Authors & Acknowledgments

Produced by: The Auditory Processing Disorder Special Interest Group

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Contents

1. Background and purpose of this document

Auditory Processing Disorder (APD) was first described more than 60 years ago as the inability 'to structure the auditory world' (Mykelbust, 1954:158). It has had a controversial history regarding definition, diagnosis and management. To address the principal controversies of APD, the BSA (2011a, 2011b) published a 'Position Statement' and 'Practice Guidance'. These documents have served as a general catalyst for a fundamental reconsideration of APD by highlighting the importance of evidence-led discussion and practice, and promoting the need for collaboration between clinicians and researchers, across disciplines and countries. Three specific action points were identified: (i) the need for 'gold standards' for diagnosing and managing APD, (ii) the value of distinguishing between Developmental, Acquired and Secondary APD, and (iii) advocating a closer link between diagnostic testing and the listening problems children and adults actually report.

The BSA Position and Practice documents led to a 'white paper' on Developmental APD that outlined current thinking in the UK and included commentaries from other research groups working on APD internationally (Moore et al, 2013). The BSA APD Special Interest Group (SIG) collaborated with the American Academy of Audiology (AAA) to present an APD International Conference as part of the AAA Annual Conferences in 2012, 2014 and 2016. As reported in the white paper and at these meetings, there has been a surge in high quality research on APD that has included randomised controlled studies and clearer report of subject selection criteria. Crucially, there is also a growing recognition of the need to assess real-world listening ability and the importance of cognitive factors. The high co-occurrence of APD with other developmental disorders in children, including specific language impairment, dyslexia and autistic spectrum disorder, is now widely recognised.

Several other groups around the world have issued APD statements, guidelines and/or white papers, including the American Academy of Audiology (AAA, 2010), the American Speech-Language Hearing Association (ASHA, 2005), the German Society of Phoniatrics and Paediatric Audiology (Nickisch et al, 2015), the Canadian Interorganizational Steering Group for Speech-Language Pathology and Audiology (2012), the Australian National Acoustics Laboratory (NAL, 2015) and the Dutch Position Statement (De Wit et al, 2017). All these statements help international understanding and communication. For example, the NAL Statement suggested that difficulty hearing in noise may lead to auditory fatigue in children with APD, requiring more effort for them to hear and thus reducing processing capacity to do other activities (e.g. school work). This may be interpreted as 'not listening' or 'a lack of interest' and may be a similar difficulty to that reported in older people with age-related cognitive decline and hearing loss (Rönnberg et al., 2014). In New Zealand, The National Foundation for the Deaf approached the United Nations, arguing that lack of rehabilitation for New Zealand children with APD breaches their right of access to education and social interaction. The New Zealand Ministries of Health and Education subsequently commissioned research which concluded that the needs of the majority of children with APD are not currently being met and led to the founding of a national expert group on APD (Esplin & Wright, 2014). The recent 2017/18 ICD-10-CM (2017) now also includes a specific diagnosis Code, i.e.

H93.25 for central auditory processing disorder (CAPD); a term used interchangeably with APD.

As a result of these publications some general themes are emerging around the concept of APD:

- Agreement regarding limitations of the pure-tone audiogram in providing information about speech perception in both quiet and noise and day-to-day demands on hearing and listening
- Need to reduce number of tests while increasing quality - appropriate norms, reliability, validity
- Concern that listening problems are neither identified nor treated before the age of 7. The success of early fitting of devices for hearing loss clearly demonstrates that early identification and management provide best results
- Importance of relating skill testing to everyday hearing and listening, and to effective rehabilitation
- Importance of cognitive functions, and their impairments, for all aspects of hearing including APD
- Value of individualised medical and audiological care of APD, especially given its heterogeneous nature

The BSA is committed to strengthening international collaboration to better understand APD and advise best practice. In light of rapidly evolving developments, we offer this shortened, revised Guidance that complements existing documents, and will be updated as needed. Its purpose is to generate further dialogue and research, and provide information to professionals and funders to make evidence-based choices. The previous APD Practice Guidance (BSA, 2011b) provides further detail about specific management interventions and useful practical handouts.

2. Updated BSA definition of APD and categories of APD

APD is characterised by poor perception of speech and non-speech sounds. It has its origins in impaired neural function, which may include both the afferent and efferent pathways of the central auditory nervous system (CANS), as well as other neural processing systems that provide 'top down' modulation of the CANS. These other systems include, but are not limited to vision and the cognitive functions of language, speech, attention, executive function, fluid reasoning, memory and emotion. APD is often found alongside and may contribute to primary disorders of those systems. APD may thus include both auditory and cognitive elements.

APD impacts on everyday life mainly through a reduced ability to listen, and therefore respond appropriately to speech and other sounds. Individuals referred for APD assessment typically present at clinics reporting listening difficulties and other behaviours consistent with hearing loss, despite a normal audiogram. These behaviours include greater difficulty hearing in noise, mishearing speech, frequent requests for repetition, and poor attention to and/or memory of auditory instructions. There may also be reports of generally impaired speech, language, literacy, attention and academic performance. Poor attention and memory are generally present, either as a secondary feature (e.g. fatigue associated with listening demands) or as a primary feature of reported impaired auditory perception.

Previously, we recommended three categories of APD (BSA, 2011a,b) that appear to have met with international acceptance. Here, we propose some refinements:

- Developmental APD: Cases presenting in childhood with listening difficulties, but with normal audiometric hearing and no other known aetiology or potential risk factors other than a family history of developmental communication and related disorders. These individuals may retain APD into adulthood
- Acquired APD: Cases associated with ageing or a known medical or environmental event (e.g. brain lesion)
- Secondary APD: Cases where APD occurs in the presence, or as a result of either transient or permanent peripheral hearing impairment

There continues to be international focus on Developmental APD, primarily because of concerns that it may contribute to learning difficulties, especially affecting language and literacy, and hence to poor school performance. As new evidence accumulates on the biological basis of APD, and predisposing genetic factors, it seems likely that these categories will be further refined. It is also important to consider Acquired and Secondary APD, together with the concept of APD across the lifespan. The high co-occurrence of APD with language, attention, memory, and executive difficulties in both children and adults underscores the importance of a multi-faceted approach throughout life. We are also seeing a larger ageing population, where the interaction between declining cognition, hearing loss and auditory processing needs to be considered and appropriately managed. Clinicians may choose to address this in different ways, for example requesting that language, memory and cognition are assessed prior to referral for APD testing, or by offering an interdisciplinary, in-house service that covers both assessment and intervention. Appropriate medical care should be sought in cases of Acquired and Secondary APD. The remainder of this Statement is specific to Developmental APD.

3. APD assessment guidance

The BSA (2011a,b) documents and 'white paper' (Moore et al, 2013) have led a surge of international dissatisfaction with the current, most commonly used APD clinical protocols. Although we have been effective in marshalling a consensus that questions the most fundamental tenets of these protocols, we have been less effective in proposing a useful alternate agenda. There continues to be no universally accepted diagnostic criteria or test batteries for APD.

There is, however, growing agreement that:

- Current clinical practice in APD evolved from the perspective of audiologists who understand hearing problems derived from a malfunction of the ear or of the central CANS. However, the audiologist typically has less knowledge regarding listening problems having other origins
- Commonly used clinical tests developed for adults with identified brain lesions (Acquired APD) are not appropriate for children with Developmental APD
- Audiologists (together with many other professionals, individuals with APD and parents) often attribute listening problems to impaired processing in the CANS when audiograms are normal. However, contemporary evidence suggests APD may be due primarily to language and other cognitive processing outside the traditional auditory system. This underscores the importance of a multi-disciplinary approach, particularly for children with Developmental APD but also for the other APD categories
- Developmental APD may contribute to childhood learning difficulties, but its status as a distinct learning disability is controversial. Other more commonly used and agreed disorders (e.g. language impairment, dyslexia, attention deficit/hyperactivity disorder, autism spectrum disorder) should take diagnostic precedence
- Most currently used tests of APD are primarily tests of language and auditory attention that lack sensitivity and specificity for deficits of auditory perception
- There is a need to develop a smaller battery of tests that are well validated, normed, and relevant to the problems reported by those presenting in clinic

As a first step, the reason for the referral should be reviewed, considering whether further assessment will add anything to a diagnosis and/or support already in place. Initial screening and assessment should include a structured case history, a well-validated questionnaire, and previous professional reports. A case history is essential to understanding the difficulties experienced and impact on education/work, social interactions and other achievements. Research to develop an appropriately structured case history would be useful. A number of parent-report questionnaires on listening skills are available for children, including the Fisher's Auditory Problems Checklist (Fisher, 1985) and the Children's Auditory Performance Scale (CHAPS: Smoski, Brunt, & Tannahill, 1998). These questionnaires provide some useful information but are not well validated. A newer, well-validated questionnaire is the Evaluation of Children's Listening and Processing Skills (ECLiPS) (Barry & Moore, 2014; Barry et al., 2015). The ECLiPS has been standardised for UK children aged 6-11 years. It has five scales to assess auditory processing, environmental sensitivity, language, memory and attention, and pragmatic skills. Other questionnaires, for example concerning executive function and communication skills, have also been proposed (DeBonis, 2015). There is an unmet, urgent need for validated and standardised APD screening questionnaires for children younger than 6 years of age, teenagers and adults.

Pure-tone audiometry (250-8000Hz) and immittance testing (including ipsi- and contralateral reflexes) are necessary to identify hearing impairment and medical ear pathology, requiring medical and/or audiological intervention. Speech perception tests in quiet or using noise or speech maskers could follow next. For example, the Listening in Spatialized Noise -Sentences (LiSN-S) test (Cameron and Dillon,

2007) can be used to diagnose 'spatial processing disorder' (SPD), a reduced ability to use spatial cues to hear in background noise. De Bonis (2015) suggested the Words-in-Noise Test (WIN) and the Bamford–Kowal–Bench Speech in Noise Test (BKB-SIN). These tests are both suitable for children and present monosyllabic words and sentences, respectively, in a background of multi-talker babble. They thus have some functional specificity, age-appropriateness, reliability and validity, and are well standardised. However, all tests of speech perception have recognized involvement of language, attention and working memory. A further important issue concerns the extent to which speech tests are available in an appropriate language (i.e. home language), and even accent because these are known to have highly significant effects on test performance (Dawes and Bishop, 2007; Loo et al., 2013). There is also a need for further development of appropriate speech-in-noise measures having these features, but measuring different functions (e.g. auditory attention), or for use with other specific populations (e.g. younger children or different language and cultural groups).

There are no agreed criteria as to when electrophysiology should be included in the clinical evaluation of APD. There is little evidence to support the inclusion of these tests in cases of normal audiometry, with the exception of the ABR which when used with oto-acoustic emissions and/or cochlear microphonic potentials is necessary in identifying auditory neuropathy spectrum disorder (ANSD; BSA, 2013). Several studies have reported abnormalities of the speech-evoked ABR associated with a variety of learning difficulties that include impaired auditory perception (Hornickel et al., 2012). Further discussion of ANSD and its relation to APD continues in Section 5. In general, onward referral (e.g. to ENT, Neurology, Speech Language Therapist) should be considered following any abnormal electrophysiology.

The extent to which listening deficits are attributable to language or cognitive factors may be informed by initial language and cognitive assessments done prior to or alongside audiological testing. It seems desirable for audiologists to be trained in some simple cognitive testing. For example, Australian Hearing is now testing for verbal working memory using 'digit span' (Cameron et al.,2015) and a simple test of auditory attention (Zhang et al., 2012) is under clinical development. However, it is important for audiologists to recognise that cognitive tests and alternate diagnoses also have their limitations. For example, a child's poor performance on a speech-in-noise test may not be assumed to be auditory in origin, rather than based on an attentional problem, even if the child passes a single test of attention.

DeBonis (2015) suggested that identification of a 'listening deficit' in school-aged children could involve performance outside of the norms on at least two of four measures of his proposed test battery (Behavior Rating Inventory of Executive Function, Children's Communication Checklist–Second Edition, WIN and the BKB-SIN), with at least one of these measures being a speech-in-noise test. Prescription of such criteria is currently necessary in some jurisdictions to receive support and funding. However, adherence to arbitrary criteria has unfortunately contributed to much of the current controversy in APD. Practical problems with arbitrary criteria in professional guidelines (e.g. ASHA, 2005; AAA, 2010) were highlighted by Wilson and Arnott (2013), who analysed nine different scenarios for diagnosing APD based on several such criteria. They reported hypothetical overall diagnostic rates ranging from 7.3% to 96.0% among 150 school-aged children referred to their audiology service for APD assessment. Aside from the absurdity of such a huge range of rates, it is important to note that any diagnosis of APD needs to be accompanied by the criteria used, both when reporting research and when applied clinically.

Finally, an integrated report and management plan (see below) needs to be developed; with primary versus secondary concerns carefully considered. All results should be analysed and integrated against the background of other professional reports, cognitive functions and the support already in place – a holistic approach. Rather than labelling a person with APD, it is more helpful and appropriate to describe the presenting hearing and/or listening problem, and to outline an evidence-based approach to address the specific needs of the particular patient. Where a label of APD is, however, necessary to secure support/funding (e.g. ICD-10; H93.25), we recommend that testing include only measures that fulfil the criteria of functional specificity, reliability, validity, age-appropriateness and standardisation, as outlined above with a clear statement of the diagnostic criteria included.

4. APD management guidance

A top priority for further research, discussion and clinical practice in APD should be intervention. For example, new technologies, such as remote microphone devices, personal sound amplification products (‘PSAPs’) and smartphone apps are promising, but require further investigation. Remote microphone devices are also proving to be beneficial to those with language and attention difficulties as the technology allows for better access to the primary signal, reducing background noise and reverberation. A positive development is that these technologies are becoming less expensive and thus more accessible.

Current intervention strategies can be divided into three main categories, as summarised in Table 1: (1) modifying the listening environment, (2) auditory training and (3) compensatory strategies. The strategies listed under ‘Modifying the listening environment’ are more evidence-based than the other strategies. Several ‘Auditory training’ approaches have been tested rigorously, with mixed results. ‘Compensatory strategies’ are widely advocated but have not been validated.

Table 1: Management strategies with supporting evidence (based on Campbell et al, 2012)

Modifying the listening environment	
Room acoustics	Architectural interventions to reduce reverberation and improve the signal-to-noise ratio. Acoustic treatments such as carpets, curtains, doors, seals, rubber shoes on furniture legs, and double-glazed windows help reduce noise. The installation of noise absorbent partitions or screens and preferential seating can also be considered. In addition, there are specific acoustic performance standards which UK schools are required to meet (Building Bulletin 93, 2015).
Remote Microphone Technology (also known as Wireless Communication Devices)	Wireless devices that deliver input from a remote microphone to the ear. They reduce the impact of background noise and reverberation. For individuals with APD who have normal audiograms the sound can be delivered without amplification. A trial with the technology is advised before final fitting to ensure benefit and acceptance. There should also be support in place to support the technology on a day-to-day basis (Schafer et al., 2014).
Teacher and speaker adaptations	Teachers and speakers are advised to face the listener, secure their attention, use clear speech, alter the pacing, emphasis and segmentation of their speech, and regularly check on the comprehension of verbal instruction (Chermak & Musiek, 2014a).
Auditory training	
Interactive training devices	Computer software can provide automated training using game-like formats, adaptive individualised challenge, and performance feedback. For example, LiSN & Learn specifically targets and improves spatial processing disorder (SPD), reduced ability to use spatial cues to hear in background noise, diagnosed using the same task (LiSN-S; Cameron et al, 2012). The National Acoustic Laboratories have recently launched an updated version of LiSN & Learn for the iPad, called Sound Storm (http://capd.nal.gov.au/sound-storm-about.shtml). Memory Booster (www.lucid-research.com) targets working memory and memory strategies in children (aged 4-11). Earobics (www.earobics.com) and Fast ForWord (www.innovative-

	therapies.com) target phonological awareness, phonics, auditory attention and language. However, the ability of each of these programs to improve cognitive and language skills remains controversial. In summary, current software provides robust 'on-task' learning of the exact skill trained, but little or no transfer of learning to untrained tasks or skills (Loo et al., 2010).
Musical Training	Musical training has been found beneficial for learning important auditory skills and tuning underlying brain processes (Strait et al., 2013; Alain et al., 2014). However, the extent of benefit and transfer to real world tasks and settings is controversial.
Compensatory Strategies	
Improving listening skills	Developing awareness that listening is an active process involving self-regulation and monitoring, while hearing is a passive process (Truesdale, 1990; 2013).
Meta-cognitive and meta-linguistic strategies	Training in self-regulation and problem solving by identifying individual listening strengths and weaknesses, listening situations that are more challenging and possible solutions (e.g. move to a quieter area, use visual material, visual imagery and/or 'chunking' to remember and recall verbal information, write information down to stay focussed and remember verbal information). Verbal rehearsal (also known as subvocalisation or reauditorisation) can be used to commit verbal information to memory (Chermak & Musiek, 2014a). These strategies, though widely advocated, have not been rigorously tested.

5. Current research and future directions

The last five years have seen a surge of interest in and publications on APD (e.g. Barry & Moore, 2014; Chermak et al., 2012, Chermak & Musiek, 2014b; Dillon et al., 2012; Gallun & Lee, 2014; Kopp-Scheinpflug & Tempel, 2015; Ludwig et al., 2014; Tomlin et al., 2015; de Wit et al., 2016). These efforts have resulted in a broadening of the scope of APD, but with an increased focus on individual differences and a renewed interest in biological mechanisms. The result has been to place APD on a scientifically more rigorous trajectory.

The scope of APD has broadened because of a greater recognition of auditory phenomena that are both centrally (Gallun & Lee, 2014) and peripherally (Saxena et al., 2015) mediated. These phenomena include aspects of neuropathology, auditory trauma, maturation, ageing and cognition. Each phenomenon has been associated with changes in auditory perception in the absence of audiometric hearing loss. Two new terms, 'auditory synaptopathy', a form of ANSD (Moser et al., 2013), and 'hidden hearing loss' (HHL; Schaette & McAlpine, 2011), covering a range of neuropathy, hair cell pathology and very high frequency audiometric deficits (Liberman et al., 2016), have been used to describe biologically defined phenomena originating in the adult cochlea and brainstem that may overlap with or contribute to APD. These phenomena are thought to reflect reduced auditory transduction or temporal encoding, and may have adverse perceptual consequences (e.g. with localisation of sound, or listening to speech in noise; Plack et al., 2014). Current diagnosis of auditory neuropathy spectrum disorder is based on absent or grossly abnormal ABR and present OAE and/or cochlear microphonic potentials, with pure-tone audiogram thresholds ranging from normal to profound hearing impairment (BSA, 2013). Reduced contralateral acoustic reflexes have recently been reported in response to high level sounds in some children with normal hearing thresholds, but with suspected APD, suggesting a possible mechanism for impaired speech in noise perception (Saxena et al., 2015). It has long been known that the audiogram is a far from perfect predictor of more typical listening skills, in particular those requiring supra-threshold perception such as speech-in-noise (Bergman, 1971). Mechanisms underlying such supra-threshold deficits in the presence of normal audiometric thresholds are currently under intensive investigation. For example, in an ongoing longitudinal study, White-Schwoch et al (2015) measured the precision of the neural coding of consonants in noise and found that pre-reading children with stronger neural processing had superior early literacy skills and reading skills one year later.

Understanding brain function beyond the traditional auditory system continues to evolve, with an explosion of findings both in neuroimaging and in another emerging area, 'cognitive hearing science' (e.g. Rönnberg et al., 2011). These findings emphasise the intimate and obligate relationship between hearing and other cognitive phenomena (e.g. attention, memory, language, intelligence, executive function). Excluding children from a diagnosis of APD on the basis of cognitive difficulties, as previously advised (ASHA, 1996) is therefore likely to exclude those most in need of care. As outlined in section 2, the high co-occurrence of APD with other disorders underscores the importance of a multi- or interdisciplinary approach.

Individualised medicine has recently become a catch phrase to emphasise the genetic differences between us that are becoming accessible in the modern era of molecular medicine (Chen et al., 2012). Identifying specific deficits in subgroups of patients may help in the search for biomarkers of their clinical presentation. At the other end of methodology, as we catalogue individual gene variants contributing to aspects of central hearing pathology, so we can search for those variants in individual genomes. These developments may result in specific behavioural and acoustic interventions, or preventative treatments in the case of early, subclinical stages of APD (Ruan et al., 2014). For the moment, however, raising awareness of the need to tailor assessment and management to individuals should elevate the standard of care.

6. Final thoughts and the way forward

Individuals with APD typically report listening difficulties and other behaviours consistent with hearing loss, despite a normal audiogram. Although audiometric descriptors provide a useful summary of an individual's hearing thresholds, they should not be used as the sole determinant for the provision of hearing and/or listening support. The ability to detect pure-tones or speech using earphones in a quiet environment is not in itself a valid indicator of hearing and/or listening ability and audiometric descriptors alone should not be used as the measure of difficulty experienced with communication, particularly in background noise. Difficulties reported by individuals with APD typically include greater difficulty hearing in noise, mishearing speech, frequent requests for repetition, and poor attention to and/ or memory of auditory instructions. These individuals are currently not well supported in the UK.

The purpose of this document and our plans forward are to:

1. Generate further international dialogue and research.

2. Provide information to enable clinicians to make informed choices, based on current evidence. This document complements rather than replaces our existing documents, and will be updated as new evidence and consensus emerges.

3. Educate funders and professionals at a local and national level about APD, its nature, assessment and management, and simultaneously to develop national policy with respect to APD. APD is an area that straddles both health and education and consultation with the key stakeholders in both domains is essential. Additional stakeholders include caregivers and other members of the public, and professionals and researchers working in related fields of language, learning and cognitive function, paediatricians and GPs.

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