it is important that such children in addition to routine hearing test (pure tone audiogram) have assessment of their auditory processing (AP) and cognitive abilities.

The SCAN was reported to be a commonly used test battery in the UK to assess AP [5], which has now been replaced by SCAN-3 [6,7]. The previous versions of SCAN test battery only assessed speech sound that was 8 dB louder than the background noise, a

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signal to noise ratio (SNR) of +8 dB (Auditory Figure Ground +8 dB; AFG+8). The SCAN-3 battery has additional option to make speech intelligibility in noise test more challenging, with the background noise level being equal to that of the speech sounds, a SNR of 0 dB (Auditory Figure Ground 0 dB; AFG0). It is recognised that different APD tests vary in their ability to confirm real-life listening difficulties [8], but there is no published literature demonstrating if AFG+8 or AFG0 is superior to the other in confirming speech perception difficulties in the presence of background noise. AP assessment is time consuming, and therefore, identifying one speech-in-noise test that is more effective in confirming APD would improve efficiency. The primary aim of this paper is to explore how children referred with suspected APD performed in the two speech-in-noise sub-tests of the SCAN-3 test battery.

Psychoacoustic AP tests on their own often fail to confirm real life listening difficulties [8–10]. Therefore, the use of appropriate questionnaires along with AP tests has been suggested to assess children with suspected APD [9,11,12]. Different validated questionnaires are available to screen for co-morbid neurodevelopmental conditions [12–14]. Attention deficit hyperactivity disorder (ADHD) and language impairment are common neurodevelopmental conditions that accompany APD [2], and questionnaires to screen for these two conditions are used in some clinics. The Swanson Nolan and Pelham-IV Rating Scale (SNAP-IV) [13] and the Children's Communication Checklist-2 (CCC-2) [14] are validated and widely used questionnaires to screen for ADHD and language impairment respectively. It is hypothesised that the AFG0 sub-test have a higher sensitivity and specificity, compared to AFG+8, in confirming overall poor performance in SCAN-3, CCC-2 and SNAP-IV.

Up to 90% of children with ADHD has co-morbid language impairment [15], and there are three different sub-types of ADHD [16,17], of which the combined and the inattention sub-types are more common and the hyperactive/impulsive sub-type is rare [17,18]. The combined and inattention sub-types of ADHD are suggested to involve separate neural networks [17,19,20]. A recent diffusion tensor imaging (DTI) study demonstrated that children with combined sub-type of ADHD have decreased neural connectivity in the right cerebral cortex compared to those with the inattention sub-type [19]. However, it is not known if the different subtypes of ADHD varied in psychoacoustic tests that are routinely used in clinical practice to assess children with suspected APD. The secondary aim of this study was to compare the outcome of different sub-tests of SCAN-3 between combined and inattention sub-types of ADHD.

2. Material and methods

Data for this retrospective study was collected as a part of a service improvement project to explore the appropriateness of referrals received by the pediatric audiology service for assessment of APD, effectiveness of the SCAN-3 test battery, and monitoring referrals to multidisciplinary team with suspected neurodevelopmental conditions like ADHD and LI.

2.1. Participants

Data from 201 children, 115 males and 86 females (m:f = 1.33:1), between 6 and 16 years of age (Mean = 10 years 6 months, SD: 2 years 8 months), who were routinely assessed in a tertiary pediatric audiology clinic for APD between October 2014 and March 2017 were used in this study.

The participants were English speaking children attending mainstream schools in the North West of England who had been referred for assessment of suspected APD. These children were referred by: Audiologists, Community Pediatricians, Educational Psychologists, General Practitioners, Otolaryngologists, School Nurses or Speech and Language therapists. During the assessment, a detailed history of the presenting complaints, birth, early developmental milestones, medical illness and family history was noted. In addition to the above history, in the structured history sheet the parents had one of four fixed choices (Always, Most-times, Occasional and Never) to express some non-academic concerns and one of five fixed choices to express some academic concerns (Very poor, Poor, Average, Good and Very good) (please see Table 1). The case notes of the children also had records to confirm that the eardrums were intact, pure tone average threshold (0.5, 1, 2 & 4 kHz) were within normal limits (≤20 dB HL), the ears were free of any active disease and that the listening difficulty did not arise following any illness.

2.2. Auditory processing tests

The SCAN-3 is a commercially available test battery to assess APD; SCAN-3:C designed for children (between 5 years and 12 years 11 months) [6] and the SCAN-3:A for adolescents (13 years and older) [7], with normative data available for different age groups. Six sub-tests from the SCAN-3:C and SCAN-3:A were used in this study, where participants were required to repeat the speech sounds presented through headphones in a sound treated room:

Table 1
Number (percentage) of children with suspected auditory processing disorder with different academic and non-academic presenting complaints.

Non-Academic concerns					
Extent of concerns	Listening in noise N = 201	Hyperacusis N = 200	Short attention span N = 200	Forgetfulness N = 200	Clumsiness N = 200
Never	18 (8.9)	64 (32)	13 (6.5)	5 (2.5)	83 (41.5)
Occasional	71 (35.3)	62 (31)	49 (24.5)	53 (26.5)	72 (36)
Most times	74 (36.8)	43 (21.5)	77 (38.5)	89 (44.5)	32 (16)
Always	38 (18.9)	31 (15.5)	61 (30.5)	53 (26.5)	13 (6.5)
Academic concerns					
Extent of concerns	Reading N = 200	Spelling N = 200	Handwriting N = 200	Numeracy N = 200	
Very good	41 (20.5)	20 (10)	21 (10.5)	29 (14.5)	
Good	34 (17)	30 (15)	24 (12)	32 (16)	
Average	44 (22)	38 (19)	58 (29)	60 (30)	
Poor	61 (30.5)	76 (38)	55 (27.5)	47 (23.5)	
Very poor	20 (10)	36 (18)	42 (21)	32 (16)	