NEW ZEALAND GUIDELINES ON AUDITORY PROCESSING DISORDER

2019

NEW ZEALAND
Audiological
Society

Published by the New Zealand Audiological Society, 2019.

Citation: Keith, W. J., Purdy, S. C., Baily, M. R., & Kay, F. M. (2019). *New Zealand Guidelines on Auditory Processing Disorder*. New Zealand Audiological Society. https://www.audiology.org.nz/

This document is located on the New Zealand Audiological Society website under Menu/For the Public/Other Hearing Conditions/Auditory Processing Disorder or can be downloaded from the following link. NZ APD GUIDELINES 2019

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LIST OF ABBREVIATIONS

AAA	American Academy of Audiology
ABR	auditory brainstem response
ACPT	Auditory Continuous Performance Test
ADD	attention deficit disorder
ADHD	attention deficit hyperactivity disorder
ADHD-RS-IV	ADHD-Rating Scale-IV
ADT	Auditory Discrimination Test (Wepman)
AEP	auditory evoked potential
AGREE II	Appraisal of Guidelines for Research & Evaluation II
AIT	Auditory Integration Training
ANSD	auditory neuropathy spectrum disorder
ANSI	American National Standards Institute
AoDC	Advisor on Deaf Children
APD	auditory processing disorder
APDNZ	Hear for Families – APDNZ (support group)
APDQ	Auditory Processing Domains Questionnaire
AR	acoustic reflex
ARIA	Auditory Rehabilitation for Interaural Asymmetry
ASA	Auditory Skills Assessment
ASD	autism spectrum disorder
ASHA	American Speech-Language-Hearing Association
ASSW	Australian Staggered Spondaic Word Test
ATC	Assistive Technology Coordinator
ATTR	Adaptive Tests of Temporal Resolution
BKB-SIN	Bamford-Kowal-Bench Speech-in-Noise test
BM-0ms	STAR2 Backward Masking (BM-0ms) Test
BSA	British Society of Audiology
CAEP	cortical auditory evoked potential
CANS	central auditory nervous system
(C)APD	(central) auditory processing disorder
CBAT	computer-based auditory training
CBCL	Child Behavior Checklist
CCC-2	Children's Communication Checklist-2
CELF-4	Clinical Evaluation of Language Fundamentals, Fourth Edition

CELF-5	Clinical Evaluation of Language Fundamentals, Fifth Edition
CELF-5 A&NZ	Clinical Evaluation of Language Fundamentals Australian and New Zealand, Fifth Edition
CELF-5 Screener	Clinical Evaluation of Language Fundamentals, Fifth Edition, Screening Test
CELF Preschool-2	Clinical Evaluation of Language Fundamentals: Preschool, Second Edition
CHAPS	Children's Auditory Performance Scale
CISG	Canadian Interorganizational Steering Group for Speech-Language Pathology and Audiology
COVD-QOL	College of Optometrists in Vision Development Quality of Life Questionnaire
CRPD	Convention on the Rights of Persons with Disabilities
CTOPP	Comprehensive Test of Phonological Processing
dB	decibels
dBA	decibels A-weighted
dB HL	decibels Hearing Level
dB SPL	decibels Sound Pressure Level
DDT	Dichotic Digits Test
DIID	Dichotic Interaural Intensity Difference
DM	digital modulation
DPOAE	distortion product otoacoustic emission
DPST	Duration Pattern Sequence Test
DPT	Duration Pattern Test
DSTP	Differential Screening Test for Processing
DWT	Dichotic Words Test
ECLiPS	Evaluation of Children's Listening and Processing Skills
FDT	Frequency Discrimination Test
FLE	Functional Listening Evaluation
FM	frequency modulation
FPT	Frequency Pattern Test
GIN	Gaps-in-Noise test
HL	Hearing Level
HINT-C	Hearing in Noise Test for Children
HEAR-QL	Hearing Environments and Reflection on Quality of Life Questionnaire
ICD	International Classification of Diseases
ICF	International Classification of Functioning, Disability and Health
IEP	Individual Education Plan
IQ	Intelligence Quotient
IVA CPT-2	Integrated Visual and Auditory Continuous Performance Test 2nd ed

LACE	Listening and Communication Enhancement
LI	language impairment
LIFE	Listening Inventories for Education
LiSN-S	Listening in Spatialized Noise-Sentences test
MBC	Motor Behavior Checklist
MLD	Masking Level Difference
MLR	middle latency response
MMS	Mortality and Morbidity Statistics
MoCA	Montreal Cognitive Assessment
MRC	Medical Research Council (UK)
MSSW	Macquarie Staggered Spondaic Word Test
MUSEC	Macquarie University Special Education Centre
N	number (of subjects)
NAL	National Acoustic Laboratories (Australia)
NFD	National Foundation for the Deaf
NMF	Number Memory Forward subtest (of TAPS-4)
NMR	Number Memory Reversed subtest (of TAPS-4)
NU-6	Northwestern University Auditory Test Number 6
NZ	New Zealand
NZAS	New Zealand Audiological Society
NZSTA	New Zealand Speech-language Therapists' Association
PB	phonetically balanced
PEST	parameter estimation by sequential tracking
PIPA	Preschool and Primary Inventory of Phonological Awareness
PPS	Pitch Pattern Sequence test
PPS-A	Pitch Pattern Sequence test – Adult Version
PPS-C	Pitch Pattern Sequence test – Child Version
PSI	Pediatric Speech Intelligibility test
QuickSIN	Quick Speech in Noise test
QUIL	Queensland University Inventory of Literacy
RASP	Rapidly Alternating Speech Perception
RD	reading disorder
RDDT	Randomized Dichotic Digits Test
RGDT	Random Gap Detection Test
RM	remote microphone
RMHA	remote microphone hearing aid/remote microphone hearing aid system
RTLB	Resource Teacher for Learning and Behaviour

SCAN	SCAN Test for Auditory Processing Disorders
SCAN-3:A	SCAN-3 for Adolescents & Adults
SCAN-3:C	SCAN-3 for Children
SENCO	Special Education Needs Coordinator
SIFTER	Screening Instrument for Targeting Educational Risk
SNR	signal to noise ratio
SPELD	SPELD NZ organisation
SPL	Sound Pressure Level
SSI-CCM	Synthetic Sentence Identification-Contralateral Competing Message
SSI-ICM	Synthetic Sentence Identification-Ipsilateral Competing Message
SSQ	Speech, Spatial, and Qualities of Hearing Scale
SSW	Staggered Spondaic Word test
STAR	System for Testing Auditory Responses
TAPS-4	Test of Auditory Processing Skills–4
TAPS-R	Test of Auditory Perceptual Skills-Revised
TCST	Time Compressed Sentence Test
TEA-Ch	Test of Everyday Attention for Children
TEAP	Teacher Evaluation of Auditory Performance
TONI-4	Test of Nonverbal Intelligence – Fourth Edition
TOVA	Test of Variables of Attention
TRF	Teacher Report Form
UCAPI	University of Cincinnati Auditory Processing Inventory
UCAST-FW	University of Canterbury Adaptive Speech Test-Filtered Words
UK	United Kingdom
UQUEST	University of Queensland Understanding Everyday Speech Test
US	United States of America
VA	Veterans' Administration
WHO	World Health Organization
WIN	Words in Noise test

SUMMARY

These Guidelines are intended to provide guidance to clinicians, public agencies, the wider community of professionals who need to know about auditory processing disorder (APD), and people with APD and their families.

APD is a generic term for hearing disorders that result from atypical processing of auditory information in the brain. APD results in persistent limitations in the performance of auditory activities with resultant significant consequences for participation. The symptoms of APD bear many similarities to other types of hearing disorder, but APD differs in that it is not detected by standard audiometric assessments. The overall prevalence in children in New Zealand (NZ) is estimated at 6.2%, with higher rates in some populations, particularly the elderly. APD affects academic achievement, participation, career opportunities and psychosocial development.

APD should be suspected when there are reports of poor hearing and auditory comprehension in some circumstances despite normal pure tone hearing test results. Checklists of symptoms and comorbidities provide a simple and effective method of identifying children and adults who should be referred for diagnostic assessment.

APD frequently co-occurs with other learning or developmental disabilities. It is recommended that children with dyslexia, language disorder, disorders affecting the brain, significant history of middle ear disease, autism spectrum disorder and reading difficulties are referred for APD assessment. Referral is also recommended for children with attention deficit disorder/attention deficit hyperactivity disorder (ADD/ADHD) if listening concerns persist after treatment.

A diagnosis of APD is made by an audiologist using specific audiological tests. Although evidence of APD can sometimes be observed in electrophysiological studies and confirmation of APD is being investigated using imaging studies, behavioural tests are typically used for diagnosis. Tests suitable for use in New Zealand are recommended in the Guidelines. Recommended diagnostic criteria are also presented.

Screening or assessment of cognitive and language abilities, usually by psychologists and speech-language therapists respectively, is highly recommended before a diagnosis of APD is confirmed. In the absence of such assessments audiologists can administer screening tests of language and cognition.

Early detection of auditory processing difficulties and subsequent early intervention are recommended. These Guidelines encourage APD testing below the traditional age of seven years, using validated assessment tools that have been developed for younger children. In cases where a formal diagnosis is not possible because of age, intervention may still be warranted. Similarly, in the presence of comorbidities and peripheral hearing loss, audiologists with relevant experience can frequently deduce some meaningful conclusions about auditory processing ability and suitable interventions

Management is a multidisciplinary process involving audiologists, speech-language therapists, hearing therapists, teachers, learning support personnel, psychologists and potentially a variety of other professionals depending on the individual's specific requirements. Management should also include referral to other specialists when required, provision of information, and information about support organisations. As the professionals responsible for diagnosing APD and initiating treatment, it is recommended that audiologists take the lead role in APD case management.

Management of APD includes treatment, further referral if required, and the provision of information and support. The three main recommended approaches to treatment are auditory training with selected evidence-based programmes, amplification with remote microphone hearing aid systems[1] (RMHAs) and language therapy including phonological processing therapy. The merits of other approaches are also discussed in the Guidelines. Treatment progress may be slowed or limited by the presence of comorbid conditions.

The evidence base supports an initial treatment approach that is "bottom-up", concentrating first on improving the hearing. Treatments provided by

1. See Amplification/Terminology section for definition.

audiologists include auditory training and fitting of amplification. Through neuroplasticity, auditory training and amplification can engender permanent improvements in auditory skills.

Amplification with RMHAs over a period of time can facilitate improved attention, participation, academic achievement, phonological awareness, reading and social adjustment, and is associated with permanent improvement in hearing abilities in a number of studies (measured without RMHAs being worn). It is recommended that the fitting and verification of RMHAs is always carried out by a qualified audiologist with real ear measurement equipment and functional (behavioural) verification of fittings, and that fittings are reviewed annually. Binaural RMHA fittings are strongly recommended. Support from Advisors on Deaf Children or other education personnel trained in APD is a critical factor in achieving success with the use of remote microphone technology in schools.

Bottom-up treatment is supplemented by top-down interventions. Top-down treatments including language therapy are usually provided by speech-language therapists or by support personnel guided by a speech-language therapist. Treatment focussed on recognition and discrimination of phonemes may be offered by a range of professionals. Metacognitive strategies to enhance the coping resources of the individual may be provided by speech-language therapists, psychologists or other intervention specialists. Home training with selected software programmes, under clinical guidance, can supplement other therapies.

It is important to look at the wider context of a person's functioning in their own environment in assessing the effect of APD on an individual and deciding how best to manage it. There is a need for measures of functional hearing ability, as distinct from diagnostic APD tests, to measure degree of hearing difficulty in realistic everyday life listening and learning situations, to assess performance before and after treatments, and to focus management on enabling people with APD to participate fully in their own lives and in society.

PURPOSE OF GUIDELINES

The purpose of these Guidelines is to provide practical guidance for clinicians and education personnel providing APD services, and information for the wider community involved with people with APD. In particular, the Guidelines are intended to inform service development and policy for public agencies such as the Ministries of Health and Education. They are intended to provide specific guidance to audiologists, speech-language therapists, psychologists and learning support personnel directly involved in the identification, referral, diagnosis and/or management of children with suspected APD.

The Guidelines are also intended to provide useful information to people with APD, or their parents/caregivers in the case of children. The intended audience therefore comprises parents of children with APD, adults with APD, consumer support groups, public agencies, audiologists, speech-language therapists, teachers, learning support personnel, hearing therapists, psychologists, otologists, paediatricians, general practitioners, and anyone else involved with people with APD.

The Guidelines address the following questions:

- What are evidence-based tests suitable to comprise age-appropriate test batteries to diagnose APD in New Zealand children and adults?
- What are recommended tools suitable for the comprehensive evaluation of children with APD encompassing language, cognitive, classroom performance and any other factors affecting their functional ability?
- What are evidence-based treatment methods suitable for inclusion in the management of New Zealand children and adults with APD?
- Who, in the New Zealand context, should provide APD services?

Issues of cost, funding, access and barriers to service which exist in New Zealand are not addressed in these clinical Guidelines. These have been documented in the Ministry of Health review: "Auditory Processing Disorder: New Zealand Review" (Esplin & Wright, 2014) and are the subject of policy review by the Auditory Processing Disorder Reference Group (APD Reference Group). The APD Reference Group requested completion of these Guidelines before addressing these policy issues. Nonetheless the recommendations are practical and can be easily implemented in existing clinical practices. Other than the purchase of some tests, treatment tools and minor additional equipment, there are minimal costs to implementing recommendations. Restrictions on public funding of amplification devices remains a barrier to treatment for some consumers.

It is recommended that these Guidelines be reviewed on a four-year cycle by the New Zealand Audiological Society in consultation with other stakeholders.

AUTHORSHIP AND METHODOLOGY

Auditory Processing Disorder Reference Group

This document has been prepared by a subcommittee of the Auditory Processing Disorder Reference Group (APD Reference Group) in consultation with the Ministries of Education and Health and the New Zealand Audiological Society (NZAS). The APD Reference Group was established by the Ministries of Education and Health in response to a recommendation of the Sapere report "Auditory Processing Disorder: New Zealand Review" (Esplin & Wright, 2014) commissioned by the Ministries of Health and Education. Past and present members of the Auditory Processing Disorder Reference Group are listed below.

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Leonie Wilson MA (Psychology); Chair, Hear for Families APDNZ – consumer and parent representative

Craig O'Connell; independent facilitator

The backgrounds of the reference group members included audiology, speech language therapy, psychology, special education and learning support, teaching, assistive technology, research, human rights advocacy and public policy. The group membership included two consumer representatives – one adult with APD and one parent of children with APD.

Conflicts of interest are listed at the end of the document in Appendix 1.

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Wayne Wilson PhD, MAudSA CCP, Associate Professor, Head of the Discipline of Audiology, School of Health and Rehabilitation Sciences, University of Queensland, Australia

Methodology

Methods

The document was written by the author sub-committee drawing on their combined databases of APD research articles, supplemented by literature searches of specific topics.

Literature searches on auditory processing tests were carried out using online databases (including Medline, PubMed, PsychINFO, Google Scholar, ScienceDirect, Scopus, Web of Science Core collection, PyscBOOKS), and supplemented by communication with original authors in some cases. A database (Appendix 4) was compiled evaluating tests against the following criteria: validity, test-retest reliability, ages pertaining to norms, sensitivity, specificity, clinical acceptability, published studies and limitations. The author sub-committee reviewed all of the tests evaluated and selected recommended tests for use in New Zealand (Table 3). Essential inclusion criteria to qualify for selection for Table 3 were: Standardised tests supported with published studies showing good psychometric properties and appropriate norms, evaluated on groups of individuals with diagnosed or suspected APD, practical to administer and accessible and affordable for clinical use in New Zealand.

Recommendations

Key points and recommendations were identified by authors and additionally reviewers and are highlighted throughout the document. The evidence base for recommendations is reported.

Applicability of recommended tools

All recommended tools were considered and selected by the author sub-committee as being practical, straightforward to implement and suitable for use in New Zealand. Most if not all of the tests, treatments and other evaluations recommended in this document have been or are currently used in some clinics and research projects in New Zealand. The recommended diagnostic criteria have been piloted by two clinics.

Reviewer and stakeholder input

The Guidelines were released in draft form in April 2017 and were extensively revised following feedback from reviewers and stakeholders.

The draft Guidelines were reviewed by members of the full APD Reference Group.

The draft Guidelines were distributed for review to the Ministry of Education (including Advisors on Deaf Children), the Ministry of Health (including their resident paediatrician/Adviser on Child and Adolescent Health), the memberships and executive bodies of the New Zealand Speech-Language Therapists' Association and the New Zealand Audiological Society, University Audiology programmes, Life Unlimited (hearing therapists) and consumer organisations (Hear for Families APDNZ and National Foundation for the Deaf). Hear for Families APDNZ engaged a group of parents of children with APD to provide feedback. Multiple consequent recommendations from organisations and individuals have been incorporated into the final document.

The draft Guidelines were reviewed by four international peer reviewers in the UK, USA, Canada and Australia, and the revised version following their recommendations and other changes was resubmitted to them and approved.

Risks and side effects

Side effects and risks were considered. All of the recommended tests are typical of commonly-used audiological tests and the stimulus intensity levels are safe. Similarly the recommended treatments are consistent with common clinical practice, use safe sound output levels and carry minimal risk when implemented correctly in accordance with relevant guidelines and protocols.

KEY POINTS AND RECOMMENDATIONS

Key points and practical suggestions about methods or tools suitable for use in New Zealand are highlighted in inserts throughout this document.

- *Recommendations are also highlighted.*

Editorial independence and funding

The work on these Guidelines has been mostly voluntary. Some funding was provided by the Ministry of Education and NZAS to cover remuneration for the work carried out by Rose Kalathottukaren (Ministry of Education) and a portion of the work carried out by Melissa Baily (Ministry of Education and NZAS). The design and formatting for publication was financially supported by the M G Martin Charitable Trust. The author sub-committee had full editorial independence, and the views and interests of the funding bodies have not influenced the final recommendations other than through the broad process of stakeholder input.

Methodological quality

The methodological quality of the final document was appraised using the Appraisal of Guidelines for Research & Evaluation II (AGREE II) protocol by experts in evaluation of guidelines in the USA. Helpful advice was provided by the US group after a preliminary evaluation of an early draft. This Guidelines document is rated as “Highly recommended”, indicating that it meets criteria for both consensus and evidence-based documents.

ACKNOWLEDGEMENTS

These Guidelines would not have eventuated without the initiative of the Ministry of Education and Ministry of Health to review APD services nationally and establish the APD Reference Group. The authors also wish to acknowledge with gratitude the support and active participation of both Ministries throughout the preparation of this document.

The invaluable input from the four international peer reviewers, Drs Doris-Eva Bamiou, Benoît Jutras, Robert Keith and Wayne Wilson, is acknowledged with gratitude.

Rose Thomas Kalathottukaren PhD, University of Auckland, is acknowledged for her work in compiling the information on APD tests in the tables and Appendix 4.

The M G Martin Charitable Trust is gratefully acknowledged for financial support for the design and formatting of this publication.

The Ministry of Education is gratefully acknowledged for funding of the work carried out by Rose Kalathottukaren.

The Ministry of Education and NZAS are gratefully acknowledged for funding of a portion of the work carried out by Melissa Baily.

The authorship subcommittee is grateful to all members of the APD Reference Group for their input and oversight of this document.

This document quotes from and builds on four international guidelines:

- (Central) Auditory Processing Disorders Technical Report, American Speech-Language-Hearing Association (ASHA) (ASHA, 2005)
- American Academy of Audiology (AAA) Guidelines for the Diagnosis, Treatment and Management of Children and Adults with Central Auditory Processing Disorder (AAA, 2010)
- Practice Guidance: An overview of current management of auditory processing disorder (APD), British Society of Audiology (BSA) (BSA, 2011)
- Canadian Guidelines on Auditory Processing Disorder in Children and Adults: Assessment and Intervention, Canadian Interorganizational Steering Group for Speech-Language Pathology and Audiology (CISG) (CISG, 2012).

Reference is also made to the:

- National Acoustic Laboratories (NAL) Position Statement on Auditory Processing Disorders, NAL, Australia (Dillon & Cameron, 2015).

These Guidelines are also largely consistent with a more recently published European consensus document:

- "European perspective on auditory processing disorder – Current knowledge and future research" (Iliadou, et al., 2017).

INTRODUCTION

INTRODUCTION

Auditory processing occurs at all levels of the auditory system. The term central auditory processing disorder (CAPD) is used in some documents (ASHA, 2005; AAA, 2010) with the intention of more precisely denoting processing in the central auditory nervous system (CANS). In 2016 the term CAPD was recognised with a US International Classification of Diseases (ICD) code, ICD-10 H93.25 (Iliadou, Sirimanna, & Bamiou, 2016), and is also included in the ICD-11 MMS (Mortality and Morbidity Statistics) beta version in section AB5Y[2]. The abbreviated term APD is also commonly used to refer to auditory processing in the CANS. The current understanding of the auditory brain is that there is no clear boundary between central and peripheral auditory function because efferent signals from the brain modulate outer hair cell activity in the inner ear (cochlea), changing the response of the cochlea and consequently changing the afferent input from the cochlea to the brain. There is also evidence for impaired efferent function in people with APD, although this is not consistent across studies (Pavlich et al., 2013). The distinction between central and peripheral auditory function is further challenged by research showing altered central processing associated with poor temporal coding at the level of the auditory nerve, despite the presence of normal hearing thresholds. In some cases temporal dys-synchrony in the CANS may arise from encoding problems at the level of primary auditory neurons (Bharadwaj, Masud, Mehraei, Verhulst, & Shinn-Cunningham, 2015). For reasons such as this, use of the term "central" was not recommended by the Consensus Conference on the Diagnosis of Auditory Processing Disorders in School-Aged Children (Jerger & Musiek, 2000). APD has become the preferred term in New Zealand but common international usage may yet revert to CAPD.

The Canadian Guidelines (CISG, 2012) emphasise the importance of assessing the functional impact of auditory processing disorder on an individual's ability to function in the context of their broader capabilities and their own environment. The Canadian document therefore adopts the World Health Organization (WHO) International Classification of Functioning, Disability and Health (ICF) approach (WHO, 2002) (see Figure 1).

> *The ICF has functional health as its primary focus, and emphasizes the importance of the interaction between an individual's health conditions or status, and the contextual factors around him/her. This report is based on a perspective that shifts the focus from cause to impact, from biological dysfunction to an individual's ability to participate fully in his/her own life and in society; it emphasizes the importance of thinking about auditory processing as a part of the construct of cognitive hearing science, which considers the interaction between hearing and cognition. (CISG, 2012, p. 5)*

> *The ICF allows us to consider auditory processing within a framework that considers both the clinical manifestations of a presumed underlying auditory system abnormality, and the ways in which these difficulties are exacerbated or ameliorated by environmental and personal factors. It provides a framework within which to consider the assessment findings, and to choose appropriate recommendations. (CISG, 2012, p. 8)*

2 The ICD-11 MMS (Mortality and Morbidity Statistics) beta version was released by the World Health Organization (WHO) in 2018 (https://icd.who.int/browse11/l-m/en, download date 6/3/19).

ICF FRAMEWORK

The ICF Framework provides a functional impact perspective that is helpful in considering APD.

This emphasis on the functional impact of the disorder provides a useful framework to adopt when diagnosing and managing APD (Figure 1). Functional impact within the ICF framework is described in terms of activity and participation which are defined as follows (WHO, 2002):

> ***Activity*** *is the execution of a task or action by an individual.*
>
> ***Participation*** *is involvement in a life situation.*
>
> ***Activity Limitations*** *are difficulties an individual may have in executing activities.*
>
> ***Participation Restrictions*** *are problems an individual may have in involvement in life situations.*
>
> *(WHO/EIP/GPE/CAS/01.3 Original: English Distr.: General. Towards a Common Language for Functioning, Disability and Health ICF World Health Organization Geneva 2002 http://www.who.int/classifications/icf/training/icfbeginnersguide.pdf)*

In this document "hearing disorder" refers to an impairment diagnosed using specified criteria, "hearing deficit" refers to a specific physiological problem with demonstrated poor performance on an auditory task, and "hearing difficulty" refers to functional disability (activity limitations and participation restrictions) and observed listening problems.

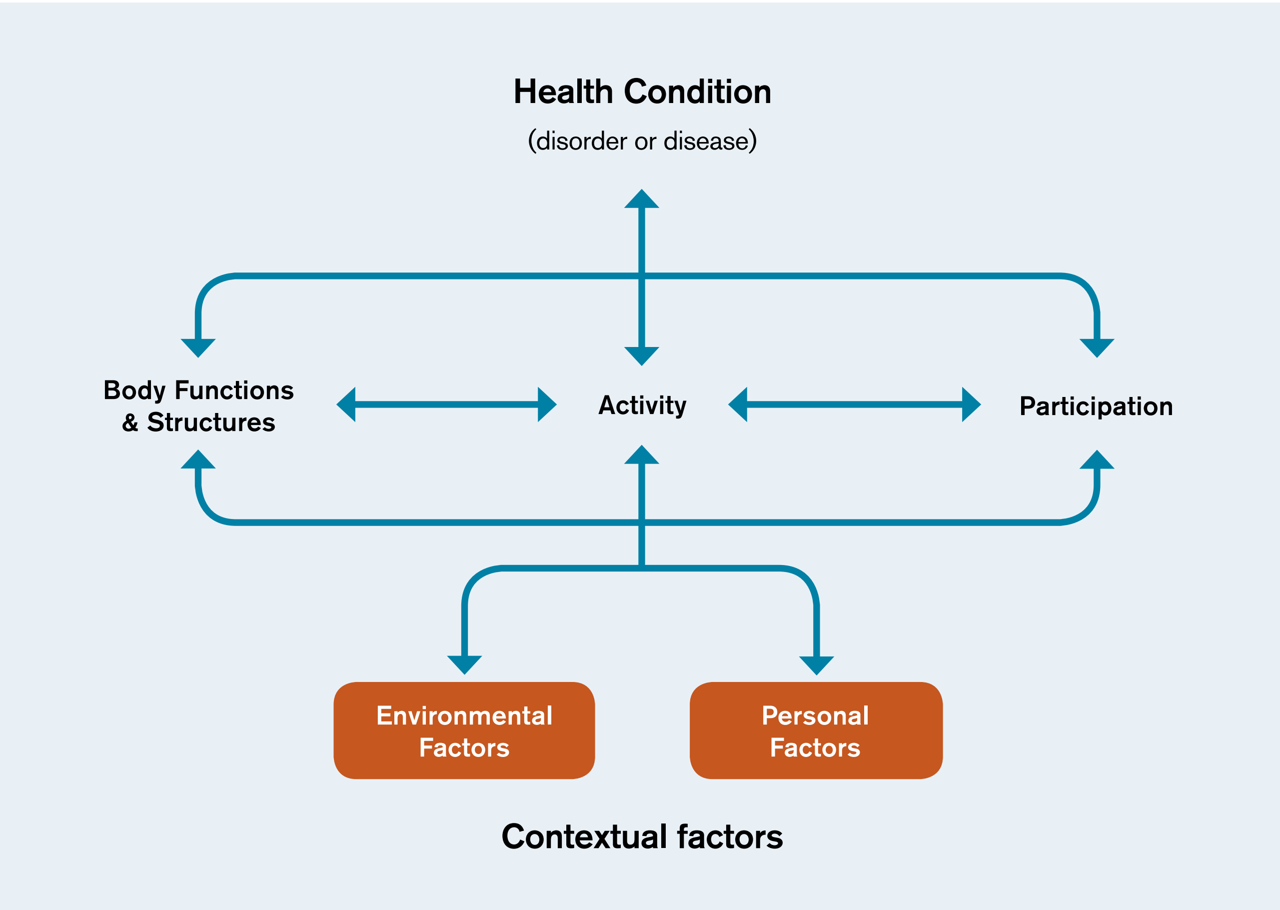

Figure 1: Diagrammatic representation of the model of disability that is the basis for the ICF (from WHO, 2002, p. 9)

The ICF framework is complemented by the United Nations Convention on the Rights of Persons with Disabilities (UN CRPD) which provides a human rights based model, in which disability "is seen as the result of an unwelcoming environment that prevents people with disabilities from living their lives as other people can... It recognises the innate potential and inherent dignity of persons with disabilities and emphasises addressing barriers to an inclusive society." (The International Federation of Hard of Hearing People United Nations Convention on the Rights of Persons with Disabilities Implementation Toolkit, Carroll & Warick, 2013 p. 8). The CRPD Articles apply to all people with disabilities and address such rights as independence, non-discrimination, awareness of the disorder, access to education and health services, access to treatment and equipment, and participation in work and leisure activities. Relevant Articles from the UN CRPD are noted in a later section. Professionals need to keep these principles in mind when working with people with APD, and recognise that the ultimate goal is to support the person to achieve a life of dignity.

A multidisciplinary approach is required for effective assessment and management of APD. Input from speech-language therapists and psychologists is especially helpful for some of the pre-assessment evaluations. Speech-language therapists are essential for provision of some of the treatments, and Advisors on Deaf Children (AoDCs) or other learning support personnel with training in APD are essential for liaison with schools and for parent and teacher guidance, especially when amplification is fitted. Depending on comorbidities and a client's needs, other specialists may also need to be involved. An APD assessment may sometimes lead to referrals for additional assessments, e.g. cognition and language. Parents and teachers have a key role in management. It is also important that families are offered the opportunity to connect with APD family support networks. As the professionals responsible for diagnosing APD and initiating treatment, it is recommended that audiologists take the lead role in APD case management.

MULTIDISCIPLINARY APPROACH

A multidisciplinary approach is required for effective assessment and management of APD.

- *It is recommended that audiologists take the lead role in APD case management.*

BACKGROUND

BACKGROUND

Definition of auditory processing disorder

The following definition is adapted from the definition in the Canadian Guidelines (CISG, 2012). The Canadian definition adopts the ICF approach which considers activity and participation limitations.

Auditory processing disorder is a generic term for hearing disorders that result from atypical processing of auditory information in the brain. Auditory processing disorder is characterised by persistent limitations in the performance of auditory activities and has significant consequences for participation.

Nature of auditory processing disorder

Individuals with APD may have normal pure tone audiometric thresholds but to refer to them as having "normal hearing", as often occurs, is inaccurate. They may have normal "audiometric thresholds" or a "normal pure tone audiogram" but by definition they will demonstrate reduced hearing ability on some other measures of hearing. The preferred term (rather than "normal hearing") that has been adopted by the international Pathways APD Group (Phoenix, 2016) is "normal hearing sensitivity for pure tones".

The National Acoustic Laboratories (NAL) Position Statement on Auditory Processing Disorders states:

1. *An Auditory Processing Disorder (APD) is a deficit in the way the neural representation of sounds is processed by the brain, resulting in a distorted neural representation of the auditory signal within the auditory nervous system.*
2. *APD creates difficulty in listening (i.e. hearing with intent to extract information).*
   (Dillon and Cameron, 2015)

From a practical point of view APD usually refers to hearing disorders arising in structures from the cochlear nuclei of the brainstem and higher in the CANS. Other guidelines point out the complexity and non-modularity of these central structures.

The AAA Guidelines state:

> *The processing of auditory information within the central nervous system is quite complex, involving both serial and parallel processing within the auditory structures of the CANS itself, as well as shared processing with other sensory and/or higher order brain structures and systems (e.g., language, attention, and executive control). Given the organization of the central nervous system and the nature of processing, the behaviors, symptoms, and levels of impairment observed in individuals with (C)APD are often quite diverse and are by no means homogenous. Since the brain is non-modular, with many regions responsible for the processing of information from multiple sensory systems as well as higher order cognitive (e.g., attention, memory, etc.) and language functions (Ghazanfar & Schroeder, 2006), the behaviors and symptoms noted in individuals with (C)APD often overlap with those that are observed in individuals with other sensory and/or cognitive disorders. (AAA, 2010, pp. 6-7)*

DEFINITION OF APD

Auditory processing disorder is a generic term for hearing disorders that result from atypical processing of auditory information in the brain. Auditory processing disorder is characterised by persistent limitations in the performance of auditory activities and has significant consequences for participation.
(Adapted from Canadian Guidelines (CISG, 2012).

The ASHA Working Group observed that a requirement of modality-specificity (i.e., affecting audition only and no other senses such as vision) as a diagnostic criterion for APD is not consistent with how processing occurs in the brain. Neuroscience has shown that there are few if any entirely compartmentalised areas in the brain that are solely responsible for a sensory modality. Multimodality influences affect even the most basic neural encoding and manipulation of sensory stimuli. The ASHA Working Group concluded that any definition of APD that specifies complete modality-specificity as a diagnostic criterion is neurophysiologically untenable, and that APD is best viewed as a deficit in the neural processing of auditory stimuli that may coexist with, but is not the result of, dysfunction in other modalities (ASHA, 2005, pp. 4-5).

The Canadian Guidelines note a limitation of the current audiological test battery approach in that it focuses on identifying disconnected areas of difficulty whereas current evidence instead suggests that the brain is characterized by highly complex interactive networks (CISG, 2012, p. 6).

Causes

Some causes of APD are listed below:

- hereditary developmental abnormalities
- maturational delay
- antenatal, perinatal and postnatal factors including prematurity and low birth weight, prenatal anoxia, prenatal exposure to cigarette smoke or alcohol, hyperbilirubinemia
- diseases, toxins and neurological conditions affecting the brain including space-occupying lesions; Moyamoya disease and other cerebrovascular disorders; multiple sclerosis and other neurodegenerative diseases; bacterial meningitis; herpes simplex encephalitis; Landau Kleffner Syndrome and other seizure disorders; Lyme disease; metabolic disease; heavy metal exposure; solvent exposure
- traumatic brain injury
- blast injury
- auditory deprivation
- aging.

(Bamiou, Musiek, & Luxon, 2001; AAA, 2010, p. 13; Witton, 2010)

There is growing evidence, some from animal research, indicating that auditory deprivation secondary to otitis media during critical early developmental periods can result in central auditory deficits (Caras & Sanes, 2015) including amblyaudia (Whitton & Polley, 2011; Kaplan et al., 2016). Amblyaudia is larger than normal interaural asymmetry together with normal performance in the dominant ear on dichotic testing (Moncrieff & Wertz, 2008; Moncrieff, Keith, Abramson, & Swann, 2016). Interaural asymmetry with a right ear advantage is typical in young children, and may reappear in older adults (Roup, Wiley, & Wilson, 2006). Hence, amblyaudia is diagnosed by comparing interaural asymmetry to age norms. Binaural speech discrimination in competition and spatial listening ability have also been shown to be significantly impaired in children with a past history of otitis media compared to a control group of children with no middle ear history (Tomlin & Rance, 2014). In an animal model, occlusion of one ear (creating a conductive hearing loss) led to atypical suppression of neural activity from that side by neural activity in the non-occluded ear (Popescu & Polley, 2010).

APD is experienced by more than 50% of adults and children who have sustained traumatic brain injury (TBI) (Bergemalm & Lyxell, 2005; Flood, Dumas, & Haley, 2005). The Canadian Guidelines report that in the United States the number of individuals with possible traumatic brain injury induced APD has increased as significant numbers of veterans (10–20%) have returned home from overseas service with head injuries and/or blast injuries (Fausti, Wilmington, Gallun, Myers, & Henry, 2009; Martin, Lu, Helmick, French, & Warden, 2008; Okie, 2005; CSIG, 2012, p. 14).

Other causes of acquired brain injury such as stroke are also associated with auditory processing deficits, presumably when auditory cortical or subcortical areas are affected, resulting in slower cortical auditory evoked responses and impaired performance on behavioural temporal auditory processing tasks (Bamiou et al., 2006; Purdy, Wanigasekara, Cañete, Moore, & McCann, 2016; Szelag et al., 2014).

Aging is also a significant cause of APD.

> *Evidence of age-related changes is noted beyond the cochlea, throughout the brainstem and into the auditory cortex. A loss of neural synchrony is considered another influential change that occurs as age affects auditory processing … Depending on stimulus parameters, such as frequency, intensity, or spatial location, auditory neurons are either excited or inhibited. Older adults show a lack of inhibition…*

and decrease in excitatory synchronization … resulting in the degradation of neural coding throughout the central auditory nervous system. (Tun, Williams, Small, & Hafter, 2012)

Prevalence

The prevalence of APD in children has been estimated at 2-7% in US and UK populations (Chermak & Musiek, 2007; Bamiou et al., 2001). Musiek, Gollegly, Lamb, & Lamb (1990) estimate that 3-7% of school-aged children have learning disabilities, and that a major portion of this number would also have APD. Brewer et al. (2016) state that APD prevalence in children may be approximately 10% taking into account comorbidity with other developmental disorders with which APD occurs. Hind et al. (2011) found that 5.1% of children referred to an audiology service for hearing testing had normal pure tone audiograms and were thus suspected of having APD[3].

Skarzynski et al. (2015) cite a prevalence of 9-11% using the Dichotic Digits Test (DDT) (Musiek, Gollegly, Kibbe, & Verkest-Lenz, 1991) on 76,429 children as a screen for APD. In a sample of 396 school children Moloudi, Rouzbahani, Rahbar, & Saneie (2018) measured suspected APD prevalence in 8-12 year old children in Iran as 9.8% based on data from an APD questionnaire validated against two tests of auditory processing. The Sapere Report (Table 1, p. 29 "Auditory Processing Disorder: New Zealand Review") (Esplin & Wright, 2014) estimates overall New Zealand childhood prevalence at 6.2%, http://www.health.govt.nz/publication/auditory-processing-disorder-new-zealand-review). It should be noted that diagnostic criteria for APD differed across these prevalence studies.

APD prevalence has been measured at higher levels in certain populations such as children in Pacific Island families in Auckland (34%) (Purdy et al., 2012) and adjudicated adolescents in a US juvenile detention centre (72% based on screening tests) (Moncrieff, Demarest, Mormer, & Littlepage, 2014). In New Zealand APD was diagnosed in 27% of a group of 33 male youth offenders and remandees aged 14-17 (Lount, Purdy, & Hand, 2017).

In the elderly, APD prevalence is seen to increase with age. Cooper and Gates (1991) report 23% prevalence in 1026 members of the Framingham Heart Study cohort aged 64-93 years. Stach, Spretnajak and Jerger (1990) reported 61% prevalence in adults aged 75-79 years, and 72% prevalence in those aged 80 or over. Ageing is associated with loss of hearing sensitivity (presbycusis) as well as changes in cognitive and central auditory processes. Humes (2012) reviewed the evidence and concluded that:

…interactions between cognitive and central auditory processing can be expected to be quite common among older adults. To the extent that cognitive elements, such as executive function (e.g., short term memory, attention, inhibition, arousal), play a role in speech understanding in competing stimuli by older adults, the distinction between auditory, central auditory, and cognitive factors is further blurred. (Humes, 2012, p. 638)

Behavioural manifestations

Behaviours in children and adults with APD that may be reported and/or observed include, but are not limited to, the following:

- difficulty following multiple or lengthy oral instructions
- difficulty understanding speech in competition, for example, in the presence of competing messages, background noise
- difficulty hearing when a signal is not clear or is 'degraded' (for example, soft, rapid or distorted speech, accented speech, speech in reverberant environments, phone conversation)
- mishearing auditory information
- slowness in processing and responding to auditory information
- inconsistent or inappropriate responses to spoken requests for information
- frequent requests for repetition and/or rephrasing of information, saying "what" or "huh" often
- listening fatigue
- difficulty or inability to interpret prosody cues that underlie emotion, humour and shades of meaning in speech
- difficulty maintaining attention, poor listening skills,

3 Hind et al. (2011) attempted to estimate the prevalence of APD in the general population from numbers of children and adults referred for hearing testing. They measured the occurrence of those with hearing difficulties and normal pure tone audiograms (possible APD) to be 5.1% in children and 0.9% in adults referred for hearing assessment, leading to an estimated prevalence of APD of 0.5 – 1.0% in the general population.

tendency to be easily distracted
- poor auditory memory
- hyperacusis including reduced tolerance for noise and sensitivity to noise
- difficulty localising the source of a signal and tracking sounds.

(ASHA, 2005; AAA, 2010; Geffner, 2012; Campbell, Bamiou, & Sirimanna, 2012)

Secondary difficulties associated with APD may include:

- speech and language delay/disorder in children including difficulties with phonological and phonemic awareness
- academic difficulties, including reading, spelling and/or learning problems
- psychosocial difficulties
- exhaustion after school from listening effort.

(Campbell et al., 2012; Crandell, 1998; Kreisman, John, Kreisman, Hall, & Crandell, 2012; Esplin & Wright, 2014, p. 10; Lawton, Purdy, & Kalathottukaren, 2017)

This list is not exhaustive nor are these behavioural characteristics exclusive to APD (ASHA, 2005). Reported symptoms may be more revealing of the true functional impact of APD on an individual's daily life than the specific results of diagnostic APD testing (ASHA, 2005; Baran, 2007; Bellis, 2003; AAA, 2010). The effects of APD come to the forefront in complex listening environments and are not always easily observed in a clinical environment (CISG, 2012). Most individuals will present with some, but not all, of these symptoms. The AAA Guidelines state:

> *Since (C)APD involves many processes that are mediated at different levels of the CANS, it is unlikely that an individual will present with all of these behaviors or characteristics. Also, since there is considerable overlap in the behaviors or characteristics outlined above with those that are often associated with other cognitive, linguistic, or behavioral disorders, the manifestation of one or more of these behaviors does not necessarily indicate that the individual has a (C)APD. Many, if not most, of these behavioral manifestations and characteristics are not unique to individuals with (C)APD. These symptoms and/or behaviors may be attributable to another disorder or condition that may either be the aetiological basis for the individual's condition or which may coexist with (C)APD; therefore, the presence of one or more of these behaviors should only place the individual at-risk for (C)APD and not be treated as a definitive diagnostic indicator of (C) APD. (AAA, 2010, p. 9)*

Many studies have found that some children with APD have difficulty with speech perception in noise (Johnston et al., 2009, Hoen, Rogiers, & Mulder, 2010; Lagacé, Jutras, Giguère, & Gagné, 2011). In one study, however, children with APD appeared to perform as well in quiet and noise as mainstream children for certain stimuli and conditions (Ferguson, Hall, Riley, & Moore, 2011). Speech perception results are task- and stimulus-dependent. The effects of hearing disorders are more evident in children when they perform more cognitively demanding auditory comprehension tasks, rather than a simple recognition task (Lewis, Valente, & Spalding, 2015). Speech perception also varies greatly with the type of noise and few studies have attempted to replicate true classroom listening conditions for children (Lewis et al., 2015; Mealings, Buchholz, Demuth, & Dillon, 2015; Wilson et al., 2014).

The auditory environment of classrooms can be particularly difficult for children with APD. For effective classroom learning for typically developing children the signal to noise ratio (SNR) of the teacher's voice should be +15dB or better (ASHA, Guidelines for fitting and monitoring FM systems. 2002). The ANSI S12.60-2010 standard specifies that maximum reverberation times for kindergarten to Year 12 classrooms should be 0.6s for small classrooms (total volume < 283m^3) and 0.7s for moderate size classrooms (total volume 283-566m^3). However, many classrooms exceed this standard and hence personal amplification systems may be required for children with APD (Keith & Purdy, 2014). Background noise levels in kindergartens and classrooms in New Zealand and overseas frequently exceed 70 dBA when occupied (Whitlock & Dodd, 2006; Wilson et al., 2002; Wilson et al., 2011). The situation is exacerbated when traditional classrooms are replaced by large open plan "modern learning environments" with 60 or more students (Mealings et al., 2015; Shield, Greenland, & Dockrell, 2010).

Children with APD may be more disadvantaged at softer presentation levels than the average speech levels typically used in research studies. Typically developing children require higher speech presentation levels, lower levels of reverberation and better signal-to-noise ratios than adults in order to perceive speech as accurately as adults (Klatte, Lachmann, & Meis, 2010; Wróblewski, Lewis, Valente, & Stelmachowicz, 2012; Stuart, 2008). Speech perception ability improves with age during childhood (Leibold, 2017). Therefore, it follows that children who have APD associated with neuromaturational delay will need higher speech presentation levels and better acoustics to access speech signals as accurately as their peers. In a classroom environment, children with APD may require speech levels that are louder than found in typical classrooms in order to function optimally.

Speech perception in adverse listening conditions is strongly influenced by the linguistic background of the listener (Bidelman & Dexter, 2015; Von Hapsberg, Champlin, & Shetty, 2004). In a culturally diverse society linguistic background may add extra difficulty for some children.

Incorrect hearing of speech sounds may be a contributor to apparent auditory memory deficits in children with APD, dyslexia and autism spectrum disorder (ASD) (Hornickel, Zecker, Bradlow, & Kraus, 2012; Schafer et al., 2016). Similar findings are evident in children with sensorineural hearing loss (Bharadwaj, Maricle, Green, & Allman, 2015; Kronenberger, Beer, Castellanos, Pisoni, & Miyamoto, 2014). Jutras and Gagné (1999) showed evidence that, even with hearing aids, children with hearing loss performed more poorly than children with normal hearing on auditory sequential organization tasks. The poorer performance was attributed to their auditory deficits rather than poorer short term memory capabilities.

> *Impaired speech sound identification may contribute to impaired phonological awareness and memory skills, thought to be strong contributing factors to the poor literacy of children with dyslexia. (Hornickel et al., 2012)*

Untreated APD commonly leads to reduced communication (Smaldino & Crandell, 2004), which in turn can lead to a variety of psychosocial effects including loneliness, social anxiety, depression, anger and fear (Crandell, 1998; Kreisman et al., 2012). In a New Zealand study, Lawton et al. (2017) describe psychosocial effects of APD reported through child and parent interviews. This research highlights the need to develop pathways to support positive coping strategies to enable children living with APD to overcome problems and improve psychosocial well-being. An Australian study which interviewed young adults (18-30 years) who were earlier assessed for APD in childhood showed persisting listening and communication difficulties across a range of daily situations and lasting impacts on the participants' sense of self (Del Zoppo, Sanchez, & Lind, 2015). These studies of potential psychosocial consequences of APD highlight the need to consider the impact of APD more broadly.

APD may be persistent. Del Zoppo et al. (2015) showed that young adults with a diagnosis of APD as children continued to experience auditory processing difficulties across a range of daily situations. Padilla et al. (2015) found that 81% of children reassessed for APD several years later still had auditory processing deficits.

Comorbidities

APD frequently co-occurs with other learning or developmental disabilities. Sharma, Purdy and Kelly (2009) reported a high degree of comorbidity between APD, specific language impairment and reading disorders. Individuals with Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD) frequently exhibit auditory deficits (Schafer et al., 2013). Auditory processing deficits in individuals with ASD are more evident for complex auditory stimuli such as speech (O'Connor, 2012). APD also frequently co-occurs with dyslexia (Burns, 2013), and visual processing disorder (Dawes et al., 2009; Tu'i'onetoa, 2015). The BSA Practice Guidance document states:

> *APD is a collection of symptoms that usually co-occurs with other neurodevelopmental disorders. Like other such symptoms (poor language, literacy or attention, autism) APD is often found alongside other diagnoses. (BSA, 2011, p. 6)*

APD will often co-exist with attention, language and learning impairments as well as autism spectrum disorder. (BSA, 2011, p. 13)

COMORBIDITIES

APD frequently co-occurs with other learning or developmental disabilities.

Children with APD in clinical cohorts typically have high or average IQ (Sharma et al., 2009), but more assessment for children with other developmental disabilities such as ASD is advocated (Speech-Language and Audiology Canada, Position Statement 2018).

ADHD

Some symptoms of APD and ADHD may appear similar on casual observation but on closer attention are quite different. Chermak, Tucker and Seikel (2002) ranked the occurrence of key signs of APD and ADHD as shown in Table 1, with the ADHD rankings provided by paediatricians and the APD rankings by audiologists.

Table 1
Top Four Characteristics of ADHD and APD in Rank Order of Occurrence

ADHD	APD
Inattentive	Asks for things to be repeated
Academic difficulties	Poor listening skills
Daydreams	Difficulty following instructions given orally
Distracted	Difficulty hearing in background/ambient noise

Note. From Chermak, Tucker, & Seikel, 2002.

Speech, language and reading impairment, dyslexia

A large proportion of children with APD (47%) will have co-occurring language and reading difficulties (Sharma et al., 2009). Because research studies are typically cross-sectional and only examine performance at one point in time it is not possible to determine whether APD has caused language and reading difficulties in an individual case, or whether there is some other difficulty that accounts for all of these problems (Moore & Hunter, 2013). For example, differences in implicit and statistical learning (e.g., learning of the probability of auditory or phonological patterns) could be a common mechanism for variations in auditory and language processing across individuals (Bishop, Nation, & Patterson, 2014). Readers are referred to the chapter by Martha Burns (2013) in Auditory Processing Disorders: Assessment, Management and Treatment (2nd Edition), for a review of evidence linking language disorder, reading disorder and dyslexia to auditory processing deficits.

LANGUAGE AND READING IMPAIRMENT

- *It is recommended that children with suspected or diagnosed language impairment, reading disorder or dyslexia be referred for APD assessment and management.*

Burns (2013) states that auditory processing, language, and reading impairment are neurologically entwined. There is considerable research evidence that the underlying core deficit in many children with developmental dyslexia is a phonological processing deficit. It has been further hypothesised that an auditory processing deficit underlies the phonological processing impairment (Burns, 2013). Children with APD are likely to have poor phonological processing because of difficulties discriminating speech sounds. Children with dyslexia exhibit difficulty processing rapid spectro-temporal characteristics of phonemes (Burns, 2013), difficulties with slow auditory sampling (Goswami, 2011), and show poor consistency of the auditory brainstem response to speech stimuli (Hornickel et al., 2012). Because of limitations in the design of existing studies, underlying core deficits cannot be conclusively established for children with APD and comorbid conditions. However, central auditory deficits should be treated irrespective of whether or not they are associated with a comorbidity.

Deficits in speech in noise perception and temporal discrimination problems are associated with reading deficits and language delay in children (Burns, 2013).

> *Specifically, it appears that rapid auditory processing, at cortical and subcortical levels, represents a core component of phonological awareness. Rapid auditory processing deficits are correlated with problems in phonological decoding of words. ...the emerging neurophysiological longitudinal evidence points to temporal auditory processing disorders as at least one salient causative factor in some children who continue on to develop language problems and, because of the relationship between language and reading, reading problems as well. (Burns, 2013)*

There may be an association between APD and some cases of speech sound disorder. Barrozo, Pagan-Neves, Vilela, Carvallo, & Wertzner (2016) found that children with APD demonstrate greater frequency and severity of speech sound disorders than typically developing children.

It is recommended that children with suspected or diagnosed language impairment, reading disorder or dyslexia be referred for APD assessment and management.

Visual processing disorder

Due to overlap of sensory systems in the brain (AAA, 2010, pp. 6-7), children with APD may have comorbid visual processing disorder. This is a common clinical observation. Dawes et al. (2009) confirmed that children with APD may also have visual processing disorders. New Zealand data from 86 children aged 4-14 years with suspected or confirmed APD show significant correlations between TEAP (Teacher Evaluation of Auditory Performance) scores and COVD-QOL (College of Optometrists in Vision Development Quality of Life Questionnaire) scores (Tu'i'onetoa, 2015). The TEAP questionnaire evaluates teachers' perceptions of children's listening, auditory function (e.g., recall and reliance on visual cues) and speech/language. The COVD-QOL questionnaire assesses risk of developing visual disorders. The correlation between TEAP and COVD-QOL scores could reflect the difficulty that teachers are likely to have separating auditory from visual difficulties in the classroom, or comorbidity of auditory and visual processing disorder.

ASSESSMENT

ASSESSMENT

Screening and identification for referral

One challenge in identifying children with APD in the classroom is that their behaviours can appear to overlap those of children with other related conditions, though, as shown in the previous ADHD example (Table 1), differences often become clear on closer examination.

Questionnaires have been developed for children, teachers and parents to help identify everyday listening behaviours that are typical of APD. However, until recently (Barry, Tomlin, Moore, & Dillon, 2015), there has been no clear evidence validating most of them as screening tools.

> *While a number of questionnaires have been used to screen for (C)APD (Anderson & Matkin, 1996; Anderson & Smaldino, 1999, 2000; Fisher, 1976; Geffner & Ross-Swain, 2006; Kelly, 1995; O'Hara, 2007; Schow, Chermak, Seikel, Brockett, & Whitaker, 2006; Smoski, Brunt, & Tannahill, 1992; Willeford & Burleigh, 1985), they generally have poor specificity, tend to over-refer, and have not been validated. (AAA, 2010, p. 13)*

> *Research has indicated weak or no ability of screening questionnaires to predict auditory processing disorder, including instruments such as the Children's Auditory Performance Scale (CHAPS) (Drake et al., 2006; Lam & Sanchez, 2007; Wilson et al., 2011), the Screening Instrument for Targeting Educational Risk (SIFTER) (Wilson et al., 2011) and the Test of Auditory Perceptual Skills-Revised (TAPS-R) (Wilson et al., 2011). (CISG, 2012, p. 20)*

Recent evidence supports the use of certain questionnaires. The TEAP is a brief questionnaire that can be used by classroom teachers to screen for auditory processing difficulties (Barry et al., 2015; Purdy, Kelly, & Davies, 2002). Children can self-rate their listening difficulties using the LIFE (Listening Inventories for Education) or LIFE-R (Listening Inventory for Education – Revised) which also have a teacher version that can be used to evaluate the effects of amplification in the classroom (Anderson & Smaldino, 1999; Anderson, Smaldino, & Spangler, 2011; Arnold & Canning, 1999; Purdy, Smart, Baily, & Sharma, 2009). The LIFE-7 is a brief 7-item version of the LIFE child-report questionnaire, developed with New Zealand norms by Purdy, Sharma and Morgan (2018). A British questionnaire, the ECLiPS (Evaluation of Children's Listening and Processing Skills), has been developed using rigorous test development methods and may have some ability to distinguish between APD and other developmental disabilities (Barry & Moore, 2014). ECLiPS parent ratings for three subscales (Speech and Auditory Processing, SAP; Language/Literacy/Laterality, L/L/L; Memory & Attention, M&A) were correlated with dichotic and spatial listening APD test scores (Barry et al., 2015). The Auditory Processing Domains Questionnaire (APDQ, O'Hara, 2006; O'Hara & Mealings, 2018) was developed as a screening questionnaire for APD where parents or teachers rate students' listening skills. Scores calculated from three scales (auditory processing, attention and language) have been shown to significantly separate three clinical groups of children with APD, ADHD or learning disability (O'Hara & Mealings, 2018). On a cohort of school children in Iran, Moloudi et al. (2018) validated the APDQ against two tests of auditory processing and showed high specificity for the questionnaire. A questionnaire designed for adolescents and adults, the UCAPI (University of Cincinnati Auditory Processing Inventory), is currently being developed (Tektas, Ramsay, & Keith, 2017; Ramsay, Tektas, & Keith, 2017 ; Keith, Tektas, Ramsay, & Delaney, 2019) to look at current and past perceptions of listening difficulties.

Scores for the TEAP teacher-report questionnaire used in New Zealand and the LIFE-7 correlated well with the ECLiPS in Barry et al.'s (2015) validation study. Both the LIFE and the TEAP have good internal reliability (Barry et al., 2015). The TEAP, LIFE-7, APDQ and ECLiPS are all recommended as suitable for pre-assessment of referred children, and for pre- and post-treatment measurement in New Zealand.

Although the TEAP, LIFE and ECLiPS questionnaires all differentiated typically developing control children from children with suspected auditory processing difficulties, these questionnaires cannot be used as a tool to diagnose APD.

> *Behavioural checklists and questionnaires should only be used to provide guidance for referrals, for information gathering (for example, prior to assessment or as outcome measures for interventions), and as measures to describe the functional impact of auditory processing disorder, not for the purpose of diagnosing auditory processing disorder. (CISG, 2012, p. 20)*

Because APD is an umbrella term for a heterogeneous range of auditory processing deficits, by definition there cannot be a single screening test that reliably identifies children with APD versus other difficulties, unless it includes screening sub-tests for each auditory processing task included in a diagnostic test battery. Since the diagnostic test battery varies with age there would need to be age-specific screening sub-tests for each task category, or the screening test would have to be sensitive to all possible deficits at all ages. This is not currently possible.

The NAL Position Statement states in regard to the possibility of a single test to detect APD:

> *Because APD is an umbrella term for a number of separate deficits, it seems unlikely that there could be any single test that is sensitive to all deficits – either currently known or yet to be discovered – that could come under the term APD. (Dillon & Cameron, 2015)*

Test batteries intended for screening (e.g., Auditory Skills Assessment, Geffner & Goldman, 2010; SCAN3:C, Keith, 2009) may nonetheless be useful for audiologists in the assessment of young children to determine whether they may be at risk for a diagnosis of APD.

In place of a screening test battery or screening questionnaires, a simple and effective method of encouraging appropriate referral for APD assessment is to distribute and use checklists of key symptoms of APD, and to identify populations at risk for APD (Keith, 2015).

A checklist of key symptoms of APD or comorbidities that can be used to identify individuals who should be referred for APD assessment is shown following and is provided as a handout in Appendix 2.

IDENTIFYING APD

Checklists of symptoms and comorbidities provide a simple and effective method of identifying children and adults who should be referred for diagnostic assessment.

- *A recommended checklist is shown.*

Questionnaires can also be useful.

- *Recommended questionnaires suitable for identification of children for referral in New Zealand are the TEAP, LIFE-7, APDQ and ECLiPS.*

Symptoms of hearing or listening problems not consistent with results of basic hearing assessment:

- difficulty following spoken directions unless they are brief and simple
- difficulty attending to and remembering spoken information
- slowness in processing spoken information
- difficulty understanding in the presence of other sounds
- being overwhelmed by complex or “busy” auditory environments e.g., classrooms, shopping malls
- undue sensitivity to loud sounds or noise
- poor listening skills
- preference for loud television volume
- insensitivity to tone of voice or other nuances of speech.

Presence of other factors:

- brain injury
- neurological disorders affecting the brain
- history of frequent or persistent middle ear disease (otitis media, ‘glue ear’)
- difficulty with reading or spelling
- suspicion or diagnosis of dyslexia
- suspicion or diagnosis of language disorder or delay.

In New Zealand, schools may request a pure tone audiometry hearing and tympanometry screen from a Vision Hearing Technician for children with suspected hearing difficulties. If a child passes the hearing screening, and there are still concerns about hearing difficulties, the child should be referred for further assessment. If a child does not pass the hearing screening, it is policy to refer the child for audiometric assessment. APD assessment should be considered in all cases if a child's hearing difficulties cannot be fully explained by audiometric results, and other causes such as auditory neuropathy spectrum disorder (ANSD) have been ruled out.

Assessment for APD should be considered for adults with unexplained receptive communication difficulties and a normal pure tone audiogram (assuming ANSD has been ruled out), and adults with a peripheral hearing loss who have hearing difficulty disproportionate to their audiogram or who do not obtain expected benefit from amplification.

Pre-assessment information gathering and case history

In addition to the case history, information from other sources, where available, can be helpful in understanding a client's hearing difficulties.

Preliminary information

Reports of other relevant assessments, for example educational psychology or speech and language in the case of a child, should be requested as they can be informative in elucidating the client's difficulties and possible comorbidities.

Questionnaires can make a useful contribution to clinical management by providing background information and measuring performance pre- and post-treatment. Parents, and teachers in the case of school age children, can be invited to fill out questionnaires, prior to an assessment, on auditory behaviour and classroom performance.

BACKGROUND INFORMATION

A comprehensive case history, pre-assessment questionnaires, reports of other relevant assessments and direct observation can all be helpful in understanding a client's hearing difficulties.

- *Recommended pre-assessment questionnaires suitable for use in New Zealand include the TEAP, LIFE-7, APDQ, ECLiPS and SIFTER.*
- *The TEAP plus Question 1 of the SIFTER is recommended for routine use with children.*

Older children and adults can be asked to fill out self-report questionnaires. Questionnaires used in New Zealand are the CHAPS (Smoski et al., 1992), SIFTER (Anderson, 1989; Anderson & Matkin, 1996), the LIFE-7 (Anderson & Smaldino, 1999; Barry et al., 2015; Purdy et al., 2009; Purdy et al., 2017) and the TEAP (Purdy et al., 2002; Barry et al., 2015). The limitations of the CHAPS and SIFTER as screening tools for identifying APD have been noted in the previous section on Screening. However, in the context of providing background information the SIFTER is useful as it includes the teacher's assessment of a child's academic standing relative to their peers. This is especially helpful if information about cognitive ability is not available. The SIFTER has moderate reliability and examines Academics, Attention, Communication, Participation and Behaviour (Damen, Langereis, Snik, Chute, & Mylanus, 2007). Question 1 in the SIFTER, which asks about academic standing ("What is your estimate of the student's class standing in comparison to that of his/her classmates?") also has good predictive capacity for language development in children with hearing loss (Damen et al., 2007). The ECLiPS (Barry & Moore, 2014; Barry et al., 2015) questionnaire and APDQ (O'Hara, 2006; O'Hara & Mealings, 2018) are currently being evaluated in New Zealand. They appear promising and hence are included as recommended instruments. Recommended pre-assessment questionnaires suitable for use in New Zealand therefore include the TEAP, LIFE-7, APDQ, ECLiPS and SIFTER.

The Speech, Spatial, and Qualities of Hearing Scale (SSQ) originally developed for adults with hearing loss has been adapted for use by children, parents and teachers (Galvin & Noble, 2013; Bamiou et al., 2015). Bamiou et al. (2015) evaluated three questionnaires (SSQ; (Modified) Amsterdam Inventory for Auditory Disability; and Hyperacusis Questionnaire) for use with adults and found good correlation between the questionnaires and with diagnostic APD tests. The Hearing Handicap Questionnaire (HHQ) developed by Gatehouse and Noble (2004) may be another useful tool for evaluating the effects of APD on everyday listening and participation for adults and children. The recently developed UCAPI mentioned previously (Tektas, Ramsay, & Keith, 2017; Ramsay, Tektas, & Keith, 2017 ; Keith, Tektas, Ramsay, & Delaney, 2019) assesses perceptions of listening difficulties in adolescents and adults.

The TEAP plus Question 1 of the SIFTER comprises a brief but useful set of questions and is recommended for routine use. Since the TEAP is not as readily available as other questionnaires it is appended to this document (Appendix 3).

Case history

A comprehensive case history informs both diagnosis and management. Case history information can help uncover the possible cause if a disorder is diagnosed, and reveal the functional impact of the disorder on the individual and their academic performance. It can also serve to document the presence or absence of any comorbid condition(s) that the individual may be experiencing thus assisting with decisions regarding the need for onward referral, for example to an educational psychologist, paediatrician, speech-language therapist, occupational therapist, neurologist, optometrist or other specialist (AAA, 2010, pp. 7-8).

It is recommended that information obtained during a case history includes:

- auditory and/or communication difficulties experienced by the individual
- pre-, peri- and post-natal information
- physical developmental milestones
- speech and language development
- family history of learning and hearing difficulties
- medical history, including birth, otologic and neurologic history, general health history, and medications
- age of onset, frequency and treatment of middle ear problems
- allergies
- academic skills
- information on his/her participation at school, at home, in sport and leisure, at work
- existence of any known comorbid conditions, including cognitive, intellectual, and/or medical disorders
- prior and/or current therapy for any cognitive, linguistic, or sensory disorder or disability
- musical abilities and interest
- cultural and linguistic background.

Direct observation

Often information can be gained by direct observation of the individual during the interview and testing processes. The clinician should observe auditory comprehension and responsiveness and be alert for signs of distractibility, impulsivity and neurologic compromise (AAA, 2010, p. 8).

Direct observation of children in their everyday contexts by an educational specialist such as an AoDC, Resource Teacher for Learning and Behaviour (RTLB) or speech-language therapist can be particularly informative. Observation in everyday contexts aligns with the ICF participation model previously described. Typically observers watching one child see evidence of difficulties that a teacher attending to an entire class will not always notice. Classroom observation is always included as part of recording the trial outcomes when trialling Ministry of Education funded assistive technology. Information is collected on such areas as:

- classroom participation
- ability to follow class directions and individual directions
- peer relationships
- participation in noisy activities, including outdoor play and physical education activities.

Assessment of related developmental capacities

Because of the cognitive and language requirements necessary to complete an APD test battery, and because of the possibility of coexisting disorders, APD cannot be diagnosed accurately in isolation from knowledge of other developmental ability levels. Inclusion of assessments of language, cognition and other capacities is recommended to reduce misinterpretation of APD test results and provide a more comprehensive picture of a person's difficulties, consistent with the WHO ICF approach which considers an individual's ability to function in the context of their broader capabilities. If there is any suggestion of additional difficulties occurring as well as hearing difficulties, the clinician has a responsibility to recommend referral for other expert assessment.

For individuals of average abilities, cognitive and other factors should not distort APD test results because norms are derived on an average population. Clinicians should however keep in mind that in the case of individuals with higher or lower than average cognitive or other abilities, APD test scores may be influenced. For example, poor cognitive ability may contribute to low APD test scores, and high cognitive ability may tend to mask auditory processing deficits.

Cognition and language

The British Guidelines state that minimum assessment for APD should include screening language and cognitive assessments.

> *…the minimum multidisciplinary assessment for APD should include … A screening language and cognitive assessment (including tests for auditory memory and attention). In particular, children referred for suspected APD need to have, in addition to their audiometric assessment, a screening workup, including assessments of nonverbal ability, language and literacy, because problems in these areas may contribute to problems experienced by the child (Rosen, 2009). Administering audiological APD tests in isolation, without considering these issues may result in misdiagnosis and delays in the appropriate management of individuals with co-existing disorders. (BSA, 2011, p. 9)*

Ideally pre-assessment will be carried out by an educational psychologist and/or speech-language therapist or other accredited assessors. A suitable language test which can be administered by speech-language therapists is the Clinical Evaluation of Language Fundamentals Australian and New Zealand Fifth Edition (CELF-5 A&NZ) (Wiig, Semel, & Secord, 2017). Although not ideal, if specialist assessments are not available screening assessments should be substituted. User Level B screening tools[4] which may be used by audiologists and certain learning support personnel that are suitable for use in New Zealand include the Test of Nonverbal Intelligence – Fourth Edition (TONI-4) (Brown et al., 2010) for nonverbal IQ screening and the Clinical Evaluation of Language Fundamentals – Fifth Edition, Screening Test; Australian & New Zealand Language Adapted Edition (CELF-5 Screener) (Wiig, Secord, & Semel, 2013) for language screening.

Since impaired auditory processing may impact the consistent and accurate recognition of phonemes (Hornickel et al., 2012), phonological awareness may well be impaired (Burns, 2013). Many tests of phonological awareness are available, for example the Preschool and Primary Inventory of Phonological Awareness (PIPA) (for children up to age 7), (Dodd, Crosbie, McIntosh, Teitzel, & Ozanne, 2000; https://www.pearsonclinical.co.uk/Psychology/ChildCognitionNeuropsychologyandLanguage/ChildLanguage/PreschoolandPrimaryInventoryofPhonologicalAwareness(PIPA)/PreschoolandPrimaryInventoryofPhonologicalAwareness(PIPA).aspx), the Queensland University Inventory of Literacy (QUIL) (Dodd, Holm, Oerlemans, & McCormick, 1996), the Comprehensive Test of Phonological Processing (CTOPP) (Wagner, Torgesen, & Rashotte, 1999), and the Test of Auditory Processing Skills–4 (TAPS–4) (Martin & Brownell, 2005).

The Children's Communication Checklist-2 (CCC-2) (Bishop, 2006) is a well-validated norm-referenced parent-report questionnaire that can be used to rate a child's communication skills to determine if further testing is required.

Adults with suspected APD can be screened for cognitive impairment using screening tools such as the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005). The MoCA has been used

4 Certain tests are restricted according to User Levels. Audiologists and special education personnel qualify to use Level A, T and B tests, but not Level C and S tests which are restricted to psychologists and speech-language therapists, respectively.

to screen for cognitive impairment in adults with hearing loss (e.g., Smith & Pichora-Fuller, 2015).

Attention and memory

Children with APD can have attention (Gyldenkærne, Dillon, Sharma, & Purdy, 2014) and/or auditory memory (Sharma, Dhamani, Leung, & Carlile, 2014; Sharma et al., 2009) difficulties, however not all children with APD have attention or memory problems. It is important that these areas are separately assessed. Attention can be assessed by checklist or behavioural assessments such as: the Auditory Continuous Performance Test (ACPT) (Pearson Publishing) (Keith, 1994); the Test of Everyday Attention for Children (TEA-Ch) (Manly et al., 2001; Heaton et al., 2001); the Test of Variables of Attention (TOVA) (Greenberg & Waldman, 1993); or the Integrated Visual and Auditory Continuous Performance Test (IVA–2, BrainTrain®, http://www.braintrain.com/iva-plus/).

A number of checklists completed by parents or teachers have been used to screen for attention deficits, including the Attention Scales of the Motor Behavior Checklist (MBC), the Teacher Report Form (TRF), the Child Behavior Checklist (CBCL), and the ADHD–Rating Scale–IV (ADHD-RS-IV) (Efstratopoulou, Simons, & Jannsen, 2013). The CBCL and TRF (Achenbach & Rescorla, 2001) are among the most widely used parent-report measures of emotional and behavioural problems in children. Efstratopoulou, Simons and Jannsen (2013) found that the Lack of Attention Scale of the MBC (10 items) was significantly correlated with results for ADHD-RS-IV and with the Attention Problem Scale of TRF. The MBC was evaluated by Efstratopoulou, Jannsen and Simons (2013) on a large sample (N=841) of elementary school-age children; this showed good internal reliability for the seven problems scales (Lack of Attention, Hyperactivity/Impulsivity, Rules Breaking, Low Energy, Stereotyped Behaviors, Lack of Social Interaction, and Lack of Self-Regulation). Raters (classroom teachers or physical education teachers) are asked to observe the child during physical education classes and free play situations and to rate each behaviour on a Likert scale ranging from "never" (0) to "almost always" (Efstratopoulou, Jannsen, & Simons 2013). The authors concluded that, although the MBC is not a diagnostic tool, it provides useful information on children's attentional, emotional, and developmental problems in school settings.

Auditory short term memory can be screened using standardised forward and backward digit span tests, available in standardised language assessments such as the Clinical Evaluation of Language Fundamentals, Fourth Edition (CELF–4), or the Test of Auditory Processing Skills–4 (TAPS–4). Both tests provide normative data for forward and backward digit repetition tests. The TAPS–4 requires the administrator to have only qualification Level B, which means it can be administered by audiologists with a Masters or higher level qualification (http://www.pearsonclinical.com/language/qualifications.html).

It should be kept in mind that a lower than average auditory memory score may be due to a hearing rather than a memory deficit. If scores improve at a higher stimulus presentation level any observed deficit is more likely due to hearing difficulty. Clinical observation suggests that a true memory deficit is more likely when an auditory memory test score is extremely low.

Vision

Because of the high comorbidity between auditory and visual disorders (Tu'i'onetoa, 2015), administration of a checklist for visual dysfunction including signs of visual processing disorder is recommended to determine whether referral to a behavioural optometrist is advisable. There is little published information on validated checklists for visual processing to be used in individuals with suspected APD, however, vision checklists do exist (Bakar, Hong, & Pin, 2012). A College of Optometrists in Vision Development (COVD-QOL) questionnaire can be used as a vision checklist (https://www.covd.org/page/QOLstart). A score higher than 20 on the COVD-QOL indicates risk for developing vision difficulties (Harris & Gormley, 2007; Bakar et al., 2012) and warrants referral to a behavioural optometrist.

Interpretation

Clinicians need to be alert to difficulties or complicating factors which could affect results. Examples include poor attention, speech of such poor intelligibility that it is difficult to confidently score spoken responses to speech tests. Non-native fluency in the test language could also affect speech test results. Clinicians should be sensitive to the consideration of cultural and linguistic diversity of the New Zealand population. These or other difficulties do not preclude testing but must be considered in interpreting results. Tests involving closed-set responses such as picture pointing rather than verbal responses and discrimination of non-speech stimuli or speech stimuli with low language loading such as digits are recommended for testing people with receptive and/or expressive language difficulties. Diagnosis in the presence of comorbid factors is discussed in a later section.

Cognitive ability outside the normal range may affect APD test results. A test of non-verbal intelligence is often used if APD is suspected since a hearing impairment can adversely affect test scores on oral tests (Peelle, 2018). However, if as is commonly the case, an individual has comorbid vision processing difficulties, they might still be disadvantaged. A population study of auditory processing in school aged children conducted in the UK indicated a statistical link between reduced nonverbal Intelligence Quotient (IQ) and auditory processing skills (Moore et al., 2010). In this study 8% of the variance in speech perception in noise scores was accounted for by "cognition" (including attention, memory, language and literacy scores). Brenneman et al., (2017) investigated the association between cognition, language, and APD, and found a correlation with language or cognition for two APD tests. However less than 20% of the variance in APD scores on those tests was attributable to language or cognition.

Studies which include orally presented auditory memory tests in assessing the contribution of cognition to APD test performance, without providing the participants with amplification, e.g. from assistive listening devices (Moore, 2011; Dillon, Cameron, Glyde, Wilson, & Tomlin, 2012), may overestimate the contribution of cognitive ability since it has been shown that impaired audition adversely affects auditory memory test scores (van Boxtel et al., 2000). Scores on auditory memory tests improve for some children with auditory processing difficulties if they are allowed to wear amplification during auditory memory testing

PRE-ASSESSMENT

- *It is recommended that pre-assessment of children includes non-verbal cognitive ability and language assessments.*

If comprehensive pre-assessment information on language and cognitive ability is not available, audiologists and special education personnel can screen non-verbal intelligence, language, and phonological awareness using the TONI-4, the CELF-5 Screener, and the PIPA, QUIL, CTOPP or TAPS-4.

Attention can be screened by questionnaire (e.g. Lack of Attention Scale of the MBC), or by test (e.g. TEA-Ch or IVA CPT-2).

Auditory short term memory can be screened using the TAPS-4.

- *The COVD QOL questionnaire is recommended to screen for children who should be referred for assessment by a behavioural optometrist.*

The MoCA can be used for cognitive screening of adults.

(Schafer et al., 2016). Jedlicka (2018) reported that veterans with hearing loss tested on the Montreal Cognitive Assessment (MoCA) showed scores indicating cognitive impairment when tested without hearing aids but scored in the normal range with hearing aids. In contrast, Saunders, Odgear, Cosgrove, & Frederick (2018) found that while adults with hearing loss performed less well on the MoCA than normal hearing adults, the use of amplification did not compensate for this performance deficit.

IQ screening may indicate low cognitive functioning in some children. Care should be taken in delivering such a result from screening to parents. The limitations of the screening test need to be made clear and referral to an educational psychologist for more comprehensive diagnostic assessment should be considered. It should also be borne in mind that because of the increasing reliance on language as children mature, even for nonverbal tasks, nonverbal IQ scores may also be negatively affected by poor language abilities (DeThorne & Schaefer, 2004).

As reported above, visual processing disorder is frequently comorbid with APD (Tu'i'onetoa, 2015; Dawes et al., 2009). Comorbid vision processing deficits may affect non-verbal IQ scores. Due to overlap of sensory systems in the brain (AAA, 2010, pp. 6-7), auditory-visual integration may also be impaired. This could in turn affect the ability to lip-read speech whilst listening, for example.

It is common for children with APD to have comorbidities. This should not prevent APD assessment from being attempted. Clinicians require additional knowledge and skills to exhibit care and good clinical judgement when assessing children with other types of developmental or personality disorders (CISG, 2012, p. 19). Involvement of a multidisciplinary team is key in such cases. This area is discussed further in the section "Diagnosis in the presence of comorbidities".

Preliminary hearing assessment

It is recommended that the following tests are included in an audiometric assessment prior to APD testing (BSA, 2011, p. 9; AAA, 2010, p. 19):

- pure tone audiometry (including 3000 Hz and 6000 Hz)
- word recognition testing in quiet with age-appropriate recorded monosyllabic phonetically balanced (PB) words
- tympanometry
- ipsilateral and contralateral acoustic reflexes
- distortion product otoacoustic emissions (DPOAEs).

Abnormal acoustic reflexes or auditory brainstem response (ABR) audiometry can be a sign of central auditory pathology or ANSD. ABR with an appropriate test protocol (using a high-level click with condensation and rarefaction polarity to check for cochlear microphonic versus neural responses) can be used to rule out ANSD if acoustic reflexes are absent or abnormal. A pattern of normal ipsilateral acoustic reflexes with absent contralateral acoustic reflexes is consistent with a brainstem site of lesion and also warrants ABR assessment and/or medical referral.

AUDIOMETRIC ASSESSMENT

- *It is recommended that the following tests are included in audiometric assessment prior to APD testing:*
  - *pure tone audiometry*
  - *word recognition in quiet*
  - *tympanometry*
  - *ipsilateral and contralateral acoustic reflexes*
  - *distortion product otoacoustic emissions.*

Auditory processing tests

Many auditory processing tests have been developed to assess a range of different auditory processing abilities. ASHA (2005) and AAA (2010) Guidelines recommend a test battery approach using behavioural and electrophysiological approaches to diagnose APD. The AAA Guidelines state that test procedures:

> *…may include, but are not limited to, assessment of the following auditory processes: 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. (AAA, 2010, pp. 16-17)*

These processes are involved in complex auditory activities such as participating in conversations and meetings and hearing a teacher present instructions and information in the classroom. The WHO ICF framework separates impairment of body structure and function from activities and participation and contextual factors such as the environment. The beta version of the International Classification of Functioning, Disability, and Health (ICF) brief core set for hearing loss in adults has been found to be a valuable tool for use in audiological rehabilitation clinical practice and research design (Alfakir, Holmes, & Noreen, 2015).

Figure 2 uses WHO ICF codes from the Hearing Core Set as examples of areas for assessment that are relevant to APD as a health condition.

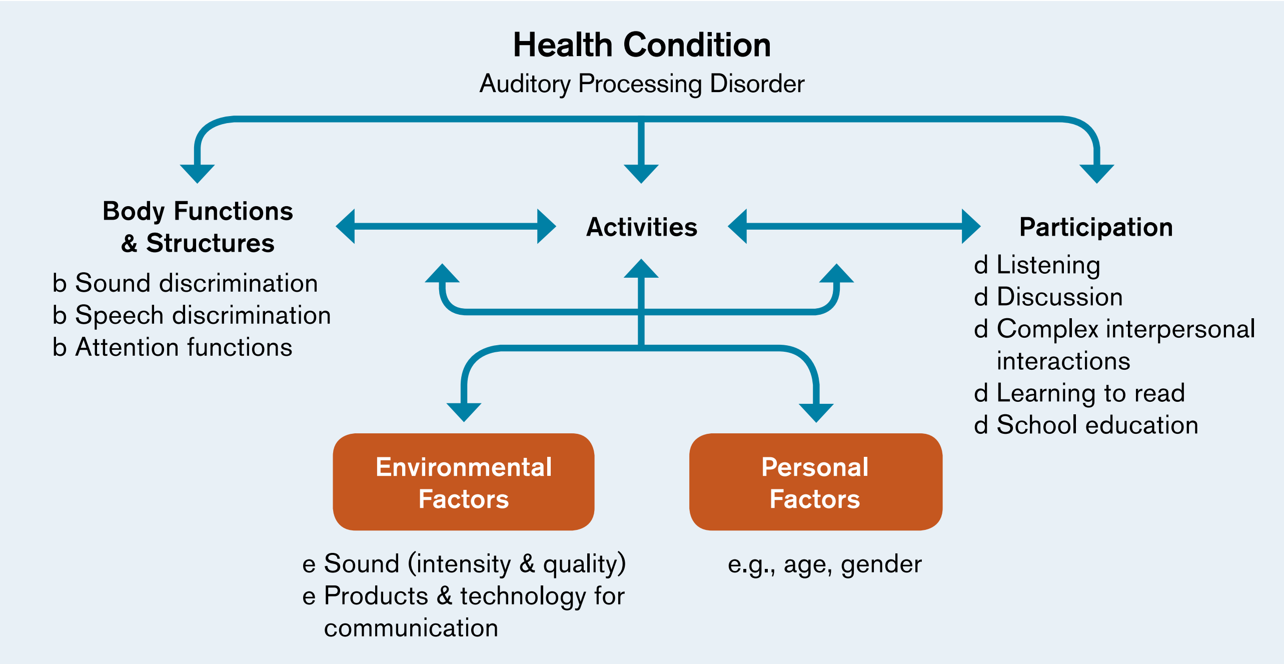

Figure 2: Examples of WHO-ICF codes from the Hearing Core Set that are relevant to APD, b=body functions, d=activity and participation, e= environmental factors, (from the Comprehensive ICF Core Set for hearing loss (https://www.icf-research-branch.org/download/send/10-otherhealthconditions/172-comprehensive-icf-core-set-for-hearing-loss)

Also see the Brief ICF Core Set for hearing loss (https://www.icf-research-branch.org/download/send/10-otherhealthconditions/171-brief-icf-core-set-for-hearing-loss), and information on ICF Core Set for Hearing Loss (https://www.icf-research-branch.org/icf-core-sets-projects2/other-health-conditions/icf-core-set-for-hearing-loss). Diagnostic procedures are used to evaluate the effects of APD on body structures and functions.

Auditory processing test procedures have been developed to determine whether there is an impairment of body structure and function (e.g. poor frequency or temporal auditory discrimination) or whether there is an impact on auditory activities such as listening in noise or reverberation. Clinical audiologists diagnose APD by testing different auditory capacities to see whether particular skills are impaired compared to age-norms, usually by applying a specific criterion, such as performance that is two standard deviations or more below the norm. For example, the AAA Guidelines (AAA, 2010, p. 22) recommend diagnosis of APD when a score is "two standard deviations or more below the mean for at least one ear on at least two different behavioral central auditory tests". (Recommended diagnostic criteria are discussed later.)

Test battery versus hierarchical approach

The test battery approach adopted by most national guidelines for assessing APD has been questioned due to its perceived inefficiency and the inclusion of assessments that are not directly linked to evidence-based treatments (Dillon et al., 2012). Musiek, Chermak, Weihing, Zappulla and Nagle (2011) proposed an efficient APD test battery (e.g. using just two or three tests) that would maximise sensitivity and specificity to impaired central auditory pathways. Dillon et al. (2012) recommended "a master test battery containing a small number of single tests, each of which assesses a different group of skills necessary for understanding speech in difficult listening conditions" followed by individual tests based on the failed test(s) from the master test battery. They suggest this hierarchical approach so that resources can be allocated to assessment of auditory function and treatment. These hierarchical approaches do not consider the complex and differing profiles of auditory processing deficits that are evident across individuals with suspected auditory processing difficulties.

Understanding the profile of an individual's deficits enables customisation of treatment. There is increasing evidence for specific treatments that are effective for particular types of auditory processing difficulties such as spatial processing disorder, amblyaudia and impaired temporal processing (Cameron & Dillon, 2011; Moncrieff & Wertz, 2008; Hornickel et al., 2012).

The diversity of central auditory deficits supports the need for a comprehensive test battery. Mainstream clinical practice favours the test battery approach, with the battery updated as newer and better tests become available. While using as few tests as possible in a battery may seem more time efficient, the primary goal of testing is accurate assessment of an individual's auditory processing abilities. When testing children, clinicians should monitor the child's attention level during testing and spread testing over more than one appointment if necessary to complete all the testing required.

Test validation

The traditional approach to validating tests for APD has been to ensure that the assessment is sensitive to the effects of known brain pathology, for example in adults with acquired brain injury (Musiek et al., 2011). Well established behavioural tests of auditory processing such as the Frequency Pattern Test (FPT) (Musiek, 1994) and the Dichotic Digits Test (DDT) show excellent sensitivity and specificity when results are compared to this 'gold standard' of known auditory brain lesions in adults (Musiek, Pinheiro, & Wilson, 1980; Musiek, 1983). This approach has been criticised as a means for validating tests for children with suspected APD however, since most children with APD would not have a lesion that could be identified in a brain imaging study. This may change with advances in imaging that will allow more precise measurement of white matter microstructure and connectivity. Recent studies show correlations between such measures and performance on auditory processing tasks for groups of children (e.g., Schmithorst, Holland, & Plante, 2011; Owen et al., 2013).

Other approaches to the validation of test procedures include population studies (e.g., Moore et al., 2010), comparison of performance across different clinical groups including children with dyslexia or language disorder (e.g., Cameron & Dillon, 2008; Moncrieff & Musiek, 2002), and comparison of performance across age groups within the school aged and adult population (e.g. Barker & Purdy, 2016; Neijenhuis, Snik, Priester, van Kordenoordt, & van den Broek, 2002). Frequency discrimination and backward masking (temporal discrimination) tests developed in the UK have been standardised on a large population sample of children aged 6-12 years (Moore et al., 2010). Validity has also been assessed by determining whether a test identifies auditory abilities that are distinct from other abilities such as attention (discriminant validity) (e.g., Gyldenkærne et al., 2014) and consistent with other related measures such as auditory evoked potentials (concurrent validity) (e.g., Billings, McMillan, Penman, & Gille, 2013; Sharma, Purdy, & Kelly, 2014).

Widely used validated tests of auditory processing include the Frequency Pattern Test, the Dichotic Digits Test, the Random Gap Detection Test (Keith, 2000; Dias, Jutras, Acrani, & Pereira, 2012; Muluk, Yalcinkaya, & Keith, 2011) and the LiSN-S test (Listening in Spatialized Noise-Sentences) (Cameron & Dillon, 2008). These tests have well established norms but are only suitable for children aged 6-7 years and older. A number of other auditory processing screening and diagnostic tests have been developed for children as young as three years (Keith et al., 2014) (see Section on Age of Assessment and Diagnosis).

Dichotic tests

Dichotic tests are affected by language loading and hence linguistic background should be considered when interpreting test results for dichotic word and sentence tasks. Auditory memory contributes only a small amount of the variance in performance on dichotic tests such as the Dichotic Digits Test (DDT) (Sharma et al., 2009). Open-set word tests are more difficult than closed set digit tests. Dichotic tests typically show a maturational effect, with a right ear advantage (the score from the right ear is higher than from the left ear) in young children and the elderly. As the CANS reaches maturity (in late adolescence) in typically developing individuals, the right ear advantage becomes minimal (Moncrieff & Musiek, 2002; Moncrieff, 2002). For a widely used dichotic test such as the DDT, the right ear advantage is not measurable by age 10 and older due to a ceiling effect (Moncrieff & Musiek, 2002; Moncrieff, 2002). Thus, more challenging dichotic tests may be needed to determine whether school-age children and adults have abnormal ear asymmetry results. Amblyaudia is more evident on more difficult dichotic tests (Hill & Purdy, 2011; Moncrieff & Musiek, 2002; Moncrieff, 2011; Findlen & Roup, 2016). Clinical experience suggests that the DDT, for example, is less sensitive to amblyaudia than more difficult tests such as the Dichotic Words Test (DWT) (Moncrieff, 2011; Moncrieff, 2015) or Randomized Dichotic Digits Test (RDDT) (Moncrieff & Wilson, 2009; Moncrieff, 2011) and the SCAN:3-C Competing Words and Competing Sentences Test. Moncrieff et al. (2016) based the diagnosis of amblyaudia on two, or the best of three, dichotic tests. Ear advantage norms for diagnosing amblyaudia with the DWT and RDDT dichotic tests are provided in Moncrieff et al. (2016) and with the tests from https://www.dichoticsinc.com/.

Pitch pattern tests

There are a number of commercial pitch pattern tests that include a sequence of three different tones (referred to as pitch pattern, frequency pattern and pitch sequence tests) (Frequency Pattern Test (FPT); Pitch Pattern Sequence Test, Pinheiro, 1977). The different versions are easily confused but do differ in the timing of the tone presentations and hence the level of difficulty. It is important that the appropriate norms are used for the test version that is selected. In New Zealand the FPT is the most widely used. This is based on the original pitch pattern test developed by Pinheiro (1977). Normative data (Kelly, 2007) is available for New Zealand children in the age range 7;0 to 12;11 years for the Musiek (1994) FPT which is available from AUDiTEC™ and on the Tonal and Speech Materials for Auditory Perceptual Assessment CD (Disc 2.0, Department of Veterans Affairs) developed by Dr Richard Wilson. Tomlin, Dillon and Kelly (2014) reported combined normative FPT data for NZ, Australian and US children and developed a “z score calculator” Excel worksheet that calculates the standard deviations from the norm (i.e. the z scores) for the child’s exact age. The child’s age and scores for the FPT and DDT are entered and individual ear z scores are automatically provided.

If a listener is unable to perform a pitch pattern task by labelling the responses then there is the option of responding with humming or singing. If a listener can hum the pattern but not label it, this suggests a deficiency in interhemispheric integration of auditory information (Bellis, 2003).

Younger children have variable performance on the FPT, as evidenced by large standard deviations, and find the test difficult due to the speed of the test. The Pitch Pattern Sequence (PPS) is a slower version of the FPT suitable for younger children (Smart, Purdy, & Leman, 2012) but lacks normative New Zealand data other than the small sample reported by Smart et al. (2012). In the AUDiTEC™ PPS child version each tone is 500 ms in duration and the interval between each tone in the pattern is 300 ms; the low and high tones are 880 and 1430 Hz. Each tone in the AUDiTEC™ FPT test has a 10 ms rise-fall time and a duration of 150 ms and the interval between the tones within each sequence is 200 ms; the low and high tones are 880 Hz and 1122 Hz (Delecrode, Cardoso, Frizzo, & Guida, 2014). Thus the PPS and FPT pitch pattern tests differ substantially in the length of each tone, the temporal gap between the tones and the frequency difference between the tones, and the PPS is much easier and hence more suitable for younger children.

Memory tests

Poor scores on memory tests have been reported for children with sensorineural hearing loss and cochlear implants (Bharadwaj, Maricle, Green, & Allman, 2015; Kronenberger et al., 2014; Jutras & Gagné, 1999) and for children who have autism spectrum disorder with auditory processing deficits (Schafer et al., 2016). A hearing disorder likely contributes to the poor scores, as the memory scores of the children with auditory processing deficits in the Schafer study were better when they wore their RMHAs for the test (Schafer et al., 2016). In their study, Jutras and Gagné (1999) also showed that the poorer memory performance of the children with hearing loss was attributable to auditory rather than memory factors.

Short term auditory memory and working memory are typically assessed in an APD test battery using forward and backward digit span tests. Two test batteries that include the digit span subtests are the TAPS-4 and the CELF-4. Barry et al. (2015) found correlations between functional hearing difficulties of children with APD measured using questionnaires and auditory memory for backward digits but not for forward digit span scores. Thus, backward digit span scores may be a more appropriate measure of apparent auditory working memory deficits in children with APD. More comprehensive testing of auditory memory and memory in other sensory modalities is conducted by psychologists using standardised cognitive tests. Referral to a psychologist is recommended if screening indicates significant memory deficits that are unlikely to be explained by hearing deficits.

Rationale for test selection

Test battery approaches that endeavour to profile an individual's range of auditory difficulties require assessment tools that measure different auditory processes. Published tests of auditory attention, auditory discrimination, dichotic listening, distorted speech, localisation/lateralisation, auditory memory, spatial segregation and temporal processing were reviewed by the authors of these Guidelines (Table 2). Supplementary information with more detailed information on the tests reviewed is accessible online from the link in Appendix 4. Table 2 (Parts A-D) lists the tests that were reviewed and indicates whether the tests meet the following inclusion criteria: relevant norms, test-retest reliability, validity, sensitivity and specificity, clinical acceptability, included in peer-reviewed literature. This approach to test selection differs from the hierarchical approach suggested by Dillon et al. (2012) and from theoretically-driven test battery approaches such as the Buffalo model developed by Katz (2009) or the Bellis/Ferre model (Jutras et al., 2007).

Published test batteries

There are some published test batteries available where tests have been bundled together into groups for easy accessibility for clinicians.

The SCAN-3:C for Children and SCAN-3:A for Adolescents & Adults (Keith, 2009), are collections of tests designed for different age groups which aim to screen and diagnose auditory processing difficulties with one co-normed battery of tests. The revised versions of each test battery have been standardised with norms based on large populations (525 children for SCAN-3:C and 250 adults for SCAN-3:A), and validated with a group of 40 children with APD for SCAN-3:C and 61 adolescents and adults with APD for SCAN-3:A. It is important to note that published reports show some evidence of poor test-retest reliability and validity for the earlier versions of the SCAN.

The IMAP test battery developed at the MRC Institute of Hearing Research was designed to supplement current tests in the investigation of cases of suspected auditory processing deficits and assesses a range of auditory and cognitive skills (Barry, Ferguson, & Moore, 2010). It has been standardised on 1500 normally-hearing children from across the UK, aged 6-11 years. Tests are presented in a child-friendly game format using software-controlled presentation.

The Multiple Auditory Processing Assessment (MAPA) (Domitz & Schow, 2000) was developed based on recommendations from Musiek and Chermak (1994) and ASHA (1996). It was designed to identify adults and children aged 8 years and over who have auditory processing disorders. It is a battery of four commonly used tests of auditory processing that covers three auditory processing domains as defined by ASHA (monaural separation/closure, auditory pattern/temporal ordering, and binaural integration and binaural separation). The test battery was standardised on 81 children aged 8-9 years. A practical limitation is that norms are only provided from 8 years of age (Domitz & Schow, 2000).

Feather Squadron (Acoustic Pioneer https://acousticpioneer.com/assessmentapp.html) is a recently developed adaptive interactive game-based test battery, administered on a tablet, for measuring auditory processing in school-aged children. Its intention is to provide "a relatively fast, engaging, and easy way to measure a wide range of (C)AP abilities" (Barker & Purdy, 2016). Barker and Purdy (2016) evaluated the Feather Squadron battery on a cohort of 893 school children with normal audiograms and no known learning disorders. The Feather Squadron subtests showed good test-retest reliability on six of seven measures. Low-moderate correlations were found between three traditional APD tests and corresponding Feather Squadron measures in a sub-group of 46 participants. There are no reported construct validity studies for Feather Squadron on children diagnosed with APD, though in poor readers Barker, Kuruvilla-Mathew and Purdy (2017) found altered auditory processing as defined by Feather Squadron measures and speech-evoked cortical potentials. A small scale/case study report (including two children with APD) showed overall diagnostic agreement (though not necessarily on individual tests) between Feather Squadron and traditional APD test battery results (Maffetone, 2017). There are as yet no sensitivity and specificity data for the Feather Squadron test battery, or the associated screening version, as they have not undergone trials on children diagnosed with APD. The Acoustic Pioneer website warns that APD diagnosis cannot be made by a software programme in isolation, stating "We do not diagnose APD with 'Feather Squadron'" (Acoustic Pioneer https://acousticpioneer.com/audiologists.html). Barker and Purdy (2016) note that "further research is … needed to compare results of Feather Squadron to children who have been diagnosed with (C)APD using traditional means". Feather Squadron is clearly engaging for children and easy to administer but neither version has yet been tested on children diagnosed with APD.

Suggested test battery

From the tests listed in Table 2 a number of standardised tests with good psychometric properties and appropriate norms, that are practical to administer and accessible and affordable for clinics, were identified (Table 3). Appropriate tests were selected for each auditory processing assessment area.

Table 3 accordingly lists the subset of tests currently considered most suitable for use in New Zealand.

SELECTED TESTS

Mainstream clinical practice favours the test battery approach.

- *APD tests recommended as suitable for use by audiologists in New Zealand are shown in Table 3.*

Many of the auditory processing assessments that rely on commercially available speech recordings are only available with U.S. accented speech. This is less problematic for assessments that use nonverbal stimuli or highly linguistically redundant speech material such as spoken digits. Linguistic materials have been used in auditory processing testing for many years, for example, the Ivey Filtered Word Test (Willeford, 1977). Results for assessments that use more linguistically-challenging U.S. accented speech materials (Staggered Spondaic Word (SSW) (Katz, 1962), Pediatric Speech Intelligibility Test (PSI) (Jerger & Jerger, 1982), Hearing in Noise Test for Children (HINT-C) (Nilsson, Soli, & Gelnett, 1996), Bamford-Kowal-Bench Speech-in-Noise Test (BKB-SIN) (Killion, Niquette, Revit, & Skinner, 2001), Words in Noise Test (WIN) (Wilson, 2003), SCAN-3 word tests) that do not have normative data for New Zealand children and adults should be used and interpreted with caution.

Auditory evoked potentials

Auditory evoked potentials (AEPs) represent summed neural activity in the auditory neural pathways recorded via surface electrodes attached to the scalp. AEPs are objective and can be recorded during passive listening (e.g. while the person being tested watches a silent movie). Hence they allow the possibility of testing very young children and others who are uncooperative or unable to perform behavioural assessments.

The AAA Guidelines acknowledge that auditory processing gives rise to auditory evoked potentials:

> *(C)APD refers to difficulties in the perceptual processing of auditory information in the central nervous system and the neurobiologic activity that underlies that processing and gives rise to the electrophysiologic auditory potentials. (AAA, 2010, p. 5)*

AEPs include the auditory brainstem response that may be included in the preliminary test battery to rule out ANSD. ANSD may appear similarly to APD as it can present as poor speech perception with minimal hearing loss evident on the audiogram (Rance, 2005).

AEPs are an important research tool as group data show consistent differences in AEPs from different levels of the auditory pathway (auditory brainstem response, ABR; middle latency response, MLR; cortical auditory evoked potentials, CAEPs) when typically developing control participants are compared to children or adults with diagnosed or suspected APD (Kraus & Hornickel, 2012; Purdy et al., 2002; Sharma et al., 2014). Jerger, Martin and Fitzharris (2014) have, through a series of studies, drawn attention to the many possible contributions to APD diagnosis of word-evoked AEPs, including evaluation of dichotic function and isolation of the significant factors of listening effort and attention involved in dichotic tasks.

There are several barriers to the widespread adoption of AEPs for APD clinical assessment: a wide range of test stimuli and protocols have been used in research investigating AEPs in clinical groups and typically developing children and adults; there is a lack of normative data for different age groups; and there is limited evidence that AEPs can reliably differentiate individuals with APD from controls. The AAA Guidelines state:

> *"There are no widely accepted criteria as to when AERs [auditory evoked responses] should be included in the clinical evaluation of APD." (AAA, 2010, p. 21)*

Hence AEPs are currently used on an ad hoc basis and in research only. With developments in the technology and better consensus about optimal stimuli and recording parameters, cortical AEPs may be included more routinely in future APD assessment batteries.

Acoustic reflexes

The diagnostic value of acoustic reflex (AR) patterns in eighth nerve and brain stem lesions has long been recognised (Jerger & Jerger, 1977). ARs are important in the diagnosis of auditory neuropathy (Berlin et al., 2005). AR abnormalities are also noted in APD. Children with suspected APD often show elevated or absent AR thresholds, especially in the crossed condition (Allen & Allan, 2014; Saxena, Allen, & Allan, 2017; Smart, Kuruvilla-Mathew, Kelly, & Purdy, 2019). Saxena, Allan and Allen (2015) also recorded reduced growth of AR amplitudes in children with suspected APD compared to typically developing children. Further research on AR parameters may increase the sensitivity of AR measurements in the diagnosis of APD. In the meantime, it is recommended that clinical evaluations for APD include ipsilateral and contralateral ARs. Clinicians should be alert to unexplained abnormalities of AR thresholds or patterns.

Review of tests

Table 2 summarises key features of behavioural tests of auditory processing that are currently used or that are available and have been used in published studies[5]. The tests are grouped based on the ASHA definitions for auditory processes[6] (ASHA, 2005 pp. 3, 14-15). Note that some tests can be used to assess different processes depending on the instructions given. Most recorded tests have American-accented speech. Appendix 4 contains more specific information about these tests and summaries of the available literature pertaining to each test. Table 3 shows standardised tests (selected from Table 2) that assess a range of auditory processes and are recommended as suitable for use in NZ.

5 The process employed in collating and selecting the information in Table 2 A-D and Appendix 4 is outlined in the earlier Methodology section.

6 The auditory processes in Table 2 A-D and Appendix 4 can be defined as follows: Auditory discrimination is the ability to discriminate small differences in frequency, intensity, and/or timing in similar acoustic stimuli. Dichotic listening is the ability to integrate (binaural integration) or separate (binaural separation) disparate auditory stimuli presented to each ear at the same time. Hearing for distorted speech describes the ability to recognize degraded speech stimuli. Speech understanding in background noise is the ability to recognize speech stimuli in the presence of competing background noise. Lateralisation and localization is the ability to identify the location of an acoustic stimulus. Spatial segregation is the ability to separate acoustic stimuli from distracting stimuli that arrive from other directions (Cameron et al., 2012). Temporal processing is the ability to analyze acoustic events over time. Pattern perception is the ability to recognise differences in pitch or duration in an acoustic sequence. Auditory attention is the ability of a person to sustain attention for an extended period of time (ASHA, 2005). Auditory memory refers to the ability to remember auditory information.

Table 2
Review of Tests of Auditory Processing: Part A. Auditory Discrimination, Dichotic Listening

Tests	Appropriate age norms	Test-retest reliability has been published[1]	Reported validity[2]	Sensitivity and/ or specificity have been published[3]	Clinically acceptable[4]	Published studies[5]	Limitations
Auditory Discrimination							
STAR2 IMAP Frequency Discrimination Test (FDT)	✓		✓	✓	✓	✓	Availability[6]
Minimal Pairs Test (MPT)				✓	✓	✓	
Wepman's Auditory Discrimination Test (ADT) (2nd Edn)	✓	✓		✓	✓	✓	Live voice
Parameter Estimation by Sequential Tracking (PEST) Auditory Discrimination Paradigm							
Dichotic Listening – Binaural Integration							
Dichotic Digits Test (DDT)	✓	✓	✓	✓	✓	✓	
Randomized Dichotic Digits Test (RDDT)	✓		✓		✓	✓	
Staggered Spondaic Word (SSW) Test	✓		✓	✓	✓	✓	Note[7]
Competing Words Test – Free Recall (SCAN-3:C and SCAN-3:A)	✓	✓	✓	✓	✓	✓	
Rapidly Alternating Speech Perception (RASP) test	✓		✓	✓		✓	
Dichotic Words Test (DWT)	✓		✓		✓	✓	
Word Double Dichotic (WDD) (Feather Squadron)	✓	✓	✓		✓	✓	
Dichotic Listening – Binaural Separation							
Synthetic Sentence Identification - Contralateral Competing Message (SSI-CCM)			✓	✓	✓	✓	
Pediatric Speech Intelligibility Test (PSI)		✓	✓	✓	✓	✓	
Dichotic Competing Sentences			✓	✓	✓	✓	
Competing Words Test – Directed Ear (SCAN-3:C and SCAN-3:A)	✓	✓	✓	✓	✓	✓	
Competing Sentences Test (SCAN-3:C and SCAN-3:A)	✓	✓	✓	✓	✓	✓	
Competing Words - Directed Ear	✓				✓	✓	

1 The test-retest reliability has been published.
2 There are published studies showing the test is valid for identifying individuals with the condition specified (APD/ADHD) or the test shows convergent validity, i.e. correlation with other tests measuring the same construct.
3 The test's ability to identify individuals with APD/ADHD relative to established diagnostic criteria has been published.
4 The test is practical and time and cost efficient to administer in a clinic.
5 See Appendix 4 for references.
6 Not commercially available.
7 Australian recordings (Macquarie University and Neurosensory (Brisbane)) available but limited norms published for adults only and test recordings not readily available.

Table 2

Review of Tests of Auditory Processing: Part B. Distorted Speech, Speech Understanding in Background Noise, Lateralisation and Localisation, Spatial Segregation

Tests	Appropriate age norms	Test-retest reliability has been published[1]	Reported validity[2]	Sensitivity and/ or specificity have been published[3]	Clinically acceptable[4]	Published studies[5]	Limitations
Distorted Speech							
Time Compressed Sentence Test (SCAN-3:C and SCAN-3:A)	✓	✓	✓	✓	✓	✓	
Filtered Words Test (SCAN-3:C and SCAN-3:A)	✓	✓	✓	✓	✓	✓	
University of Canterbury Adaptive Speech Test - Filtered Words (UCAST-FW)		✓	✓	✓	✓	✓	Limited norms
Ivey Filtered Words Test	✓					✓	
Northwestern University Auditory Test Number 6 (1) NU-6 Low-Pass Filtered Speech Test (2) NU-6 Time Compressed Speech (3) NU-6 Time Compressed Speech with Reverberation	✓					✓	
Time Compressed Sentence Test (TCST)	✓					✓	
Speech Understanding in Background Noise							
QuickSIN (Speech in Noise)			✓		✓	✓	
Auditory Figure Ground Tests at 0 dB, +8dB and +12 dB S/N Ratio (SCAN-3:C and SCAN-3:A)	✓	✓	✓	✓	✓	✓	
Hearing in Noise Test (HINT) [now HINT Pro]		✓			✓	✓	Cost
Hearing in Noise Test for Children (HINT-C)		✓		✓	✓	✓	
Bamford-Kowal-Bench Speech in Noise Test (BKB-SIN)	✓	✓	✓	✓	✓	✓	
Synthetic Sentence Identification - Ipsilateral Competing Message (SSI-ICM)		✓			✓	✓	
Words in Noise (WIN) Test	✓	✓		✓	✓	✓	
Lateralisation/Localisation							
Masking Level Difference (MLD) procedures		✓			✓	✓	
Test of Localization Utilizing Precedence Effect						✓	Availability[6]
Spatial Segregation							
Listening in Spatialized Noise - Sentences Test (LiSN-S)	✓	✓	✓	✓	✓	✓	

1 The test-retest reliability has been published.
2 There are published studies showing the test is valid for identifying individuals with the condition specified (APD/ADHD) or the test shows convergent validity, i.e. correlation with other tests measuring the same construct.
3 The test's ability to identify individuals with APD/ADHD relative to established diagnostic criteria has been published.
4 The test is practical and time and cost efficient to administer in a clinic.
5 See Appendix 4 for references.
6 Not commercially available.

Table 2

Review of Tests of Auditory Processing: Part C. Temporal Processing, Pattern Perception

Tests	Appropriate age norms	Test-retest reliability has been published[1]	Reported validity[2]	Sensitivity and/ or specificity have been published[3]	Clinically acceptable[4]	Published studies[5]	Limitations
Temporal Processing							
Random Gap Detection Test (RGDT)	✓		✓	✓	✓	✓	
Gaps-in-Noise (GIN) Test	✓	✓	✓	✓	✓	✓	
Adaptive Tests of Temporal Resolution (ATTR)	✓	✓	✓	✓	✓	✓	
Backward Masking						✓	Availability[6]
STAR2 IMAP Backward Masking (BM-0ms) Test	✓		✓	✓	✓	✓	Availability[6]
Gap Detection Test (SCAN-3:C and SCAN-3:A)	✓	✓	✓	✓	✓	✓	
Pattern Perception							
Duration Pattern Test (DPT)		✓	✓	✓	✓	✓	Very difficult
Pitch Pattern Sequence Test - Child Version (PPS-C) Pitch Pattern Sequence Test - Adult Version (PPS-A)	✓	✓	✓	✓	✓	✓	
Duration Pattern Sequence Test (DPST)					✓	✓	11-12 y. data
Frequency Pattern Test (FPT)	✓	✓	✓	✓	✓	✓	
Tonal Pattern Memory (TM) (Feather Squadron)	✓	✓	✓		✓	✓	

1 The test-retest reliability has been published.
2 There are published studies showing the test is valid for identifying individuals with the condition specified (APD/ADHD) or the test shows convergent validity, i.e. correlation with other tests measuring the same construct.
3 The test's ability to identify individuals with APD/ADHD relative to established diagnostic criteria has been published.
4 The test is practical and time and cost efficient to administer in a clinic.
5 See Appendix 4 for references.
6 Not commercially available.

Table 2

Review of Tests of Auditory Processing: Part D. Auditory Attention, Auditory Memory

Tests	Appropriate age norms	Test-retest reliability has been published[1]	Reported validity[2]	Sensitivity and/ or specificity have been published[3]	Clinically acceptable[4]	Published studies[5]	Limitations
Auditory Attention							
Auditory Continuous Performance Test (ACPT)	✓	✓	✓	✓	✓	✓	Low sensitivity
Test of Variables of Attention (TOVA)	✓	✓	✓	✓	✓	✓	Low specificity
Integrated Visual and Auditory Continuous Performance Test (IVA CPT) (2nd edition)	✓		✓	✓	✓	✓	Cost
Test of Everyday Attention for Children - 2nd Edition (TEA-Ch2)	✓	✓	✓		✓	✓	Only UK normative data
Auditory Memory							
Clinical Evaluation of Language Fundamentals - Fifth Edition (CELF-5) Recalling Sentences	✓	✓	✓	✓	✓	✓	Level S Users only; numbers subtest deleted in CELF-5 but recalling sentences is retained
Clinical Evaluation of Language Fundamentals - Fourth Edition (CELF-4) Number Repetition Forwards and Backwards, Recalling Sentences	✓	✓	✓	✓	✓	✓	
Test of Auditory Processing (TAPS-4) Number Memory Forward Subtest (NMF) & Number Memory Reversed Subtest (NMR)	✓	✓			✓		Can be used by audiologists

1 The test-retest reliability has been published.
2 There are published studies showing the test is valid for identifying individuals with the condition specified (APD/ADHD) or the test shows convergent validity, i.e. correlation with other tests measuring the same construct.
3 The test's ability to identify individuals with APD/ADHD relative to established diagnostic criteria has been published.
4 The test is practical and time and cost efficient to administer in a clinic.
5 See Appendix 4 for references.

Table 3
Standardised Tests (Selected from Table 2) that Assess a Range of Auditory Processes and are Recommended as Suitable for Use in NZ[1,2,3]

	Test	Author	Age range (y;m)	Notes
Auditory discrimination	STAR2 IMAP Frequency Discrimination Test (FDT)	Barry, Ferguson, & Moore (2010); Moore et al. (2010)	6-11 years	Correlates with functional measures; not commercially available
	Wepman's Auditory Discrimination Test (ADT) (2ndEdn)	Wepman & Reynolds (1987)	4-8 years	Live voice test suitable for testing younger children
Dichotic listening	Dichotic Digits Test (DDT)	Musiek (1983)	7-12 years	Right ear advantage for younger children; NZ, Australian, U.S. norms
	Randomized Dichotic Digits Test (RDDT)	Moncrieff & Wilson (2009) Moncrieff (2011)	10-18 years; 19-28 years	Sensitive to amblyaudia; specific amblyaudia norms
	Dichotic Words Test (DWT)	Moncrieff (2011, 2015)	5-12 years	Sensitive to amblyaudia; specific amblyaudia norms; greater linguistic effect than DDT due to use of words other than digits
	Staggered Spondaic Word Test (SSW)	Katz (1962)	5-69 years (U.S. version)	New Zealand normative data available for ages 7-12 years for Macquarie SSW (MSSW) recording; MSSW recording not commercially available; Australian SSW (ASSW) recording available from Neurosensory (Brisbane) (Wilson, Katz, Dalgleish, & Rix, 2007)
	Competing Words Test – Free Recall (SCAN-3:C and SCAN-3:A)	Keith (2009)	5;0-12;11 years & 13-50 years	
	Competing Words Test - Directed Ear (SCAN-3:C and SCAN-3:A)	Keith (2009)	5;0-12;11 years & 13-50 years	
	Competing Sentences Test (SCAN-3:C and SCAN-3:A)	Keith (2009)	5;0-12;11 years & 13-50 years	

1 Inclusion criteria: Selected standardised tests supported with published studies showing good psychometric properties and appropriate norms, evaluated on groups of individuals with diagnosed or suspected APD, practical to administer and accessible and affordable for clinical use in New Zealand.
2 Unless otherwise stated language-based tests can be assumed to have an American accent.
3 For attention and memory tests – see section on Assessment of Related Developmental Capacities, Attention and Memory for recommended questionnaires and tests.

Table 3
Standardised Tests (Selected from Table 2) that Assess a Range of Auditory Processes and are Recommended as Suitable for Use in NZ[1,2,3] (continued)

	Test	Author	Age range (y;m)	Notes
Distorted speech	University of Canterbury Adaptive Speech Test - Filtered Words (UCAST-FW)	Rickard, Heidtke, & O'Beirne (2013)	7-13 years & adults	Not yet commercially available; normative data available for N=30 New Zealand participants New Zealand accent
	Time Compressed Sentence Test (SCAN-3:C and SCAN-3:A)	Keith (2009)	5;0-12;11 years & 13-50 years	
	Filtered Words Test (SCAN-3:C and SCAN-3:A)	Keith (2009)	5;0-12;11 years & 13-50 years	
	Northwestern University Auditory Test Number 6 (NU-6) Low-Pass Filtered Speech Test	Bornstein, Wilson, & Cambron (1994)	7-12 years & adults	
Speech understanding in background noise	Auditory Figure Ground Tests at 0 dB, +8dB and +12 dB S/N Ratio (SCAN-3:C and SCAN-3:A)	Keith (2009)	5;0-12;11 years & 13-50 years	
	Bamford-Kowal - Bench Speech in Noise (BKB-SIN)	Bench, Kowal, & Bamford (1979)	5+ years	Sentence test - fixed signal-to-noise ratios
	Words in Noise (WIN) test	Wilson (2003)	6-85 + years	Word test
Spatial segregation	Listening in Spatialized Noise - Sentences Test (LiSN-S)	Cameron & Dillon (2008)	6-60 years	Australian-accented speech

1 Inclusion criteria: Selected standardised tests supported with published studies showing good psychometric properties and appropriate norms, evaluated on groups of individuals with diagnosed or suspected APD, practical to administer and accessible and affordable for clinical use in New Zealand.
2 Unless otherwise stated language-based tests can be assumed to have an American accent.
3 For attention and memory tests – see section on Assessment of Related Developmental Capacities, Attention and Memory for recommended questionnaires and tests.

Table 3
Standardised Tests (Selected from Table 2) that Assess a Range of Auditory Processes and are Recommended as Suitable for Use in NZ[1,2,3] (continued)

	Test	Author	Age range (y;m)	Notes
Temporal processing	Random Gap Detection Test (RGDT)	Keith (2000)	7+ years	No result possible if listener cannot hear the longest gap
	Gaps-in-Noise (GIN) Test	Musiek et al. (2005)	7+ years	Longer test time than RGDT
	STAR2 Backward Masking (BM-0ms) Test	Barry, Ferguson, & Moore, (2010); Moore et al. (2010)	6-11 years	Correlates with functional measures; not commercially available
	Gap Detection Test (SCAN-3:C and SCAN-3:A)	Keith (2009)	8;0-12;11 years & 13-50 years	
Pattern Perception	Pitch Pattern Sequence Test - Child Version (PPS-C)	Pinheiro (1977)	6-9 years	PPS-C uses slower timing than FPT; child version suitable for 6 year olds
	Frequency Pattern Test (FPT)	Musiek & Pinheiro (1987); Musiek (1994)	7-12 years	NZ, Australian, U.S. norms; can be used with adults also

1 Inclusion criteria: Selected standardised tests supported with published studies showing good psychometric properties and appropriate norms, evaluated on groups of individuals with diagnosed or suspected APD, practical to administer and accessible and affordable for clinical use in New Zealand.
2 Unless otherwise stated language-based tests can be assumed to have an American accent.
3 For attention and memory tests – see section on Assessment of Related Developmental Capacities, Attention and Memory for recommended questionnaires and tests.

Diagnostic criteria

Audiologists are the only professionals qualified to diagnose APD. Audiologists diagnosing APD should have been educated and trained in the area of APD, including the administration and interpretation of APD tests (AAA, 2010, p. 5).

The ASHA 2005 criteria are the most commonly used for the diagnosis of APD.

> *Diagnosis of (C)APD generally requires performance deficits on the order of at least two standard deviations below the mean on two or more tests in the battery (Chermak & Musiek, 1997). … If poor performance is observed on only one test, the audiologist should withhold a diagnosis of (C)APD unless the client's performance falls at least three standard deviations below the mean or when the finding is accompanied by significant functional difficulty in auditory behaviors reliant on the process assessed. Moreover, the audiologist should re-administer the sole test failed as well as another similar test that assesses the same process to confirm the initial findings. (ASHA, 2005, p. 16)*

The ASHA (2005)/AAA (2010) diagnostic criteria of deficits of at least two standard deviations on at least two tests reflects the greater sensitivity and specificity of APD test batteries when this criterion is applied for identifying lesions in the CANS, compared to other possible combinations of number of tests failed and degrees of failure (e.g., one test by two-or-more standard deviations, two tests by one-or-more standard deviations, etc.) (AAA, 2010, p. 22; Musiek et al., 2011).

The ASHA criteria (ASHA, 2005) differ from the AAA Guidelines (AAA, 2010) in allowing for a diagnosis when there is only one central auditory deficit if such deficit is consistent with observed functional difficulty, or if the test is failed by at least three standard deviations. The case history, questionnaire responses, educational results and reports from other professionals can be helpful in providing functional evidence when required to support a diagnosis. The ASHA criteria also recommend that when only one test is failed it is re-administered to confirm the result and that a similar test that assesses the same process is also administered to confirm the finding. It is however not always possible to find a suitably similar test for reconfirmation. We endorse the recommendation to reconfirm findings when diagnosis hinges on a single test result.

The ASHA (2005) and AAA (2010) Guidelines are both difficult to interpret in regard to whether two monaural tests failed need to be in the same ear for a diagnosis of APD.

We recommend the following diagnostic criteria incorporating elements of both the ASHA (2005) and AAA (2010) recommendations. These criteria do not cover all eventualities, particularly in regard to tests for which scores are not expressed in standard deviations. Clinical judgement should always play a part in diagnosis.

APD is diagnosed:

a) when an individual presents with scores two standard deviations or more below the mean on at least two different behavioural central auditory tests (with the provision that if both tests are monaural the tests failed may be in the same ear or different ears) (adapted from AAA, 2010), or
b) if poor performance is reliably observed on only one test with a score two standard deviations below the mean but this is accompanied by significant functional difficulty in auditory behaviours reliant on the process assessed (adapted from ASHA, 2005), or
c) if poor performance is reliably observed on only one test with a score three standard deviations or more below the mean (adapted from ASHA, 2005).

The concept that more than one deficit should be confirmed in order to diagnose APD is controversial. APD is a global term used to refer to any central auditory processing deficit or combination of deficits. Individuals with central auditory processing difficulties do not always exhibit more than one central auditory deficit and hence may not fail two different tests. They might exhibit only amblyaudia or only a difficulty with spatial stream segregation, for example. Wilson and Arnott (2013) argue that it would be more useful to focus on specific central auditory deficits. They support calls to abandon the use of APD as a global label. By comparing diagnoses using nine different sets of criteria, Wilson and Arnott also demonstrate the variability that is possible in diagnostic decisions depending on the criteria used. They emphasise the importance therefore of always specifying the criteria used to make a diagnosis, for example as a footnote in case reports (Wilson & Arnott, 2013). It is recommended in these Guidelines also that clinicians report the criteria used to make a diagnosis in case reports.

The choice of two or three standard deviations for diagnostic criteria is arbitrary. The NAL Position Statement states:

> *Adopting a criterion of 2 standard deviations below average on a test as indicating a problem, for example, is not based on any evidence that this is the degree of deficit that is necessary to cause a problem in real life. (Dillon & Cameron, 2015)*

There is also criticism of using a simple pass/fail criterion based on the number of standard deviations from the normative mean as the diagnostic boundary for APD.

Tomlin et al. (2014) advocated the use of z scores to present APD test results; z scores (also known as standard scores) express test results in standard deviations of the population under consideration relative to the mean of that normative population (i.e., individual test score minus normative mean, divided by the standard deviation).

DIAGNOSTIC CRITERIA

- *The following criteria are recommended as a basis for diagnosis:*

  APD is diagnosed:

  a) when an individual presents with scores two standard deviations or more below the mean on at least two different behavioural central auditory tests (with the provision that if both tests are monaural the tests failed may be in the same ear or different ears) (adapted from AAA, 2010),

  or

  b) if poor performance is reliably observed on only one test with a score two standard deviations below the mean but is accompanied by significant functional difficulty in auditory behaviours reliant on the process assessed (adapted from ASHA, 2005),

  or

  c) if poor performance is reliably observed on only one test with a score three standard deviations or more below the mean (adapted from ASHA, 2005). Reconfirmation of findings is recommended when diagnosis hinges on a single test result.

- *It is recommended to specify the criteria used to make a diagnosis in case reports.*

It may be possible in the future to determine an overall severity of APD across a battery of tests by summing and averaging z scores, to reflect how much the person differs overall from typical performance on APD tests. Z scores for IQ or language tests are often given severity ratings (e.g. “Marginal/Below average/Mild” = z scores -1 to -1.5; “Low range/Moderate” = z scores -1.5 to -2; “Very low range/Severe” = z scores below -2). Based on these categories about a third of the 60 children in Sharma et al.’s (2009) study had moderate APD severity and about a third had severe APD, based on z scores for four APD tests. However this approach does not address activity limitations and restriction of participation which may be better described by measures of functional disability.

Some researchers have advocated the statistical method of bootstrapping to better define atypical sub-groups through improved estimation of confidence intervals (Moncrieff, 2015). Bootstrapping is a computer-intensive statistical technique involving repeated resampling to create thousands of alternate versions of a dataset to more accurately represent the population. This technique is thought to reduce the impact of outliers and sampling anomalies and may facilitate the development of more robust norms in the future.

A diagnostic criterion of two standard deviations (SD) below the mean on an APD test includes only individuals below the 3rd percentile of performance on that test. Children with somewhat higher APD test scores but clear evidence of hearing difficulty are sometimes referred to as exhibiting a “weakness” in auditory processing. Moore et al. (2018) in a retrospective review of over 1000 paediatric cases reported a large number of children categorised by clinicians as having a “weakness” who clearly had problems but did not meet common diagnostic criteria. The authors suggested an informal criterion of failing only one test by two standard deviations was being used by clinicians to diagnose “weakness”. Ahmmed and Ahmmed (2016) compared a combination of APD and cognitive test scores against “listening difficulty” defined as 2SD below the mean on the CHAPS questionnaire on 109 children with suspected APD. They concluded that test fail criteria of 1 or 1.5SD below the mean would better select children with listening difficulties.

Clinicians should keep in mind that common diagnostic criteria are arbitrary and may not detect all cases warranting intervention. In cases where test results are not completely normal but do not meet diagnostic criteria, and there is other evidence of hearing difficulty, audiologists can report that the results do not meet the criteria for a formal diagnosis of APD but indicate that the child has a specific difficulty (for example pitch pattern recognition, dichotic processing, etc.) and that this may be indicative of weakness in auditory processing. Children in this category for whom there is concern should still be followed and treatment may still be recommended.

DIAGNOSIS

Audiologists are the only professionals qualified to diagnose APD.

Diagnosis is based on all available information, not just test scores.

Diagnosis should be limited to a “provisional” diagnosis, or a diagnosis of “at risk for APD” in cases where there is incomplete information due to age or other factors.

A diagnosis should be carefully considered, or limited to a “provisional” diagnosis, or a diagnosis of “at risk for APD” if there is the possibility that the test results have been adversely affected by non-auditory factors such as cognitive ability, language limitations, poor attention, a comorbidity, or fatigue. Although these non-auditory factors are important considerations they do not preclude APD testing from being undertaken. If there are signs of fatigue and low motivation, testing should be interrupted to provide rests and encouragement; if needed testing can be halted and resumed on another day.

> *…progressively poorer scores on tests toward the end of a diagnostic session, the presence of “deficits” that resolve with reinforcement, or the observation of poor response reliability are more likely a reflection of increased fatigue and/or decreased attention or motivation rather than manifestations of true CANS dysfunction. (AAA, 2010, p. 22)*

When most or all APD tests are failed a more global disorder may account for the test results.

> *It should be noted that, while the literature on test profiles is not definitive, when poor or inconsistent performance on all tests of auditory processing is seen, clinicians should be cognizant of the strong probability of disorders which are more global in nature, and less likely specific to the auditory channel. (CISG, 2012, p. 23)*

Ultimately diagnosis is the responsibility of the audiologist based on all available information, not just test scores. Diagnosis in the presence of comorbidities is discussed in more detail in the subsequent section on this topic.

Age of assessment and diagnosis

Animal studies identifying early critical periods for CANS development (Clause et al., 2014; Penhune & de Villers-Sidani, 2014) and mitigation by auditory training (Kang, Sarro, & Sanes, 2014) support the importance of early intervention for APD. APD guidelines however usually advise caution in APD assessment of children younger than seven.

The traditional belief that management of APD should be deferred until age seven is attributed to three factors. Firstly, some early APD tests were only normed on children down to age seven. Secondly, parts of the CANS do not fully mature until adolescence or young adulthood, especially in the case of myelination of the corpus callosum which can continue into the early 20s (Yap et al., 2013). Thirdly, and in part because of these maturational factors, behavioural measures on young children show greater inter-subject variability than behavioural measures on older children; hence behavioural test results on young children must be interpreted with caution. However, the age of the child, measurement variability and incomplete audiometric data do not impede early assessment and intervention for other types of deafness (Keith et al., 2014). Hence, early detection and intervention are also recommended for APD (Keith et al., 2014; Lucker, 2015).

A number of tests and assessment tools are available for children below age seven, some with norms from as low as age three. Some describe auditory behaviour rather than assessing central auditory function. Nonetheless useful information concerning a child's hearing abilities can be ascertained. Tests suitable for use with younger children by audiologists in New Zealand are shown in Table 4.

The Pre-school SIFTER (Anderson & Matkin, 1996) is a questionnaire that can be used to assess functional hearing ability in pre-school children.

The American Academy of Audiology CAPD Clinical Practice Guidelines (AAA, 2010) urge caution but support intervention in younger children:

> *A limited number of behavioral auditory measures have been developed for use with younger children.… Use of measures such as these, coupled with behavioral checklists.… can provide insight into children who may be "at risk" for (C)APD, leading to recommendations for close monitoring of skills, enrichment activities designed to develop and augment auditory skills.… and regular follow-up to determine the appropriate diagnosis as early as possible.… Early identification followed by intensive intervention exploits the brain's inherent plasticity. (AAA, 2010, p. 23)*

EARLY DETECTION

- *Early detection of and intervention for auditory processing difficulties are recommended.*

Tests suitable for use with younger children by audiologists in New Zealand are shown in Table 4 and include SCAN-3:C from 5 years of age and the ASA and CELF Pre-School 2 (User Level B) if below 5 years.

Suspected auditory maturational delay or diagnosis of APD in children below the age range at which a complete test battery is possible, or children not capable of completing age-appropriate tests due to comorbidities, can be qualified as being "at risk for", "provisional", or "criteria for diagnosis not met but auditory skill deficits are evident". Intervention may commence at this point on the recommendation of the diagnosing audiologist. Follow-up should be scheduled for more comprehensive and definitive testing as the child matures. Involvement of a wider team is especially important in the management of younger children suspected to have APD. Intervention should not be delayed pending a definitive diagnosis for young children.

Table 4
***Age Ranges of Norms for Selected Tests and Test Batteries Suitable for Assessment of Auditory Skills in Young Children*[1,2,3]**

Tests	Age range of norms (y;m)	Description	Comments
Pediatric Speech Intelligibility (PSI) Test (Jerger & Jerger, 1982) (AUDiTEC™)	3;0 – 6;0 There is an Australian adaptation (Macquarie PSI), with normative data for 51 children aged 7-8 years (Cameron, Barker, & Newall, 2003).	Speech perception in competing sentences. Normative performance-intensity information available for 40 normal-hearing children with message-to-competition ratio levels at +4 dB (words) and 0 dB (sentences).	Normative data; validated for young U.S. children.
Preschool SIFTER (Anderson & Matkin, 1996)	3;0 to 5;11	Teacher questionnaire to identify children at-risk for developmental or educational difficulties due to hearing and other communication problems.	Normative data for 3-6 year old children (Schafer et al., 2012).
Children's Home Inventory for Listening Difficulties (CHILD) (Anderson & Smaldino, 2000)	3;0 – 12;11	Parent questionnaire investigating listening behaviour in the home.	CHILD has been used to demonstrate amplification benefits in children with hearing loss (Christensen, Richter, & Dornhoffer, 2010).
CELF Pre-School 2 (Wiig, Secord, & Semel, 2004) (Pearson Corp.)	3;0 – 6;11	Standardised Expressive and Receptive Language test; subtests include Concepts & Following Directions, useful for assessment of children with suspected APD.	Norms derived from more than 800 preschool children.
Auditory Skills Assessment (ASA) (Geffner & Goldman, 2010) (Pearson Corp)	3;6 – 6;11	Screening subtests assess speech discrimination in noise, tone discrimination and patterning and phonological skills.	Reliability and validity established on over 600 children tested at 123 locations to reflect US population demographics.
Wepman's Auditory Discrimination Test (ADT) (2nd Edn) (Wepman & Reynolds, 1987)	4;0 – 8;11	Live voice phoneme discrimination test. 40 pairs of words, child indicates same or different.	Norms derived from 2000 children. No longer available from original publisher.
Phonemic Synthesis – Picture Test (Katz & Harmon, 1982) (Precision Acoustics)	4;0 – 7;11	Phonemic blending task.	
Staggered Spondaic Word Test (SSW) (Katz, 1962) (Precision Acoustics)	5;0 – 69;11	Dichotic spondee word test. The second syllable of one spondee overlaps with the first syllable of the contralateral spondee.	U.S. norms available for 5-6 year olds and older children and adults; high validity and reliability.

1 Table adapted from Keith et al. (2014).
2 Inclusion criteria for APD tests and test batteries: Selected tests and test batteries supported with published studies with appropriate norms for younger children, evaluated on groups of individuals with diagnosed or suspected APD.
3 See Appendix 4 for information about the reliability, specificity and sensitivity of tests listed.

Table 4
Age Ranges of Norms for Selected Tests and Test Batteries Suitable for Assessment of Auditory Skills in Young Children[1,2,3] (continued)

Tests	Age range of norms (y;m)	Description	Comments
Bamford-Kowal-Bench Speech-in-Noise (SNR) Test (BKB-SIN) (Killion et al., 2001) (Etymotic Research)	5;0 – 14;11	BKB sentences in babble. Modified adaptive task.	High validity, reliability and sensitivity; may be used with any population; simple administration and scoring; portable and may be used in the classroom; inexpensive CD recording; may have ceiling/floor effects at standard SNRs (Schafer, 2010).
Speech-in-Noise Test (Katz, 1992) (Precision Acoustics)	5;0 – Adult (30 years)	Central Institute for the Deaf (CID) W22 words in quiet and at +5 dB signal to noise ratio.	
SCAN-3:C (Keith, 2009) (Pearson Corp)	5;0 – 12;11	Includes screening and diagnostic tests of a range of auditory skills including gap detection and dichotic listening.	Well known test battery with established reliability and validity.
Randomized Dichotic Digits Test (RDDT) (Moncrieff & Wilson, 2009; Moncrieff, 2011) (dichoticsinc.com)	5;0 – 28;11	Dichotic digit pairs consisting of one, two or three digits per ear are presented in random order. Two digit scores used diagnostically (Moncrieff et al., 2016).	Established reliability and validity; norms available for diagnosis of amblyaudia.
Dichotic Words Test (DWT) (Moncrieff, 2011, 2015) (dichoticsinc.com)	5;0 – 12;11	Lists of single words presented dichotically.	Established reliability and validity; norms available for diagnosis of amblyaudia.
Differential Screening Test for Processing (DSTP) (Richard & Ferre, 2006) (LinguiSystems Inc)	6;0 – 12;11	Three levels: acoustic (dichotic digits, temporal patterning, auditory discrimination) plus phonological and linguistic levels.	Norms from 509 children representing Year 2000 National Census for race, gender, age, and educational placement.
Listening in Spatialized Noise-Sentences (LiSN-S) (Cameron & Dillon, 2007) (Phonak AG)	6;0 – 60;0	Adaptive computer-based test of speech in spatialised noise perception.	Well established norms and a validated training programme linked to the assessment.
Phonemic Synthesis Test (Katz & Harmon, 1982) (Precision Acoustics)	6;0 – Adult	Phonemic blending task.	

1 Table adapted from Keith et al. (2014).
2 Inclusion criteria for APD tests and test batteries: Selected tests and test batteries supported with published studies with appropriate norms for younger children, evaluated on groups of individuals with diagnosed or suspected APD.
3 See Appendix 4 for information about the reliability, specificity and sensitivity of tests listed.

Diagnosis in the presence of comorbidities

A high proportion of children with APD have comorbidities (BSA, 2011, pp. 6, 13). At times these may limit meaningful interpretation of test results, but some useful information can usually be obtained. The conservative approach, to not test children with other disabilities, is not recommended as this may prevent children with genuine hearing problems from receiving appropriate treatment, and may breach the individual's rights. Evaluation of children with comorbidities is best carried out by audiologists experienced in APD assessment and clinicians must always be cognisant of confounding factors. Irrespective of the cause of low test scores, treatment is likely to be beneficial.

DIAGNOSIS IN THE PRESENCE OF COMORBIDITIES

Children with comorbidities, including other types of hearing disorders, can and should be assessed for APD by audiologists experienced in APD assessment.

Providing extra reinforcement and breaks may enable a child with attention difficulties to pass the test battery. Children on medication for ADHD should be tested at a time of day when the medication is at its most effective.

The presence of attention and/or memory difficulties do not preclude the possibility of reliable APD test results being obtained, but should be considered when interpreting results. If a complete assessment cannot be conducted due to comorbidities, then selected tests can be completed.

Children with language or cognitive impairment may be tested with tests developed for younger children. For example, a child with global developmental delay may be assessed on tests developed for younger children if their language and cognitive abilities are equivalent to children in the age range for that test. Tests with low language loading such as dichotic digits, frequency pattern testing, and perception of gaps in noise may provide meaningful information on a child with a language disorder.

Some tests use within-subject comparison as a measure, for example in measuring interaural asymmetry on dichotic tests for amblyaudia, or assessing spatial stream segregation using the LiSN-S Test (Cameron & Dillon, 2008). In cases where there is concern about comorbidities, findings for these tests may be more robust as the results are corrected for the child's overall performance. If a child passes despite a co-existing disorder then APD can be ruled out.

If a child fails most or all tests this may be indicative of wider learning or developmental issues rather than a primarily auditory problem. However auditory processing is likely to be adversely affected by the global developmental problem. The validity of each result must be weighed and a diagnosis of APD should be carefully considered if there is a possibility of confounding factors affecting the test results. Even when a definitive diagnosis is not possible some contribution to understanding the individual's difficulties can usually be achieved if auditory processing testing is undertaken using appropriate tests.

If a clear diagnosis of APD is not possible the audiologist has a responsibility to consider whether intervention should be considered in cases where there is poor performance on auditory tasks. There may well be comorbid APD even if it cannot be verified. Further, the interventions used for APD are generally applicable across a range of disabilities. For example, there is evidence that amplification with RMHAs is effective for children with a variety of learning disorders including autism spectrum disorder (ASD), ADHD, and dyslexia (Schafer et al., 2013; Rance, Saunders, Carew, Johansson, & Tan, 2014; Hornickel et al., 2012). Audiologists should work with other relevant professionals when assisting with treatments for conditions outside the audiological scope of practice, for example when overseeing a trial of RMHAs for children with ASD, ADHD, language disorder or global developmental delay.

The ICF framework provides a useful focus on activities and participation rather than diagnosis of the impairment and hence is particularly applicable for children with a range of difficulties in addition to hearing problems. Gathering as much information as possible about an individual's ability to participate in various auditory environments will assist in reaching management decisions when APD is suspected but cannot be clearly confirmed.

Diagnosis in the presence of other types of hearing loss

Conductive and sensorineural hearing losses are common in children and elderly persons and can adversely affect performance on auditory processing tests. In some circumstances experienced audiologists can nonetheless deduce meaningful conclusions about auditory processing ability. This is more likely with mild and/or symmetrical hearing losses. Presentation intensity can be increased to compensate for hearing loss (more gain compensation is appropriate for conductive than for sensory losses) but this too can confound results. Tests such as the Frequency Pattern Test and the Dichotic Digits Test have validated guidelines for adjusting the test presentation level to overcome the effects of mild-moderate hearing loss (Guenette, 2006; Musiek, 2002). One APD test, the LiSN-S (Cameron & Dillon, 2007) has a built-in peripheral hearing loss compensation algorithm.

If APD tests are passed despite peripheral hearing loss then APD can be ruled out. If APD tests are failed in the good ear in cases of unilateral hearing loss then the finding is suggestive of APD. Asymmetric performance on APD tests in the presence of a symmetrical hearing loss increases suspicion of APD. Results on tests with validated guidelines for adjusting presentation levels carry more weight. Clients should be cautioned that testing in the presence of peripheral hearing loss will frequently yield more limited information than testing in the absence of peripheral hearing loss. The AAA Guidelines summarise the issues well.

> *The influences of the peripheral auditory system on central auditory function must be considered to determine whether the individual can be reliably assessed. Multiple studies have demonstrated the potential negative impact of peripheral hearing loss on central auditory test performance (Divenyi & Haupt, 1997; Humes, Coughlin, & Talley, 1996; Musiek, Baran, & Pinheiro, 1990; Musiek et al., 1991; Neijenhuis, Tschur, & Snik, 2004). While those with significant degrees of bilateral hearing loss who exhibit reduced word recognition skills cannot be accurately assessed, those with lesser degrees of loss and good speech recognition abilities may be candidates for assessment using tests that have shown to be less affected by cochlear hearing loss (e.g., dichotic digit tasks, frequency patterning tasks). For example, it is possible to make a statement about CANS function in an individual with mild-to-moderate hearing loss when central auditory processing performance measures are normal. It is also possible to diagnose (C)APD in individuals with hearing loss when certain patterns of performance emerge (e.g., poorer central auditory performance in the normal hearing ear in individuals with unilateral hearing loss, asymmetrical performance on a central test battery in individuals with symmetrical hearing loss, the presence of ear or electrode effects on electrophysiologic test measures in individuals with bilateral symmetrical hearing loss) (see Baran & Musiek, 1999; Musiek & Baran, 1996). Conversely, the lack of a clear discernible pattern of central auditory performance may represent the influences of peripheral hearing loss (e.g., when central test results are depressed bilaterally in an individual with a bilateral, symmetrical hearing loss). In such cases, a definitive diagnosis of (C)APD should be withheld, even though the possibility of a (C)APD may exist. (AAA, 2010, p. 12)*

DIAGNOSIS IN THE PRESENCE OF OTHER TYPES OF HEARING LOSS

In some cases APD assessments can be conducted in the presence of peripheral hearing loss by experienced audiologists. The information obtained may be limited but frequently some helpful information is obtained.

As with diagnosis in the presence of comorbidities, the ICF framework provides a useful focus on performance and participation. Gathering as much information as possible about how an individual's hearing ability affects their participation in classroom learning and other activities will assist in planning management.

Assessment of functional disability

Most APD research focuses on the nature of APD or its diagnosis and treatment. There is a dearth of research on measurement of functional impact. The pure tone average, speech recognition scores, the articulation index, questionnaires and other metrics provide means of quantifying peripheral hearing loss. In general there is a lack of instruments that accurately quantify the impact of APD and assess an individual's ability to participate fully in their own life and in society. Some questionnaires describe the areas of difficulty experienced by the individual (ECLiPS (MRC, 2014), SSQ (Galvin & Noble, 2013), APDQ (O'Hara, 2006; O'Hara & Mealings, 2018)) but most do not quantify the disability. Measures and categories of degree of disability (e.g. mild/moderate/severe as used for other types of hearing loss) would better inform management plans and would assist in prioritisation of cases for allocation of resources.

Because individuals with APD may hear well in ideal listening situations, an objective measure of disability due to APD should incorporate factors known to create difficulty for individuals with APD, for example low signal to noise ratio (SNR), soft speech, competing speech, rapid speech, distorted speech (e.g. due to accent, reverberation, electronic processing), and lengthy or complex utterances. As well as quantifying disability, a test incorporating some of these features would be useful for measuring the effectiveness of treatments and might also prove useful for screening for cases warranting further investigation. Tests such as the University of Queensland Understanding Everyday Speech Test (UQUEST) (Kei et al., 2003; Wilson et al., 2013) and the Auditory-Visual Matrix Sentence Test in New Zealand English (O'Beirne, Trounson, McClelland, Jamaluddin, & Maclagan, 2015), though not yet commercially available, show promise in meeting some of these requirements. Questionnaires such as the ECLiPS (MRC, 2014), SSQ (Galvin & Noble, 2013), APDQ (O'Hara, 2006; O'Hara & Mealings, 2018) and UCAPI (Tektas et al., 2017; Ramsay et al., 2017; Keith et al., 2019) may also prove useful. The Hearing Environments and Reflection on Quality of Life Questionnaire for Children ages 7 to 12 (HEAR-QL Questionnaire for Children) (Umansky, Jeffe, & Lieu, 2011) is a quality of life measure designed specifically for children with hearing loss. It takes into account the child's subjective experience considering psychosocial factors, activity restriction and hearing environments, and may have promise for use with children with APD. Clinicians are encouraged to explore methods of quantifying the functional impact of APD on individuals so that treatment can be tailored to an individual's needs, as encouraged by the CRPD model.

MANAGEMENT

MANAGEMENT

Management of APD comprises:

1) Treatment

- direct treatment of the hearing disorder with amplification and/or auditory training
- treatment of accompanying or consequential areas of difficulty such as phonological development, language, reading, anxiety, psychosocial challenges, academic areas
- counselling in strategies to enhance the coping skills of the person with APD, including communication strategies

2) Referral

- to other professionals, for example speech-language therapist, psychologist, paediatrician, behavioural optometrist, for investigation of any areas of concern and/or for treatment

3) Information and support

- face to face informational counselling for clients or parents supplemented with culturally and linguistically appropriate printed and online information, and seminars for parents if available
- contact details for consumer or parent support groups
- provision of support materials to teachers, preferably with support from specialists with knowledge about APD.

The aim of therapy is to reduce activity limitation and thus improve participation (see Figure 2 for the WHO-ICF framework relevant to APD, and UN CRPD Key Principles later in this document).

Direct treatment of the auditory disorder by amplification is the role of audiologists. Direct treatment of the auditory disorder by auditory training, e.g. dichotic training, hearing in noise training, is also the responsibility of audiologists but may be delegated under supervision.

Speech-language therapists are the professionals with skills to treat the associated or consequential speech, language and phonological disorders in individuals with APD, and may also provide therapy in areas such as phonics, psychosocial adjustment and coping strategies. Speech-language therapists can provide direct therapy for the child, as well as strategies for key people in the child's life such as family/whanau, and educators. Communication strategies can be taught by speech-language therapists, audiologists and hearing therapists.

Learning support personnel and psychologists may provide specialist interventions, for example for learning or psychosocial consequences of APD.

Classroom teachers carry the daily responsibility of providing accessible education for children with APD and accordingly require support and guidance from other involved professionals.

MANAGEMENT

Management comprises:

- direct treatment of the hearing disorder with amplification and auditory training (the responsibility of audiologists)
- treatment of accompanying or consequential effects such as language disorder, phonological and reading problems, and coping difficulties (principally the responsibility of speech-language therapists and learning support personnel)
- referral to other professionals as required
- provision of information and support.

Intervention principles

Early intervention is best

Because APD arises from dysfunction within the brain, and neuroplasticity enables the brain to change, auditory processing skills may improve with appropriate treatment in children whose auditory processing skills are not developing typically. With a combination of assistive and therapeutic approaches, there is growing evidence that auditory processing disorders can be effectively treated (Chermak & Musiek, 2013). As with any type of hearing disorder, effective early intervention provides the best possibility of minimising adverse effects. Brain training research indicates that neuroplastic training can occur at any age and that treatment of APD should be possible at any age.

Informational counselling following diagnosis

For children diagnosed with APD the first step following diagnosis is effective informational counselling for the parents, child, teachers and other significant persons in a child's life. This can be provided face to face in the clinical setting and through other media. It is essential that educational personnel in the school setting acquire knowledge of APD in order to appropriately identify listening difficulties and support children with APD in the classroom. Informational counselling should be supplemented by handout and online materials, by seminars for parents, and supported by consumer and parent support groups. Culturally and linguistically appropriate materials are needed to engage families and professionals in decision making and management of APD.

Adults diagnosed with APD also require informational counselling and support may be provided by hearing therapists.

Treat the auditory disorder first

As with any hearing disorder, treatment starts by treating the auditory problems first. That is, auditory training (such as correction of amblyaudia), and fitting of RMHAs if indicated, are first priorities. Optimal audition is the first goal. This is sometimes referred to as bottom-up therapy. Other treatments such as phonological awareness training, treatment of consequential effects, language therapy and compensatory, metacognitive and metalinguistic interventions (top-down therapy) follow or can be initiated in parallel.

TREAT THE AUDITORY DISORDER FIRST

As with any hearing disorder a bottom-up approach of treating the hearing disorder first is favoured. Language therapy and compensatory, metacognitive and metalinguistic interventions (top-down treatments) follow or can be initiated in parallel.

Evidence-based treatment

Randomised controlled trials (Class 1 evidence) of treatment for APD are scarce. Clinicians have to appraise evidence from non-randomised controlled (Class 2) studies; observational, retrospective, case and cohort studies with controls (Class 3); and expert and consensus reports and studies without controls (Class 4 and 5 evidence) (AAA, 2010, p. 51). Treatments which might be useful but have never been tested, for example commercially available "brain training apps", are promoted by commercial suppliers to professionals and parents as APD treatments. Alternative treatments which have been investigated and found not to be supported by research evidence are also advertised and promoted directly to parents by individuals without relevant professional qualifications. Some of these alternative treatments are addressed later (see section on 'Alternative treatments'). Parents are encouraged to ask about the evidence behind treatments offered and are advised against using non-evidence-based treatments. Clinicians are bound by their ethical responsibility to strive to provide evidence-based services. Clinicians also bear a responsibility to educate clients about the limitations and potential dangers of non-evidence-based alternative treatments (AAA, 2010, p. 34).

Multi-disciplinary approach

A multi-disciplinary approach is required for holistic management of APD.

> *Given the potential impact of (C)APD on listening, communication, and academic success, broad and comprehensive intervention involving a multidisciplinary team typically is required to maximize treatment effectiveness. (AAA, 2010, p. 24)*

Parents are central to the management of APD in children. The various professionals who may be involved in supporting children with APD need to cooperate in providing consistent advice and support to families.

It is the responsibility of audiologists to prescribe auditory training and to administer the training in cases where the procedure requires specialist audiological expertise or equipment, for example some forms of dichotic training and some auditory recognition and discrimination tasks. Audiologists are also responsible for fitting of RMHAs. Information and training in communication strategies and metacognitive skills can be provided by a number of professionals, audiologists included.

MULTIDISCIPLINARY TEAM APPROACH

Many professionals may be involved, alongside parents, in the management of APD in children. In addition to audiologists, professionals potentially involved include speech-language therapists, classroom teachers, psychologists, SENCOs, RTLBs, AoDCs, ATCs, other learning support personnel, SPELD teachers, medical practitioners, and occupational therapists. Hearing therapists may be involved in supporting adults with APD.

As the professionals responsible for diagnosing APD, and providing first treatment, audiologists carry case management responsibility for clients with APD.

Speech-language therapists can provide some auditory training when specialist audiological equipment is not necessary. The scope of practice for speech-language therapists includes phonemic and phonological awareness training. This training may be incorporated into other language therapy as needed. Speech-language therapists may also provide therapy or support to develop compensatory, metacognitive and metalinguistic skills.

Psychologists may also be involved in providing advice on classroom, learning, compensatory, metacognitive and psychosocial interventions, and particularly in children with comorbid difficulties.

Education personnel such as AoDCs and RTLBs may provide guidance for families, Special Education Needs Coordinators (SENCOs) and teachers concerning children with APD. The local Assistive Technology Coordinators (ATCs) may be involved in provision of RMHAs. If a child is diagnosed by an audiologist as having APD, a referral can be made to the local Ministry of Education office for school liaison, additional learning support and teacher guidance. The school's Ministry of Education Service Manager would check the child's eligibility for assistive technology to support the trial of RMHAs. Following the fitting of RMHAs by an audiologist, the AoDC may provide teacher guidance and support for the assistive technology trial. SENCOs and teachers are integrally involved in in-school management including appropriate use of assistive technology. Learning support teachers, including SPELD NZ teachers, may provide phonological awareness, phonics and reading training that is helpful to children with APD (Waldie, Austin, Hattie, & Fairbrass, 2014).

If there are comorbidities, other specialists such as paediatricians, psychologists, occupational therapists and others may need to be involved. Hearing therapists can provide listening strategies and informational counselling for 16+ year olds. Young people and their families may need support from psychology or counselling services to address the psychosocial consequences of APD such as anxiety and depression (Crandell, 1998; Kreisman et al., 2012).

As the professionals responsible for diagnosing APD, audiologists carry the responsibility of case management, ensuring that appropriate referrals are made and followed through, and that parents are assisted in navigating the services involved. Audiologists may not be accustomed to providing habilitative/rehabilitative training therapies but have a responsibility to do so in providing APD services.

Auditory training

Auditory training is a fundamental form of treatment for APD. It is recommended that evidence-based auditory training is incorporated into APD management. There are many studies on the value of auditory training showing improvement in hearing skills and neuroplastic development (Jirsa, 1992; Putter-Katz, Adi-Bensaid, Feldman, Miran, Kushnir, Muchnick, & Hildesheimer, 2002; Musiek, Chermak,

& Weihing, 2007; Putter-Katz, Adi-Bensaid, Feldman, & Hildesheimer, 2008; Moncrieff & Wertz, 2008; Sharma, Purdy, & Kelly, 2012; Denman, Banajee, & Hurley, 2015; Kaul & Lucker, 2016; Loo, et al., 2016; Barker & Bellis, 2018; Kozou, Azouz, Abdou, & Shaltout, 2018; Melo, Mezzomo, Garcia, & Biaggio, 2018; Moncrieff, 2018; Nanjundaswamy, Prabhu, Rajanna, Ningegowda, & Sharma, 2018; Osisanya & Adewunmi, 2018; Saunders et al., 2018; Gopal, Schafer, & Mathews, 2018).

Because of neuroplasticity, auditory training can improve skills on certain auditory tasks. The important question is whether the auditory training generalises to real world listening skills (Dillon & Cameron, 2015). Several of the studies quoted above show generalisation to abilities beyond the particular skills trained, but this is not necessarily the case with all auditory training treatments.

Training on an individual psychoacoustic skill at a particular frequency and intensity: for example, because a test of that skill was failed, might help in passing the test but do little to improve speech perception given the multiplicity of frequencies, intensities, and temporal characteristics involved in speech.

> *…the range of neural processing operations needed to analyse a signal as complex as speech in sufficient detail to identify individual speech sounds is huge and complex. (Dillon & Cameron, 2015, p. 4)*

More comprehensive approaches such as phonological and speech-based auditory training may be more valuable than training focused on individual psychoacoustic skills. For example, auditory training to improve phoneme discrimination has been shown to improve reading (Veuillet et al., 2007). A recent study (Loo, Rosen, & Bamiou, 2016) showed significant benefits of "broad speech-based auditory training" in children with APD.

> *Research on the effects of direct intervention using auditory training to ameliorate auditory processing difficulties is variable. Moore (2011) notes that psychoacoustic research indicates that it is very possible to demonstrate improvement on a psychoacoustic task when the outcome measure is on capacities but that the research is less clear on whether that improvement will generalize to real world listening performance. Moore cites research from the field of vision and stroke rehabilitation to suggest that neurological change with training is possible, but notes that the pediatric clients with auditory processing disorder bring with them difficulties with complex problems in listening, learning and cognition, along with poor attention and memory. Moore suggests that audiologists should continue to explore auditory training interventions, but notes that "for these complex skills, the most promising method of training would seem somehow to embed highly targeted language skill development in exercises with very high levels of engagement approaches." (CISG, 2012, pp. 31-32)*

AUDITORY TRAINING

- *It is recommended that evidence-based auditory training is incorporated into APD management.*

Language-based treatments may be more effective than training on psychoacoustic tasks.

Training of individual psychoacoustic skills is not generally used in other areas of hearing habilitation whereas the effectiveness of language-based approaches is well recognised for habilitation of children with other types of hearing disorder.

Training principles

There is extensive research on principles of neuroplastic training.

> *Effective intervention should be applied consistent with neuroscience and learning principles (Chermak & Musiek, 2007; Merzenich & Jenkins, 1995). These principles indicate 1) intensive training to exploit plasticity and cortical reorganization (i.e., considerable practice and significant challenge by working near the individual's skill threshold); 2) extensive (multidisciplinary) central resources training to*

exploit large, shared, and overlapping auditory, cognitive, metacognitive, and language systems, and maximize generalization and effectiveness; and 3) active participation, coupled with salient reinforcement and feedback to motivate and maximize learning. (AAA, 2010, p. 25)

Neuroplasticity underpins auditory training and requires that activities are sufficiently challenging (i.e. at the 'Edge of competence') and repeated over extended periods of time to be likely to be effective (for example, 30 minutes, 3-4 times a week for 6 weeks). (BSA, 2011, p. 17)

An accumulating literature has demonstrated the neurophysiologic basis for auditory training, which is one of the most investigated of the treatment approaches outlined here (Palmer, Nelson, & Lindley, 1998; see Chermak, Bellis, & Musiek, 2007; Moore, 2007; Moore, Halliday, & Amitay, 2009 for reviews). The effectiveness of auditory training is maximized by:

- *Varying stimuli and tasks;*
- *Presenting stimuli at comfortable listening levels (or slightly louder and slower; e.g., dichotic listening training, clear speech, computerized software programs that incorporate amplitude and/or transition duration changes);*
- *Presenting tasks systematically and graduated in difficulty to be challenging and motivating, but not so difficult as to be overwhelming (i.e., work should be focused near the individual's skill threshold);*
- *Targeting a moderate degree of accuracy with generous feedback and reinforcement;*
- *Requiring at least a moderate degree of accuracy or performance of poorer ear comparable to that of better ear before proceeding to a more demanding task;*
- *Providing intensive practice (i.e., frequent, perhaps daily) distributed in regard to length of training sessions, number of training sessions, time intervals between sessions, and period of time over which training is conducted (Chermak & Musiek, 2002; Musiek et al., 2007). (AAA, 2010, p. 25)*

Correction of amblyaudia

Amblyaudia, a unilateral weakness or inhibition of one ear affecting binaural integration (Moncrieff, 2002), is a common and discrete auditory processing disorder which is readily ameliorated by specific auditory training. It presents as an abnormal interaural asymmetry on dichotic testing and affects approximately half of children with APD (Moncrieff et al., 2016). Amblyaudia may adversely affect any aspect of hearing requiring binaural function for optimal audition.

The ARIA (Auditory Rehabilitation for Interaural Asymmetry) procedure of Moncrieff and Wertz (2008) generally takes four dichotic auditory training sessions of one hour each (including a 20 minute break) over four weeks to correct most cases of amblyaudia (Moncrieff, Keith, Abramson, & Swann, 2017). Dichotic stimuli are presented via loudspeaker. The intensity is initially reduced in the dominant ear then gradually increased until the non-dominant ear can achieve normal performance in the presence of contralateral competition. The intensity in the dominant ear is increased in small steps, as small as 1dB, to maintain performance at the "edge of competence" in the non-dominant ear. Moncrieff and Wertz (2008) observed significant improvements in word recognition and listening comprehension as a result of ARIA dichotic training for amblyaudia. Moncrieff (2018) reported significantly improved recognition of speech in background noise in children receiving ARIA treatment.

The DIID (Dichotic Interaural Intensity Difference) training procedure (Weihing & Musiek, 2007) is similar in principle to the ARIA method but uses more standard stimulus step sizes and shorter but more frequent training sessions over 2-3 months (Weihing, Chermak, & Musiek, 2015).

Amblyaudia may be explained at least in part by a suppression mechanism affecting the non-dominant ear (Popescu & Polley, 2010). Amblyaudia treatment may release the non-dominant pathway from suppression. The possibility that resolution of amblyaudia involves release from inhibition rather than new learning, and the treatment methodology of favouring the "weak" ear while constantly maintaining the intensity of competition from the dominant ear just below the level at which contralateral inhibition is triggered, in the ARIA method in particular, might explain how amblyaudia can be quickly corrected.

Unlike some auditory processing disorders, there is no evidence that amblyaudia is ameliorated over time by fitting of RMHAs (Keith & Purdy, 2014). It is therefore recommended to treat amblyaudia concurrently or before commencing other auditory treatments.

Dichotic training

Moncrieff et al. (2016) refer to below normal dichotic scores bilaterally as dichotic dysaudia. Whereas amblyaudia can often be quickly corrected, clinical experience indicates bilateral improvement in cases of dichotic dysaudia through dichotic auditory training is slower and more difficult. Moncrieff et al. (2017) showed some bilateral improvement in dichotic scores from ARIA training (usually four sessions) in children with both amblyaudia and dichotic dysaudia. Further sessions were recommended for cases where scores remained below typical levels. Bellis (2003, 2008) and Bellis and Anzalone (2008) report case studies also showing beneficial results of dichotic training.

Hearing in noise and spatial stream segregation

A number of commercial software products include diotic exercises for training hearing in the presence of background competition. This paradigm may be useful as a figure-ground perceptual training task. There is one software programme for training spatial stream segregation (see later section on Computer-based training). Auditory training in the presence of noise may be beneficial for children who have difficulty listening in noisy conditions. A study by Maggu and Yathiraj (2011) with a small number of children demonstrated that noise desensitization training was effective.

Other deficit-specific training

Commercial software programmes for reading, learning and auditory processing disorders include various auditory skill tasks, mostly speech-based. Some of these are discussed in a subsequent section.

Specific musical pattern games such as “Simon” available online are commonly used to train pitch pattern skills (for children who fail a pitch pattern test). While there may not be specific evidence concerning this practice, there is abundant research on the value of more holistic music training for auditory processing skill development (see subsequent section). Training on one specific task is unlikely to confer all the benefits of more general music training.

Auditory memory is a discrete auditory skill for which there is a choice of remedial software programmes. There is evidence of memory training benefit but doubt as to whether this transfers beyond the training task or is long-lasting (Melby-Lervag & Hulme, 2013; Hulme & Melby-Lervag, 2012; Shipstead, Hicks, & Engle, 2012a; Shipstead, Hicks, & Engle, 2012b). In contrast, improvement in verbal memory has been measured as a result of wearing RMHAs with the improvement still measurable one year later (Phonak, 2004; Umat, Mukari, Ezan, & Din, 2011).

Computer-based auditory training

Computer-based auditory training (CBAT) typically incorporates training in game format to engage the subject. Adaptive algorithms are often incorporated to continually adjust level of difficulty to the optimal level for the subject. CBAT provides the convenience of home use, and sometimes lower cost than one on one sessions with a therapist. One such programme, at least, typically costs many thousands of dollars.

Because of the varying effectiveness and evidence quality for available programmes it is important that they are selected and used under professional guidance with reference to the evidence base. Clinicians should specify the sections and levels to be completed, rather than letting the person doing the training or a family member simply choose the tasks and levels that they like. Progress should be monitored.

A number of CBAT software programmes are promoted for APD treatment despite being originally developed for language and reading improvement. Research on these is contentious, with studies variously reporting positive and negative findings. Irrespective of whether such programmes remediate auditory processing, given the high degree of comorbidity between APD and reading disorders (Sharma et al., 2009), phonics-based reading programmes may nonetheless be helpful for many children with APD. The LDA (Learning Difficulties Australia) Position Statement (2015) released 12 May 2015 on approaches to reading instruction reflects the negative findings of meta-analytic reviews of some programmes for reading development. The importance of being able to correctly recognise and manipulate phonemes is emphasised however.

> *LDA supports approaches to reading instruction that adopt an explicit structured approach to the teaching of reading and are consistent with the scientific evidence as to how children learn to read and how best to teach them. This approach is important for all children, but is particularly important for children who have difficulty in learning to read. Programs that follow an explicit structured approach to the teaching of reading include as an integral part of the teaching program specific instruction in phonology (phonological and phonemic awareness), sound-symbol associations (letter-sound correspondences), as well as syllable structures, morphology, syntax and semantics (the structure, use and meaning of words) as a basis for developing accurate and fluent word reading and reading comprehension. Such programs conform to the definition of 'structured literacy programs' as adopted by the International Dyslexia Association in July 2014, and place emphasis on the importance of learning the alphabetic code and the twin processes of blending and segmenting as the basis of learning to read. They do not include programs that follow a whole language or 'balanced literacy' approach, which place emphasis on the three cueing system and guessing from context as acceptable strategies for identifying words. Examples of programs that follow an explicit structured approach to the teaching of reading include but are not limited to programs such as Jolly Phonics, Read Write Inc., Sounds-Write, Get Reading Right, the MultiLit suite of programs, and the various programs based on the Orton-Gillingham approach. Examples of programs that follow a whole language or 'balanced literacy' approach include but are not limited to programs such as Reading Recovery and the literacy approaches developed by Fountas and Pinnell, including Levelled Literacy Intervention and Guided Reading. LDA does not support or endorse programs that place emphasis on the exercise or training of underlying brain processes including working memory as the basis for improving reading or other academic skills. Such programs include Brain Gym, Fast ForWord, CogMed and the Arrowsmith education program. (LDA, 2015, https://www.ldaustralia.org/client/documents/LDA%20Position%20Statement.pdf)*

The BSA Practice Guidance document (2011, pp. 17-20) reviews studies of the effects of CBAT programmes on APD measures:

> *Loo, Bamiou, Campbell, & Luxon (2010) reviewed the existing evidence for computer based auditory training in children with language, learning and reading difficulties, and evaluated the extent to which it can benefit children with auditory processing deficits. Searches, using 4 data bases, were confined to studies published between 2000 and 2008, and were rated according to the level of evidence hierarchy proposed by ASHA (2004). Sixteen studies (with evidence levels ranging from I to IV) were identified: thirteen studies of Fast ForWord and three studies of Earobics. The results suggest that, apart from the phonological awareness skills, FFW and Earobics programmes do not seem to have much effect on the language, spelling and reading skills of children beyond that observed using non computer-based speech and language therapy. Loo et al. (2010) reported that there is some limited evidence to support remediation of auditory processing deficits, but emphasised that randomised control studies are necessary. (BSA, 2011)*

Some clinicians use selected sections of CBAT programmes to supplement one-on-one therapy with a child.

AUDITORY TRAINING TREATMENTS

Because of the varying effectiveness and evidence quality for available computer-based auditory training programmes, it is important that they are evidence-based and selected and used under professional guidance.

Dichotic training is widely used and may confer generalised benefits.

Software-based treatment of spatial perception disorder has been shown to effectively improve hearing in competition.

A CBAT App to explicitly teach recognition and discrimination of each phoneme in English, with sound-letter correspondences, to the point where phoneme decoding is almost automatic thus freeing up maximum cognitive resources for reading comprehension, has been developed as part of the Magic Penny Reading programme. However because the phonemes in this App are recorded with a U.S. accent it is not suitable for use in New Zealand.

The Sound Storm[7] software programme (previously LiSN & Learn) developed by the National Acoustic Laboratories, Australia (Cameron & Dillon, 2011; Cameron, Glyde, & Dillon, 2012; Cameron & Dillon, 2016) is an evidence-based CBAT programme which treats a specific central auditory deficit, impaired spatial stream segregation (the ability to separate acoustic stimuli from distracting stimuli that arrive from other directions). The programme uses head-related transfer functions to produce a three-dimensional auditory environment under headphones. Spatially separated speech stimuli simulate real life spatial listening. This is an evidence-based auditory training programme which remediates the discrete auditory processing skill of spatial stream segregation. Training can be carried out at home with five brief training sessions per week for 10 weeks. This programme has demonstrated efficacy for treatment of spatial processing disorder (Cameron, Glyde, & Dillon, 2012). Although this programme is designed for children it is sometimes used by adults who need practice on this skill.

LACE (Listening and Communication Enhancement) (Neurotone Inc) is an adaptive auditory training programme designed to improve listening and communication skills (Sweetow & Sabes, 2006). It is oriented to adults with sensory hearing loss and is evidence-based. LACE contains useful training materials for adults and older children with APD.

clEAR™ (customized learning: Exercises for Aural Rehabilitation) (Tye-Murray, 2016) is a computerised auditory brain training programme for adults with hearing loss aimed at enhancing speech perception of generic talkers and frequent communication partners. It is customised to the individual and is only offered through a hearing care professional with the patient receiving regular contact from the clinician. Its efficacy for hearing losses other than APD is supported by extensive research (Barcroft et al., 2011; Barcroft, Spehar, Tye-Murray, & Sommers, 2016; Sommers, Tye-Murray, Barcroft, & Spehar, 2015; Tye-Murray et al., 2012; Tye-Murray, Spehar, Sommers, & Barcroft, 2016) but there is as yet none specifically on APD. clEAR™ is worthy of evaluation for use with people with APD.

Programmes from Acoustic Pioneer (Zoo Caper Sky Scraper, Insane Earplane; Barker, 2015) use adaptive, repetitive activities designed to improve dichotic listening skills and tonal listening and processing skills (Ferre, 2016). Zoo Caper Skyscraper uses interaural dichotic lead and lag times for dichotic training. There is as yet little, and in some cases conflicting, research evidence in support of the effectiveness of these particular training games (Moses, 2016; Barker & Bellis 2018). Barker and Bellis (2018) showed improved dichotic listening skills in a group of children with dichotic listening problems following training with Zoo Caper Skyscraper. As is the case with many computer-based training programmes, there is a need for further research using randomised controlled study designs with adequate statistical power and appropriate outcome measures to determine the efficacy of these treatments.

7 Sound Storm is available for use on iOS devices (iPhones and iPads); the previous version LiSN & Learn is still available for use on PCs (with the same content but less engaging games).

There are many brain auditory training computer applications which claim to improve auditory processing available for mobile devices. A limitation is that they are generally not evidence-based and where there is evidence it may be from the commercial suppliers. In some cases auditory processing is claimed to be improved, but not specifically on participants with APD (Mahncke et al., 2006).

Other therapy materials and programmes for clinicians

A wide range of non-computer-based materials and programmes is available for APD therapy from speech-language therapy publishers such as LinguiSystems (www.linguisystems.com). The BSA Practice Guidance document (BSA, 2011) lists some resources commonly used by speech-language therapists. Examples of programmes include:

- Winget (2007). Differential Processing Training – three workbooks: Acoustic Tasks, Acoustic-Linguistic Tasks, and Linguistic tasks
- The Central Auditory Processing Kit by Mary Ann Mokhemar (1999).

The book 'Therapy for Auditory Processing Disorders: Simple, Effective Procedures' by Katz (Educational Audiology Association, www.edaud.org, 2009) is a workbook published in binder format with techniques for remediation of various aspects of APD according to the Buffalo Model of (C)APD. Of particular interest are specific methods for training recognition, discrimination and synthesis of phonemes. Additional information on the Buffalo Model approach can be found in chapters on APD (Katz, Ferre, Keith, & Alexander, 2015; Tillery, 2015) in the Handbook of Clinical Audiology, 7th Edition (Katz, Chasin, English, Hood, & Tillery (Eds), 2015).

Music training

There is extensive research, much of it from the Northwestern University Auditory Neuroscience Laboratory (www.brainvolts.northwestern.edu), on the positive contribution of active musical training (but not passive music listening) to auditory processing skills.

> *…there is strong evidence (Level I/II) from studies of musical training (Kraus and Chandrasekaran, 2010) that auditory training can be beneficial for a wide range of perceptual and cognitive abilities, and result in neuroplasticity. (BSA, 2011, p. 17)*

Musical training can therefore be encouraged for individuals with APD as an adjunct to therapy if there is interest in learning a musical instrument or singing, but other more direct methods of APD treatment may be faster, less time-consuming and less expensive in the long term. It is unlikely that musical training would correct interaural asymmetry on dichotic testing (amblyaudia), for example, and one study disputes the reported finding that musicians have superior hearing in noise (when the contribution of cognitive ability is excluded) (Boebinger et al., 2015).

Amplification

Terminology

After national and international consultation, the APD Reference Group resolved to follow the American Academy of Audiology in adopting the term "remote microphone" (RM) to replace the terms FM (frequency modulation) and DM (digital modulation) in referring to wireless assistive listening technologies. The APD Reference Group adopted the following families of terms to refer respectively to the hybrid wireless hearing instruments commonly used for APD, and accessory systems used with conventional hearing aids and implantable hearing devices:

- for wireless hearing instruments designed for use in APD
  - RM hearing aid (hybrid receiver/hearing aid)
  - RM transmitter (transmitter)
  - RM hearing aid system (total system)
- for accessory wireless systems used with conventional hearing aids and implantable devices
  - RM receiver
  - RM transmitter
  - accessory RM system.

Comparison of different forms of amplification

Acoustic treatment of classrooms and use of classroom sound distribution systems (loudspeaker systems) are sometimes recommended for children with APD. While such interventions may be helpful, there appears to be no peer-reviewed evidence that these alone can provide the hearing benefit required by children with APD.

The use of conventional hearing aids without remote microphones is also sometimes advocated, because of their versatility, for children with APD. However there is only limited peer-reviewed evidence, from a single study, suggesting that conventional hearing aids alone might be helpful for children with APD. The findings of reported benefit in that study were weak (Kuk et al., 2008; Kuk, 2011). Despite the paucity of supporting evidence, conventional hearing aids alone may be warranted for children in some specific circumstances such as children who are being home-schooled, older children who can manage their listening environment, or children who will not use a remote microphone system. Routine use of conventional hearing aids alone for children with APD may also sometimes be suggested because of their utility in situations where use of a remote microphone is difficult. If conventional hearing aids alone are used in cases where a remote microphone is impractical then the child should be close to the person speaking, e.g. close to the teacher in a classroom, to optimise SNR. More research on the degree of benefit of conventional hearing aids without remote microphones is warranted.

In contrast, amplification with RMHA systems is a proven and recommended treatment for APD. A number of studies strongly support the use of RMHA systems for APD and other conditions involving central auditory deficits (Blake, Field, Foster, Platt, & Wertz, 1991; Friederichs & Friederichs, 2005; Lewis et al., 2006; Johnson et al., 2009; Rance, Corben, Du Bourg, King, & Delatycki, 2010; Smart, Purdy, & Kelly, 2010; Umat et al., 2011; Yip & Rickard, 2011; Sharma et al., 2012; Hornickel et al., 2012; Schafer et al., 2013; Schafer et al., 2014; Keith & Purdy, 2014; Koohi et al., 2016; Smart, Purdy, & Kelly, 2018). High quality adaptive remote microphones can achieve signal-to-noise ratios (SNRs) of the order of 20 dB, even at high classroom noise levels (Wolfe et al., 2015), whereas it is difficult to achieve or exceed 5 dB SNR improvement with classroom sound distribution systems or conventional hearing aids alone.

REMOTE MICROPHONE HEARING AID SYSTEMS

- *Amplification with remote microphone hearing aid systems (RMHAs) is a recommended evidence-based treatment for APD, providing both immediate assistive and longer term therapeutic effects.*

Fitting of RMHAs assists most children with APD. A trial is the only way to determine which children will obtain benefit.

There is no research information on how long the devices may be required. Around two to three years is common but there is wide variation.

Assistive benefit from RMHAs can be obtained in many situations, not just at school.

- *It is recommended that the fitting and verification of RMHAs is always carried out by a qualified audiologist with real ear measurement equipment, and functional (behavioural) verification of fittings, and that fittings are reviewed annually. Binaural RMHA fittings are strongly recommended.*

Adults with APD may obtain benefit from conventional hearing aids sometimes used with accessory remote microphones.

Multiple technological considerations need to be addressed when selecting and implementing hearing assistive technology devices (AAA, 2011, p.17). Some performance criteria for devices for children with APD are listed below. Many of these apply also to adults:

- ability to deliver clear sound to any location in a classroom in noise levels at times exceeding

70 dBA with a signal-to-noise ratio of at least 15 dB and preferably 20 dB
- output limitation appropriate for users with normal hearing sensitivity for pure tones (~110 dB SPL)
- amplification limited to a level comfortable for users with normal hearing sensitivity for pure tones
- low distortion (<2%)
- low internal noise
- smooth frequency response with extended high-frequency output
- fast compression to limit excessively loud noises
- remote microphone transmitter is voice-activated, silent when speech signal is absent
- open coupling if possible
- small and lightweight designed to fit children's ears
- comfortable for all-day wear
- robust design for children
- binaural system with ability to balance gains between the ears
- programmable gain levels with tamperproof system to fix gain
- transmitter battery capacity suitable for all day use with rapid charging capability
- receiver battery life of approximately a week or more
- simple and effective wax management and cleaning systems
- compliance with radio transmission specifications and laws
- designed to operate with multiple other systems in schools without interference
- compatible with sound field amplification systems
- lightweight transmitter with easy wearing system e.g. lavaliere
- easy-to-use transmitter on-off switch
- on-off light indicator on transmitter
- minimal transmission delay <20ms to avoid disconcerting lack of synchronicity between visual and auditory stimuli
- beamforming directional microphone on transmitter
- noise cancellation technology
- adaptive gain to maintain beneficial signal-to-noise ratio even in high noise levels
- available option(s) for relaying of audio input signals from other devices
- moisture resistant
- good service backup available.

The coupling of hearing systems for children with APD should usually be as open as possible to allow for the wearer to hear other speakers and important environmental sounds around them.

Conventional hearing aids are more commonly used by adults with APD as adults are not usually in a single-speaker listening situation (e.g. a classroom) and adults do not require as much signal to noise ratio advantage as children. Hearing aids for adults with APD are sometimes fitted with accessory RM systems (Roup, Post, & Lewis, 2018; Smart, Kelly, Searchfield, Lyons, & Houghton, 2007; Papesh & Pesa, 2017; Kokx-Ryan, Nousak, Jackson, DeGraba, Brungart, & Grant, 2016; Kokx-Ryan et al., 2016). A study investigating the benefits of conventional hearing aids alone in adults with APD showed increased ability to hear speech against noise in a laboratory setting as measured by speech recognition scores and questionnaires (Donna Moore, 2015).

In the absence of guidelines for fitting of conventional hearing aids to people with normal pure tone audiograms, care should be taken to ensure gain and MPO levels are in accordance with a fitting formula such as the Desired Sensation Level (DSL) formula (Scollie et al., 2005).

Assistive and therapeutic effects of remote microphone hearing aid system fittings

Studies of RMHA treatment for children with APD consistently show therapeutic as well as assistive benefits (Keith & Purdy, 2014). The assistive benefit of improved learning is well reported (Reynolds, Kuhaneck, & Pfeiffer, 2016). Research studies also report improved attention, behaviour and participation in class (Friederichs & Friederichs, 2005; Johnson et al., 2009). Other beneficial effects include improved phonological awareness and reading (Hornickel et al., 2012) and improved self-esteem and psychosocial development (Johnson et al., 2009). Of particular interest are long term therapeutic benefits, measured without the RMHAs on, after up to 12 months of RMHA use.

Therapeutic benefits include improvements in: consistency of auditory brainstem responses to speech stimuli, amplitude and latencies of cortical auditory evoked potentials, interaural temporal resolution, frequency discrimination, frequency pattern recognition, auditory working memory, language, spatial stream segregation (speech perception in noise), self-perceived listening ability, and parent and teacher ratings of hearing ability (Hornickel et al., 2012; Friederichs & Friederichs, 2005; Smart, Purdy, & Kelly, 2010; Smart, Purdy, & Kelly, 2018; Umat et al., 2011; Yip & Rickard, 2011; Sharma et al., 2012; Johnson et al., 2009).

> *Amplification appears to treat a wide range of auditory skills simultaneously, facilitating neuroplastic change while also providing access to the auditory world. (Keith & Purdy, 2014)*

Use of remote microphone hearing aid systems by children

Research evidence and clinical experience indicate that almost all children with APD, irrespective of APD tests failed, obtain benefit from RMHAs, but there is no way to predict which children will obtain benefit without a trial. The practice of recommending RMHAs only for children who score poorly on a test of hearing in noise undoubtedly denies potential benefit to many children.

There is no research on the length of time for which children require RMHAs but clinical experience suggests about two to three years but with wide variability. Some may need life-long assistive technology. It is recommended that children be reviewed annually by their audiologist to assess whether they need to continue using amplification. Indications that RMHAs may no longer be needed include: improved or passing performance on APD tests; child, parent and/or teacher opinion that the child can cope satisfactorily without assistive equipment; and/or observation by an expert observer (e.g AoDC, RTLB, speech-language therapist) of the child in class without amplification to see if that child copes adequately. Genuine reasons for no longer requiring RMHAs need to be differentiated from a desire to stop using them to conform with peers. This can arise as children reach pre-teen or teenage years. Conventional hearing aids, though less effective in background noise, may be considered where amplification is still required but a child has become self-conscious about their use of the remote microphone.

Because of the therapeutic effects of RMHA use, children should be encouraged to wear them as much as possible. Assistive benefit is not confined to school. RMHAs can be useful in many situations such as out-of-school activities, at the dining table, in cars, in noisy environments such as busy streets and shopping malls, and with electronic devices such as TV and phones. As with other types of hearing disorder, it may also be beneficial for children with APD to wear RMHAs or use other amplification during treatments such as auditory training and language therapy.

Amblyaudia is not improved by RMHA use thus it is recommended that amblyaudia treatment be carried out concurrently with or before the fitting of RMHAs (Keith & Purdy, 2014).

Remote microphone hearing aid system use with comorbidities and other disorders

Studies report benefit from RMHA use in children with autism, attention disorders, neurological disorders and learning difficulties (Blake, Field, Foster, Platt, & Wertz, 1991; Rance, Corben, Du Bourg, King, & Delatycki, 2010; Schafer et al., 2013; Schafer, Anderson, Dyson, Wright, Sanders, & Bryant, 2014).

RMHAs are also effective for adults with conditions causing central auditory processing deficits such as stroke (Koohi et al., 2016), Friedreich ataxia (Rance et al., 2010), and multiple sclerosis (Lewis et al., 2006).

Fitting and electro-acoustic verification of remote microphone hearing aid systems

It is recommended that the fitting and verification of RMHAs is always carried out by a qualified audiologist with real ear measurement equipment. Prescription, fitting and verification procedures are specified in Section SA3 of Supplement A of the American Academy of Audiology Clinical Practice Guidelines, Remote Microphone Hearing Assistance Technologies for Children and Youth from Birth to 21 Years (AAA, 2011 https://audiology-web.s3.amazonaws.com/migrated/HAT_Guidelines_Supplement_A.pdf_53996ef7758497.54419000.pdf). The procedures in these Guidelines are also relevant for verifying remote microphone systems for adults. The two optional procedures are well explained in a chapter by Eiten (2010). One method utilises targets based on audiometric thresholds, the other sets the system gain at unity for a 75 dB SPL speech-weighted input. A recommended revised procedure is reported by Schafer et al. (2014). There are no research-based guidelines for target output levels for APD. The AAA Guidelines recommend that under normal conditions of use the system should maintain comfort and audibility of a close speech input defined as 1–6 inches from the talker's mouth. Placement of the transmitter microphone at chest level or beside the mouth allows speech input levels of 80 to 85 dB SPL and 90 to 95 dB SPL respectively. This high level input, with additional amplification if required, allows output levels in the ear of 70-90 dB SPL. Typical systems are output limited at approximately 100 dB SPL. Eiten (2010) recommends that peak real ear saturation response should not exceed 105 dB SPL when fitting ears with normal pure tone audiometric thresholds.

Clinical experience shows that monaural RMHA fittings on ears with normal pure tone audiometric thresholds can quite easily induce amblyaudia. Binaural RMHA fittings are therefore strongly recommended.

Functional (behavioural) verification

Supplement A of the AAA Clinical Practice Guidelines, Remote Microphone Hearing Assistance Technologies for Children and Youth from Birth to 21 Years (AAA, 2011) recommends functional (behavioural) verification of RMHA fittings using speech-in-noise stimuli with speech at 50 dB HL (65 dB SPL) to represent the teacher's voice at a distance of two meters, or speech at 40 dB HL to represent conversational level at two meters, with noise at 0 dB signal-to-noise ratio. To simulate doubling of the distance from the teacher (four meters) the signal level should be reduced by 6 dB. Materials and methods are outlined in the AAA Clinical Practice Guidelines and in Eiten (2010).

An alternative is the Functional Listening Evaluation (FLE) method described by Johnson (2004) for evaluating effectiveness in the classroom. The FLE is a procedure to test hearing with and without amplification with any chosen speech stimuli at varying distances in the classroom with and without background noise.

Questionnaires (e.g. TEAP, LIFE, SSQ, ECLiPS) can also be used pre and post RMHA fitting to measure changes in hearing performance (Anderson & Smaldino, 1999; Purdy et al., 2009; Purdy et al., 2002; Galvin & Noble, 2013; Barry et al., 2015; Tomlin, Dillon, Sharma, & Rance, 2015). The LIFE-UK includes teacher and parent versions designed to evaluate the impact of amplification.

School liaison and teacher and parent guidance

Teacher support is fundamentally important with remote microphone hearing technology. The quality of intervention with schools is thus a critical factor in achieving success with RMHA fittings. Cooperation must be won by a collegial approach which acknowledges and emphasises the importance of the role of teachers in APD management, assists and empowers them to optimise the effectiveness of the assistive technology, and engages their commitment.

The role of the family is equally important in the overall management and optimal use of amplification with children. In New Zealand, AoDCs are the professionals best trained to provide parent, child and teacher guidance on the effective use of hearing technology and classroom management of APD.

Irrespective of who provides this service, the following competencies are required for this aspect of the management of APD:

- parent and child guidance about the nature of APD and coping strategies
- parent and child guidance in the acceptance and effective use and care of hearing technology
- effective liaison with school personnel including SENCOs, teachers, and any other education professionals involved such as RTLBs
- teacher guidance with respect to effective use and care of hearing technology

- teacher guidance on effective communication strategies
- explanation of a child's hearing disorder and difficulties
- knowledge of APD and its management
- observation of a child's auditory behaviour and participation in class
- teacher guidance in regard to strategies for working with a child with APD
- skills in facilitating acceptance of amplification by students and their peers
- management of amplification trials
- expert knowledge of hearing technology
- assistance with Individual Education Plans (IEPs)
- assistance with funding applications
- management of technology compatibility issues in schools
- management of technologically challenging teaching situations such as team teaching or involvement of multiple teachers as in high schools
- regular follow-up plus assistance in special circumstances such as a change of teacher or graduation to a new class
- child and parent guidance about use of hearing technology in all aspects of life and activities.

REMOTE MICROPHONE HEARING AID SYSTEMS IN SCHOOLS

Teacher cooperation is fundamentally important with remote microphone hearing technology. Support from AoDCs or other trained learning support personnel is a critical factor in achieving success with the use of remote microphone technology in schools.

- *It is recommended that guidance is provided to teachers and families to manage expectations around RMHA benefits and limitations, and that information about care and use of hearing technology is provided to teachers and families.*

It is recommended that guidance is provided to teachers and families to manage expectations around RMHA benefits and limitations, and that information about care and use of hearing technology is provided to teachers and families. Fitting of hearing technology to children without expert intervention as above can result in poor compliance, ineffectual use or non-use of the hearing instruments. Delegating the school liaison role to parents is inappropriate as this is not their role, is outside their expertise and is seldom successful.

Teachers and parents also need to ensure that the psychosocial well-being of children with APD is monitored, and support provided if required, particularly when they enter adolescence (Lawton et al., 2017).

Basic strategies to assist children with APD in school may include:

- placement close to the teacher (within about two meters) unless remote microphone hearing aids are worn
- gain the child's attention before speaking and face the child when speaking
- use of clear speech by the teacher at a slightly reduced rate and slightly raised intensity
- limit noise and visual distractions
- repeat or rephrase as needed and ensure message has been understood
- schedule breaks between listening intensive tasks
- brief, clear and simple teaching instructions with verification that the instructions have been understood
- a hearing buddy beside the child with APD to assist in explaining instructions
- complementary aids such as visual materials to support oral communication, including pre-teaching materials and written instructions
- special accommodation for assignments and tests if necessary.

Further resources to assist schools may be found on the Ministry of Education Inclusive Education website http://inclusive.tki.org.nz/

Audiobooks

There appear to be no direct studies on the benefit or otherwise of audiobook listening for individuals with APD. There is, however, substantial evidence of the value of reading aloud (Duursma, Augustyn, & Zuckerman, 2008) and listening to audiobooks (Grover & Hannegan, 2012) to promote literacy and language development and engage attention for typically developing children. There is evidence of benefit of audiobook listening for children with dyslexia with improvement in reading accuracy, reduced unease and emotional–behavioural disorders, improvement in school performance and a greater motivation and involvement in school activities (Milani, Lorusso, & Molteni, 2010). There is also evidence of benefit from audiobook listening on reading skills and attitudes toward reading for struggling readers (Whittingham, Huffman, Christensen, & McAllister, 2013). In addition there is evidence of therapeutic and assistive benefit from mild amplification of speech by RMHAs for children with APD and dyslexia (see previous section on 'Assistive and therapeutic effects of remote microphone hearing aid system fittings') (Keith & Purdy, 2014). Audiobooks are usually narrated with clear speech and good use of prosody, and model good grammar and use of vocabulary. Given that audiobooks are usually listened to at a mildly amplified level it is possible that the long term therapeutic effects seen in children wearing RMHAs would also accrue from audiobook listening for children with APD.

In the absence of empirical research for guidance, guidelines for audiobook listening are necessarily based on theoretical considerations. Whereas it is recommended for reading therapy that children listen while following text in a book, it might be preferable for auditory, phonemic and language training purposes that children listen to audiobooks without visual distraction. Auditory stimulation alone is more akin to the natural developmental method by which children normally learn language. Neuroplastic training requires attention to the task. Thus other distractions should be minimised and the content should be at a suitable level of difficulty, and sufficiently interesting, to hold the child's attention. Earphones or headphones may be better for occluding extraneous noise and ensuring balanced binaural stimulation, but loudspeakers may suffice. Listening at the upper level of the child's comfortable range might approximate the listening level of RMHAs. Books read in local accents will likely reduce phonemic confusion. To approximate the effects of RMHA listening, children should listen several times per week. Session length can vary according to age, perhaps 15-20 minute sessions for primary school children. Earphones should be checked regularly to ensure both are working at appropriate output levels. If the child is already benefiting from the use of RMHAs, audiobook listening may be less important. Since the therapeutic benefits of RMHAs accrue over long periods (months or years) audiobook listening may need to be long term for best results.

AUDIOBOOKS

Mildly amplified audiobooks may provide some of the therapeutic benefits seen with RMHAs. Books should be sufficiently interesting to maintain attention. Select books with NZ or similar accents. Earphones or headphones are best. Listen without visual or other distractions, at the upper part of the comfortable range. Schedule sessions of 15-20 minutes (or more), several days per week (less important if RMHAs are worn.) Check earphones regularly to ensure outputs are normal.

Some adults with APD report that listening to audiobooks is too difficult a task. In such cases starting with children's books can be helpful.

Audiobooks can be obtained from libraries, online retailers, and some websites which offer free audiobooks.

Phonological development and therapy for children

Phonological awareness is the awareness of the underlying sound structures of spoken language, and the ability to manipulate these sound structures. Phonemic awareness is a subset of phonological awareness that focuses specifically on recognizing and manipulating phonemes, the smallest units of sounds comprising speech. Phonics refers to connecting sounds to letters. Phonemic training is the term used by Katz (2009) to describe explicit training in the identification of phonemes.

PHONOLOGICAL TRAINING

- *It is recommended that phonological processing therapy is provided to children with difficulties in this area.*

There are many methods, materials and software programmes for phonemic and phonological awareness training. Clinicians and parents are advised to consider the purpose of the programme and the individual needs of the child before selecting a programme.

Software designed for reading such as Reading Doctor, Jolly Phonics and Oz Phonics may be helpful for some children with APD.

Whereas a software package approach to phonological therapy has limitations, one-to-one phonological therapy with a suitably qualified professional is a proven approach.

There is research to suggest that there may be a correlation between correct hearing of phonemes and a child's ability to use language and access literacy. For example, studies show that phonemes may be inconsistently recognised and neurally encoded in children with central auditory deficits (Veuillet et al., 2007; Hornickel et al., 2012). It is known that for a sizeable subset of children with APD, reading disorder is a common co-occurrence (Sharma et al., 2009). Therefore these children may benefit from specific training on recognition and discrimination of phonemes until they are recognised rapidly and automatically. Given that typically developing children progress faster in phonics training in classrooms with sound field amplification (Flexer, Biley, Hinkley, Harkema, & Holcomb, 2002; Heeney, 2004), amplification may assist children with APD during phonemic training.

It is recommended that phonological processing therapy is provided to children with difficulties in this area. Speech-language therapists, reading and learning disability specialists, and teachers frequently help children develop phonics skills and phonological awareness. Therapy provided by SPELD teachers is effective for children with reading disorders (Waldie et al., 2014).

There are many approaches, methods, materials and software programmes for phonemic and phonological awareness training but most, if not all, are not specifically designed for children with APD. Most are subsets of reading training programmes or speech sound disorder treatments (phonological speech disorder) and are commonly designed for the 4-7 year old age group. Not all reading approaches explicitly include training on the foundation skills of recognition and discrimination of single speech sounds. Also, many widely used recorded materials and software programmes are not available with a New Zealand (or alternatively Australian or British) accent. But there are some exceptions.

Oz Phonics (www.ozphonics.com) is an Australian phonics programme that is available in a New Zealand accent version. Oz Phonics is a beginner reading application which concentrates on building a student's listening, sound identification and manipulation skills before introducing letters. The first exercises teach phonemic awareness and letter sounds.

A more recent Australian programme for early school-aged children that looks promising is Reading Doctor (http://www.readingdoctor.com.au/app-summary/).

Jolly Phonics (Jolly Learning Ltd, UK; http://jollylearning.co.uk/overview-about-jolly-phonics/) is one example of a number of classroom programmes presented by teachers for the explicit teaching of phonics skills for reading. Jolly Phonics is used worldwide. The UK version with UK accent (apart from some songs) is popular in New Zealand. Resources include handbooks and materials for live teaching, software training games and home training kits. Jolly Phonics starts with explicit training in learning speech sounds and among other skills moves on to blending sounds and identifying sounds in words.

Speech-language therapists have extensive knowledge of phonological processing (Carroll, Gillon, & McNeill, 2012) and use therapeutic methods such as those described by the Orton-Gillingham approach (Scheffel, Shaw, & Shaw, 2008). The Orton-Gillingham approach is widely recognised in treating children with dyslexia and emphasises systematic phonics instruction. A New Zealand programme consistent with this approach is Gillon's Phonological Awareness Training (PAT) programme, which is an intervention programme for children aged 5-7 years who may be at risk of reading disorder, speech disorders and specific language disorder (Gillon, 2000; http://www.canterbury.ac.nz/education/research/phonological-awareness-resources/) . It was designed by and for speech-language therapists and assumes a level of therapeutic skill in its application, but is commonly used by other professionals such as literacy tutors.

Speech-language therapists can provide individual and small group therapy programmes related to phonological disorders and frequently adapt programmes to meet individual client needs. The PAT programme may be one such programme whose methods could be extended by clinicians for use with older children.

The UK Practice Guidance document (BSA, 2011) mentions two programmes traditionally used by speech-language therapists to improve phonological awareness and reading. These programmes are available from Linguisystems (www.linguisystems.com):

- Just for Me! Phonological Awareness
- The Lindamood Program (LIPS Clinical Version) – Phoneme Sequencing Program for Reading, Spelling, and Speech.

The LindamoodBell Program is popular overseas but requires extensive training to learn how to apply the method and this is not available in New Zealand on a regular basis.

Katz's Buffalo Model approach to APD treatment (Katz, 2009) includes Phonemic Training using a one to one live voice approach and Phonemic Synthesis (sound blending) using recorded materials also in a one to one paradigm. The methods are fully explained in "Therapy for Auditory Processing Disorders: Simple Effective Procedures" (Katz, 2009).

Listening to audiobooks may be helpful in improving phonemic and phonological skills but requires further investigation to establish the benefits of this approach (see earlier section). Sharma et al. (2012) included listening to audiobooks in their randomised controlled trial of APD treatment approaches but did not examine the impact of audiobooks separately from other treatments.

Clinicians and parents are advised to consider the purpose of the programme and the individual needs of the child before selecting a programme. APD rarely presents without concomitant disorders and clinicians and programmes must be adaptable enough to accommodate the differences in each child. Audiologists and speech-language therapists working with children with APD should ensure, through amplification and/or auditory training, that ability to correctly identify and discriminate phonemes is optimised.

Whereas a "software package" approach to phonological therapy has limitations, one-to-one phonological therapy with a suitably qualified professional is a proven sound approach (Waldie et al., 2014). A sample worksheet and support information from a research protocol, designed for use by speech-language therapists for phonological processing training in children with APD, is shown in Appendix 5.

Language therapy

In a New Zealand study of 68 children with suspected APD, Sharma et al. (2009) showed a high rate of comorbidity between APD, Language Impairment (LI) and Reading Disorder (RD). Of the APD group 65.3% had all three disorders, 14.3% had APD and LI, and 14.3% had APD and RD. Just 6% had APD alone. In all, 80% of the children with APD also had LI. In at least some of the cases the language and reading disorders may have been a consequence of the APD. It follows that language therapy, as well as phonemic training, may be warranted for many children diagnosed with APD.

Therapy should also be provided for other areas of language deficiency indicated by language assessment. Areas of difficulty may include grammar and how to build sentences and stories, vocabulary, language concepts (e.g., before/after, first/last, etc.) and auditory comprehension. Where language difficulties are suspected, assessment by a speech-language therapist is essential.

Poor perception of suprasegmental or prosodic aspects of communication is a commonly reported manifestation of APD (AAA, 2010). Prosody includes non-linguistic aspects of speech such as pitch, variation of pitch (intonation), loudness, stress, tempo and rhythm. Children and sometimes adults may require specific training from a speech-language therapist in perception of prosody. Standardised assessments of prosody perception with normative data for school aged children are available (Kalathottukaren, Purdy, & Ballard, 2015; Kalathottukaren & Purdy, 2017).

It is recommended that language therapy is provided to children with difficulties in any of these areas.

LANGUAGE THERAPY

Due to a high rate of comorbidity between APD, Language Impairment and Reading Disorder, language therapy provided by a speech-language therapist may be warranted for many individuals diagnosed with APD.

- *It is recommended that language therapy is provided to children with APD and language difficulties.*

Communication, metacognitive and compensatory strategies

Metacognitive, metalinguistic and compensatory interventions for APD are top-down therapies which use higher level processes such as knowledge, experience, language comprehension and active listening skills to help interpret auditory information. They include therapy to improve inferencing to assist with auditory closure; reasoning; working memory aids and techniques; summarising; active listening, and other high-level skills. Self-knowledge of weaknesses is required to make best use of compensatory strategies. Self-advocacy is important for requesting environmental modifications or consideration by speakers. Communication strategies are familiar techniques taught to hearing impaired adults, and teachers and families of children with hearing loss, and may include speaking techniques and environmental optimisation.

Metalinguistic strategies refer to a listener's ability to use linguistic rules, and cues such as prosody, to help infer meaning in adverse listening conditions. The BSA Practice Guidance document also mentions "training in self-regulation, problem solving, meta-memory strategies, chunking, use of analogies and acronyms, pictorial representation and verbal rehearsal/reauditorization" as helpful techniques (BSA, 2011, p. 29). The effectiveness of these approaches for children with APD has not been investigated using a high-level research design.

Education and learning support personnel, psychologists and speech-language therapists may need to employ these and other top-down interventions to complement bottom-up treatments in assisting people with APD to optimise their ability to cope in difficult listening situations.

COMPENSATORY SKILLS

Communication, metacognitive, metalinguistic and compensatory interventions provided by a speech-language therapist, audiologist, hearing therapist, psychologist or learning support personnel may be warranted for some children diagnosed with APD.

Alternative therapies

Various franchised programmes are promoted to parents of children with APD by practitioners who are not hearing or speech-language professionals. Many of these practitioners have no legitimate credentials for managing APD. Some (e.g., DORE) purport to treat APD by regimes of physical exercises or 'sensory integration', but in particular variations of Tomatis/Berard/Auditory Integration Therapy/Sound Therapy programmes purport to treat APD by passive listening to filtered music. Treatment programmes can cost many thousands of dollars. Tomatis originally developed filtered music to simulate hearing in the womb as a treatment for autism. His theories were popularised by a book 'Sound of a Miracle'. The franchisees also often purport to diagnose APD. These programmes are not supported by published peer-reviewed research evidence. Further information can be found in Tharpe's article "Auditory Integration Therapy: The Magical Mystery Cure" or "MUSEC Briefing 40: Is it a scam?" (Tharpe, 1999; Stephenson, Wheldall, & Carter, 2014). Some alternative treatments involve the use of bone conduction rather than conventional earphones or hearing aids to transmit sound to the cochlea. Unless there is a conductive hearing loss there is no reason or credible evidence to indicate that this would have any beneficial effect in the treatment of APD.

Professional bodies in audiology, speech-language therapy, and the autism field warn that these methods are unproven as treatments and advise professionals to warn parents that they may be harmful.

> *In 1994, the American Speech-Hearing-Language Association (ASHA) Subcommittee on Auditory Integration Training (AIT) concluded that AIT, a method proposed for treating a variety of auditory and non-auditory disorders, was experimental in nature and had not yet met scientific standards as a mainstream treatment. The subcommittee recommended that ASHA develop a position statement and guidelines regarding AIT as soon as more research findings became available. The 2002 ASHA Work Group on AIT, after reviewing empirical research in the area to date, concludes that AIT has not met scientific standards for efficacy that would justify its practice by audiologists and speech-language pathologists. (ASHA Technical Report, 2004)*

> *Many of the so-called "sound-based training approaches" discussed earlier in the report, lack published, peer-reviewed evidence-based research to support their use. Incorporating these alternative approaches in one's practice would not serve the individual's best interests and would therefore violate the Code of Ethics of the American Academy of Audiology (AAA, 2009), and the Code of Ethics of the American Speech-Language-Hearing Association (ASHA, (2010). Audiologists should be prepared to respond to parents or other professionals seeking an opinion or referral for these alternative approaches by conveying the lack of scientific foundation for these approaches and their claims and by conveying the likelihood that the cost for these approaches will far exceed their benefits, if any, and may in fact harm the individual. (AAA, 2010)*

Referral to other services

Clinicians need to be alert to obvious problems or possible comorbidities outside the clinician's area of expertise and should then advise or arrange referral to other experts. This is particularly important given the high prevalence of comorbidities with APD. Referral may be for assessment or treatment or both. Typical examples of referral include:

- an educational psychologist for learning difficulties not explained by APD
- a psychologist or counselling service for family therapy and/or management of psychosocial effects of APD
- learning support personnel including AoDCs and school staff including SENCOs for school support
- a paediatrician for other possible diagnoses such as ASD or ADD/ADHD
- a behavioural optometrist for possible visual processing deficits
- a reading specialist for reading delay
- a speech-language therapist for phonemic/phonological/language and/or speech problems
- an occupational therapist for motor problems
- practitioners such as SPELD teachers for tutoring
- medical practitioners for any medical concerns.

As case managers, audiologists carry particular responsibility for ensuring necessary referrals are facilitated.

Professional standards

Clinicians such as audiologists and speech-language therapists are bound by the Codes of Ethics of their respective professional organisations.

Employees of State Services are bound by the State Services – *Standards of Integrity and Conduct* http://www.ssc.govt.nz/code

Audiologists are bound by the New Zealand Audiological Society Code of Ethics and should adhere to current professional standards. (https://www.audiology.org.nz/code-of-ethics.aspx)

Speech-language therapists are bound by the NZSTA Principles and Rules of Ethics. http://www.speechtherapy.org.nz/wp-content/uploads/2013/09/NZSTA-Principles-Rules-of-Ethics-June-2015.pdf

Public hospital staff are also subject to the Codes of Conduct of their District Health Boards.

Clients with concerns about professional matters can raise issues directly with the respective professional body.

Complaints about audiologists who are members of the New Zealand Audiological Society can be made to the Society https://www.audiology.org.nz/code-of-ethics.aspx.

Complaints about speech-language therapists who are members of the New Zealand Speech-language Therapists' Association can be directed to the Association https://speechtherapy.org.nz/contact-us/.

Client rights

Clients are protected by the United Nations Convention on the Rights of Persons with Disabilities (UN CRPD) to which the New Zealand Government is a signatory, and also have recourse to the Health and Disability Commissioner.

The UN CRPD Guiding Principles are:

1. Respect for inherent dignity, individual autonomy including the freedom to make one's own choices, and independence of persons;
2. Non-discrimination;
3. Full and effective participation and inclusion in society;
4. Respect for difference and acceptance of persons with disabilities as part of human diversity and humanity;
5. Equality of opportunity;
6. Accessibility;
7. Equality between men and women;
8. Respect for the evolving capacities of children with disabilities and respect for the right of children with disabilities to preserve their identities.

Practical applications of these principles for people with APD in New Zealand may include awareness-raising programmes about APD for the public, public information about APD services, accessibility via the provision of support equipment, specialised support to help children to achieve their educational goals, and provision of captioning if required.

Health and Disability Code of Rights

In accordance with the UN CRPD, New Zealand has a Health and Disability Code of Rights that says consumers of health and disability services have:

Right 1: the right to be treated with respect;

Right 2: the right to freedom from discrimination, coercion, harassment, and exploitation;

Right 3: the right to dignity and independence;

Right 4: the right to services of an appropriate standard;

Right 5: the right to effective communication;

Right 6: the right to be fully informed;

Right 7: the right to make an informed choice and give informed consent;

Right 8: the right to support;

Right 9: rights in respect of teaching or research;

Right 10: the right to complain.

More information can be found at https://www.hdc.org.nz/disability/the-code-and-your-rights/.

Complaints in regard to client rights can be made to the Health and Disability Commissioner https://www.hdc.org.nz/making-a-complaint/ or through the free and independent Nationwide Health and Disability Advocacy Service https://www.advocacy.org.nz/ .

Complaints can be made to the Human Rights Commission at https://www.hrc.co.nz/enquiries-and-complaints/advice-and-support/.

Information and support

There is a need for a wide range of support materials for APD. In the meantime clinicians may choose to adapt overseas materials for distribution to parents and teachers.

Community support for people with APD

APD is a hearing disorder that affects every thread of a person's life. People living with APD require habilitation/rehabilitation and community support to enable them to achieve a life of dignity.

There are two organisations which provide support to individuals with APD, or families with a child with APD. They are the National Foundation for the Deaf (NFD), and Hear for Families APDNZ.

Hear for Families APDNZ (http://apd.org.nz/) is a national organisation that offers peer-support, advocacy and education for children and adults with APD and their families and carers. Hear for Families is a member organisation of the NFD and can be contacted directly or through the NFD.

Contact details for Hear for Families – APDNZ

Email: apdnzh4f@gmail.com
Call/text: 021481989
Freephone: 0800 867 446 (The National Foundation for the Deaf)
Facebook: Hear for Families – APD Support Group
www.apd.org.nz

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APPENDICES

APPENDIX 1: CONFLICTS OF INTEREST FOR AUDITORY PROCESSING DISORDER REFERENCE GROUP MEMBERS

APD Reference Group Member	Conflicts of Interest
Justine Simpson	Managing public budgets
Lynne Silcock	Managing public budgets
Marianne Linton	Managing public budgets
Sue Primrose	Managing public budgets
Nick McHarg	Member, Association Advisors on Deaf Children
Leonie Wilson	Chair, Hear for Families APDNZ
Louise Carroll	Chief Executive, The National Foundation for the Deaf General Secretary, International Federation of Hard of Hearing People Patron, Hear for Families APDNZ
Suzanne Purdy	Head of School of Psychology, University of Auckland PhD research funding, Oticon and Phonak (past) Research funding, Oticon Foundation Honorary Member, NZAS Member, NZAS Complaints Board – Poari Whakapae Member, NZAS Paediatric Technical Advisory Group Associate Member, New Zealand Speech-Language Therapists' Association Deputy Co-Director, Eisdell Moore Centre for Hearing and Balance Research Principal Investigator, Brain Research New Zealand - Rangahau Roro Aotearoa Centre of Research Excellence (CoRE) Principal Investigator, The University of Auckland Centre for Brain Research (CBR) University of Auckland representative, The Hearing House Governance Board Member of Brain Research New Zealand – Rangahau Roro Aotearoa Centre of Research Excellence (CoRE) Theme 4 'Prevention, Intervention and Delivery' Leadership Group Member of Hear for Families expert advisory group Trustee, M.G. Martin Charitable Trust (for the education of deaf and hearing-impaired children) Investigator, Deafness Research Foundation NZ (past) Member, National Foundation for the Deaf (NFD) Council Past Member of Board of Trustees, Hearing (previously 'Deafness') Research Foundation

APD Reference Group Member	Conflicts of Interest
William Keith	Representing private audiology sector. Honorary Member, New Zealand Audiological Society Owner SoundSkills APD Clinic and NZ Hearing Supplies Chair, Northern Cochlear Implant Trust Deputy Chair, Pindrop Foundation Board Member and past Chair, Hearing Association Auckland Board Member, Hearing Research Foundation Member, Scientific Committee, Hearing Research Foundation Current research funding: Oticon Foundation Denmark; Eisdell Moore Hearing and Balance Centre, University of Auckland; Phonak AG Past employee Phonak NZ Ltd.
Melissa Baily	Member, New Zealand Audiological Society Past member, Executive Council, New Zealand Audiological Society Past employee, accessable - Environmental Health Management Services (Ministry of Health hearing aid funding contract), Dilworth Hearing (private practice APD work), Phonak NZ Ltd Current research funding: Oticon Foundation Denmark
Flora Kay	Member, New Zealand Audiological Society District Health Board employee
Craig O'Connell	No reported conflicts

APPENDIX 2: AUDITORY PROCESSING DISORDER REFERRAL CHECKLIST

The following page may be reproduced as an APD referral checklist.

Auditory Processing Disorder Referral Checklist

Checklist of key symptoms of auditory processing disorder (APD) or comorbidities that can be used to identify individuals who should be referred for APD assessment:

Symptoms of hearing or listening problems not consistent with results of basic hearing assessment;

- difficulty following spoken directions unless they are brief and simple
- difficulty attending to and remembering spoken information
- slowness in processing spoken information
- difficulty understanding in the presence of other sounds
- being overwhelmed by complex or “busy” auditory environments e.g. classrooms, shopping malls
- undue sensitivity to loud sounds or noise
- poor listening skills
- preference for loud television volume
- insensitivity to tone of voice or other nuances of speech

Presence of other factors;

- brain injury
- neurological disorders affecting the brain
- history of frequent or persistent middle ear disease (otitis media, ‘glue ear’)
- difficulty with reading or spelling
- suspicion or diagnosis of dyslexia
- suspicion or diagnosis of language disorder or delay.

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APPENDIX 3: TEACHER EVALUATION OF AUDITORY PERFORMANCE (TEAP)

(see page following)

Teacher Evaluation of Auditory Performance (TEAP)

Please rate this child's behaviour compared to other children of similar age and background.

SECTION A.
RESPONSE CHOICES

less difficulty	+1
same amount of difficulty	0
slightly more difficulty	-1
more difficulty	-2
considerably more difficulty	-3
significantly more difficulty	-4
cannot function at all	-5

Scoring:

For Questions B1-B6, score Yes as 0, score No as 1. Add the scores for Questions A1-A4 to the scores for Questions B1-B6.

Total scores of 6 and above indicate average or better ability. Scores below 6 are suggestive of listening difficulties.

A1. If listening in a room where there is background noise such as others talking, children playing etc., this child has difficulty hearing and understanding . . . . +1 0 -1 -2 -3 -4 -5

A2. If listening in a quiet room (others may be present, but are being quiet), this child has difficulty hearing and understanding . . . . +1 0 -1 -2 -3 -4 -5

A3. When listening in ideal conditions (quiet room, no distractions, face-to-face, good eye contact) this child has difficulty hearing and understanding . . . . +1 0 -1 -2 -3 -4 -5

A4. This child has difficulty following multistage oral instructions . . . . +1 0 -1 -2 -3 -4 -5

SECTION B. Please circle YES or NO

B1. This child appears to have trouble picking up new spoken information and may require several repetitions in order to understand the material . . . . YES / NO

B2. This child frequently requires visual cues to help understand the curriculum, in addition to auditory information . . . . YES / NO

B3. This child has difficulty recalling auditory information, compared to other children . . . . YES / NO

B4. The child displays difficulty formulating or generating expressive language, and/or displays inappropriate use of language . . . . YES / NO

If YES, please explain: ______________________________

____

B5. The child displays language problems (evidenced in the usage of inappropriate "wh" questions, pronouns, word order, possessiveness, verb tenses) . . . . YES / NO

If YES, please explain: ______________________________

____

B6. The child displays problems with articulation (phonology) consisting of substitutions, distortions, or omissions of sounds in words (especially when producing words that sound similar) . . . . YES / NO

If YES, please explain: ______________________________

____

Appendix 3: New Zealand Guidelines on Auditory Processing Disorder

Adapted from questionnaires by Sanger et al. (1987) & Smoski et al. (1992) – see Purdy, S.C., Kelly, A.S., & Davies, M.G. (2002). Auditory brainstem response, middle latency response, and late cortical evoked potentials in children with learning disabilities. *Journal of the American Academy of Audiology, (13)* 367-382.

APPENDIX 4: LINK TO EXCEL DOCUMENT - SUPPLEMENTARY INFORMATION ON TESTS REVIEWED

Download link: APPENDIX 4 NZ APD GUIDELINES 2019

APPENDIX 5: SAMPLE WORKSHEET AND GUIDANCE FOR PHONOLOGICAL PROCESSING TRAINING IN CHILDREN WITH AUDITORY PROCESSING DISORDER

From a research study at the University of Auckland. Developed by Lucy Sparshott BSLT, MNZSTA, Speech-language therapist, Research Assistant, University of Auckland.

Worksheet

Implementation notes

Developmental sequence of phonological skills

Record Sheet: Phoneme Awareness (PA) Target Levels

Child Name:

Target Level to teach	Session# Does not know	Session# Achieving with help	Session# Achieved competency	Session# Achieved proficiency
1. Phoneme analysis CC wide contrast				
CCC wide contrast				
CC fine contrast				
CCC fine contrast				
2. Initial phoneme identification CVC				
CCVC				
Initial phoneme matching				
Initial phoneme categorisation				
3. Final phoneme identification CVC				
CVCC				
4. Medial phoneme identification Consonants CVCVC				
Vowels CVC				
5. Phoneme segmentation CVC				
CCVC				
CVCC				
6. Phoneme blending CVC				
CCVCC				
CVCC				
CVCVC				

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Target Level to teach	Session# Does not know	Session# Achieving with help	Session# Achieved competency	Session# Achieved proficiency
7. Phoneme identification and blending CVC				
CCVC				
CVCC				
8. Phoneme substitution Initial CV				
Initial CVC				
Initial CCVC				
Final VC				
Final CVC				
9. Phoneme deletion CVC to CV				
CVC to VC				
CCVC to CVC				
CVCC to CVC				
10. Phoneme addition - initial, final, VC to CVC				
CVC to CVCC				
CV to CVC				
11. Phoneme addition medial, CVC to CVCC				
CVC to CCVC				

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Advanced Target PA Levels

Target Level to teach	Session# Does not know	Session# Achieving with help	Session# Achieved competency	Session# Achieved proficiency
12. Phoneme blending CVC				
CCVCC				
CVCC				
CVCVC				
13. Phoneme identification and blending CVC				
CCVC				
CVCC				
14. Phoneme substitution Initial CV				
Initial CVC				
Initial CCVC				
Final VC				
Final CVC				
15. Phoneme deletion CVC to CV				
CVC to VC				
CCVC to CVC				
CVCC to CVC				
16. Medial phoneme addition CVC to CVCC				

Measures:
1. **Does not know:** The target needs teaching.
2. **Can achieve target with help:** Requires prompts, cues, pausing, from therapist.
3. **Competent:** Independent and accurate. Independent and rapid success to achieve 80% accuracy (8/10) on test measure before moving to next target.
4. **Proficient:** Independent, accurate and with speed (automaticity). Automatic response is the aim (no delays to think and problem-solve).

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Teaching a target sound/phoneme to proficiency level (accurate, automatic recognition and production)

Select the target phoneme from the test results e.g. 'oa'

Step 1: Target phoneme in isolation: auditory discrimination. Obtain two different coloured blocks. This yellow block is oa, point to it when you hear me say oa (e.g. oa vs ee, oa vs ay, oa vs ar). Use block of the same colour as next step. Can use more than two different phonemes to secure auditory discrimination.

Step 2: Target phoneme in isolation with grapheme prompt. Show letters and explain 'oa' together makes the 'oh' sound. Take your time with this step. Advise using picture resources. Child must be proficient at this skill i.e. immediate and prompt response to stimuli.

Step 3: Target phoneme in CVC minimal pairs. Identify the phoneme from a choice of two e.g. boat/beet. Again the use of visuals (picture, photos appropriate to the child's age) may be useful "Point to the picture that I say".

Step 4: Select target phoneme sound from within a set of rhyming words e.g. choice of 3 CVC word stimuli e.g. boat, goat, gate (fine contrast) boat, goat, , man (wide contrast). Select the level of contrast by analysing the child's response time and proficiency.

Step 5: Child to generate rhyming words verbally e.g. goat, boat, moat.

Step 6: Child to spell the rhyming words using letter tiles. Select the letter tiles for the child and have them manipulate them to spell out the rhyming words. Reinforce the 'oa' sound.

Step 7: Write the words on the whiteboard and underline/highlight the 'oa'.

Step 8: Use the letter tiles and/or whiteboard to substitute the initial phonemes to make rhymes e.g. let's make boat, change it to goat, change it to moat.

Judge the child's proficiency and advance this step to use with final phonemes also.

Step 9: Check the child can now read the 'oa' in words. Use letter tiles/whiteboard to make 'oa' CVC words for the child to read.

6. Review session and end.

Speech-language therapist to fill in Record Sheets. Set target phoneme for review and possible extension next session.

Child to fill in Chart 1 and receive reward e.g. game, sticker

Consider: your use of your therapeutic skills to ensure the dosage, prompts, rewards are maximised for the individual client.

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Developmental Sequence of Phonological Skills

80-90% of typical students achieve a targeted phonological skill

Age	Skill	Example
5	Recognizing Rhyme Clapping/Counting Syllables	Which two rhyme? bat, bug, hat dog (1 syllable), turtle (2 syllables)
5 1/2	Blends Onset and Rime Produces a Rhyme Isolates Beginning Sound	/b/ /oat/ (boat), /t/ /ree/ (tree) Tell me a word that rhymes with cat. (rat) Say the first sound in 'net'. (/n/)
6	Syllable Deletion Blending of 2- and 3-phoneme words Segments 2- and 3-phoneme words (no blends)	Say "tulip" now say it again, but don't say /tu/ (lip) /s/ /u/ /n/ (sun), /b/ /o/ (bow) Say the sounds in the word "boat" as you move a bead for each sound
6 1/2	Segments words that have up to 3- or 4- phonemes (including blends) Phoneme substitution to build new words (no blends)	Say the sounds in the word "black" as you move a bead for each sound (/b/ /l/ /a/ /k/). Change the /c/ in "cat" to /b/ (bat)
7	Phoneme Deletion (initial and final word positions)	Say "seed". Now say it again without the /d/ (see)
8	Phoneme Deletion (initial position including blends)	Say "sled". Now say it again without the /s/ (led)
9	Phoneme Deletion (medial and final blend positions)	Say "snail". Now say it again without the /n/ (sail).

Adams, et al., 1998; Gillon, 2004; Goswami, 2000, Paulson, 2004; Rath, 2001