When the brain doesn't hear:
Auditory processing disorder

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January 2021

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Affiliations and Funding

Affiliations

- Dr Bill Keith is Owner of SoundSkills APD Clinic and Research Fellow/Honorary Academic, University of Auckland
- Member, Eisdell Moore Hearing and Balance Research Centre, University of Auckland

Research and Development Funding

- Oticon (now William Demant) Foundation, Denmark
- Sonova AG, Switzerland
- Hearing Research Foundation
- Eisdell Moore Hearing and Balance Research Centre, University of Auckland
- Lottery Health Research

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William Demant Foundation

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Lottery Health Research

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Part 1: What is Auditory processing disorder?
Part 2: Identification, assessment and diagnosis of APD
Part 3: Hearing technologies for APD
Part 4: Training and therapy treatments for APD

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When the brain doesn't hear
Part 1: What is Auditory processing disorder?

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Definition of APD - NZ

Auditory processing disorder (APD) 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.

- or more simply, "when the brain can't hear"

Central auditory processing disorder (CAPD) is an equivalent term more often used in the USA. The term "Central" refers to the brain.

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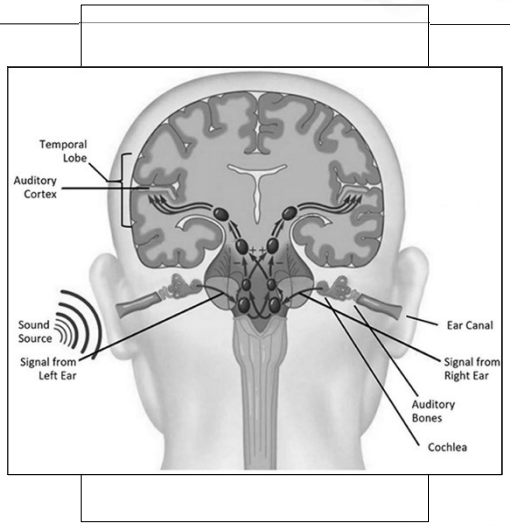
The auditory system includes more than just our ears

- the auditory system includes more than just the ears, it includes the hearing pathways and centres of the brain also
- problems can occur at any part of the auditory system
- the left hemisphere is dominant for language including grammar and spelling
- the right hemisphere is more dominant for music, and musical aspects of language like pitch, rhythm, stress



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Hearing and understanding is a complicated challenge

- we need to be able to quickly and automatically recognise every sound of speech whatever the listening conditions, loudness, voice or accent
- some speech sounds are only a fraction of a second in length, easily missed if our auditory system isn't working perfectly
- people with APD can hear speech but sometimes can't decipher some parts or can't process it quickly enough to understand all of it
- they may miss parts of speech and fail to keep up with lengthy spoken information

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A simulation of what APD might sound like

- On the next slide you will hear an audio simulation of APD

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A simulation of what APD might sound like

- Not everyone with APD will experience all these auditory distortions and problems

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Signs of APD

- 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
- poor listening skills
- difficulty with language, reading and spelling
- insensitivity to tone of voice or other nuances of speech

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Secondary effects of APD may include

- speech and language delay/disorder including difficulties with phonological and phonemic awareness (how language is built from the individual sounds of speech)
- academic difficulties, including reading, spelling; and/or learning problems
- frustration
- under-achievement in school despite effort
- receiving unfair criticism
- effects on psychosocial development and adjustment – e.g., anxiety, low self-esteem, withdrawal, difficulty with friendships, behaviour
- extreme tiredness after school

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Impact

Parent comments show the impact APD can have on children

- "She just sat in the toilets at school all day crying. The teachers said it was bad behaviour."
- "He sits a lot with his hands over his ears in class."
- "The worst thing was he lost all his confidence and friends. The best thing we did was take him out of school. For all those years he thought he was dumb. It took ages for him to get his confidence and self-esteem back."

(From Report on APD in N.Z. Ministry of Health, 2014)

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Prevalence in children and adults

- APD prevalence is estimated to be at least 6% overall in children in NZ

  (Report on APD in N.Z. Ministry of Health, 2014)

- auditory processing difficulties increase with old age, affecting more than half of people over 75 years of age

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Causes

Causes of APD include

- hereditary,
- developmental and
- birth-related factors,
- brain injury, and
- neurological disorders.

There is growing research evidence suggesting that prolonged middle ear disease (e.g., glue ear) can result in APD if hearing is disrupted during important developmental periods in infancy or early childhood.

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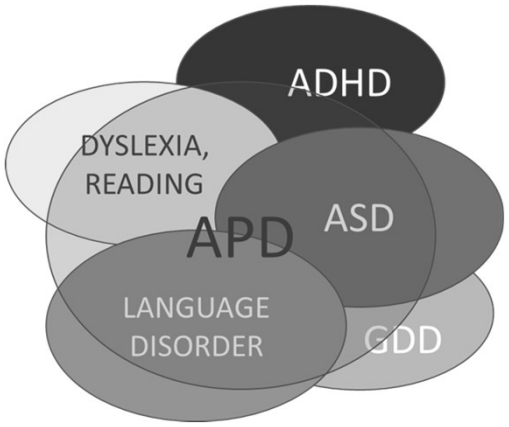
Frequently associated conditions or comorbidities

- brain injury
- neurological disorders affecting the brain
- history of frequent or persistent middle ear disease (auditory deprivation)
- dyslexia, difficulty with reading or spelling
- language disorder or delay
- autism spectrum disorder

The APD may be a cause (language disorder, dyslexia); a consequence (autism, global developmental delay); or co-occurring (attention disorders).



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Dyslexia and APD

- research indicates that auditory processing deficits underlie phonological deficits, which are in turn an underlying cause of dyslexia
- treating the auditory processing deficits improves phonological awareness and supports dyslexia treatment

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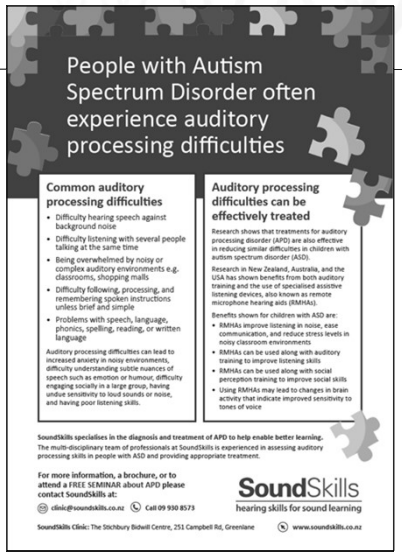
Autism and APD

- people with autism spectrum disorder (ASD) commonly have central auditory processing deficits
- auditory skills training, remote microphone hearing aid (RMHA) systems and language therapy can improve hearing and learning, reduce stress, and help with social skills
- SoundSkills staff are experienced in treating hearing disorders in people with autism
    - this A4 poster can be downloaded from Resources/Materials at soundskills.co.nz



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When the brain doesn't hear

Part 2: Identification, assessment and diagnosis of APD

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Identification, assessment and diagnosis

- APD is diagnosed by audiologists using specialised auditory processing tests in conjunction with case history information and measures of related developmental abilities such as cognition and language
- checklists of symptoms, and questionnaires, are useful in identifying people for whom referral for APD assessment should be considered

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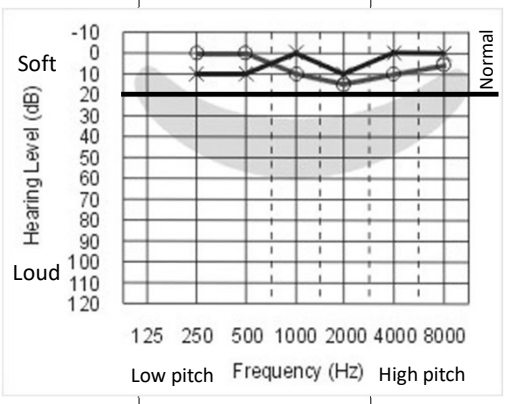
A normal pure tone audiogram
is not a guarantee of normal hearing

- audiograms show hearing thresholds for pure tones (beeps) in quiet
- people with APD often have normal audiograms like this
- taken in isolation, normal pure tone audiograms can give false reassurance that there is no hearing problem



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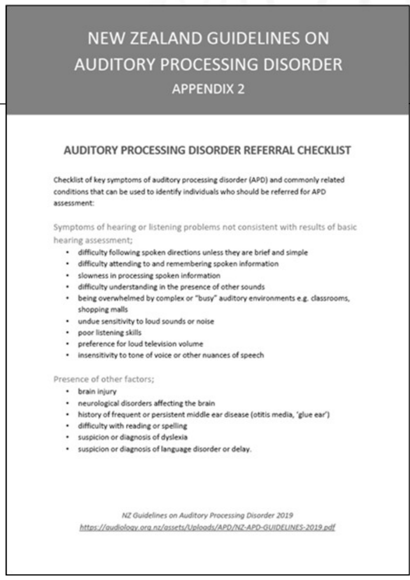
Screening for APD

- screening tests aren't recommended
  - a good screening test would have to test for every type of APD, just like a full assessment
  - also some "screeners" aren't properly validated
  - but screening tests are not needed as symptoms of APD are easily recognised
- the Auditory Processing Disorder Referral Checklist from the NZ Guidelines on APD is a good screening tool for identifying people for whom referral for assessment should be considered
- download from Resources/Materials at soundskills.co.nz



NEW ZEALAND GUIDELINES ON AUDITORY PROCESSING DISORDER
APPENDIX 2

AUDITORY PROCESSING DISORDER REFERRAL CHECKLIST

Checklist of key symptoms of auditory processing disorder (APD) and commonly related conditions 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.

NZ Guidelines on Auditory Processing Disorder 2019
https://audiology.org.nz/assets/Uploads/APD/NZ-APD-GUIDELINES-2019.pdf

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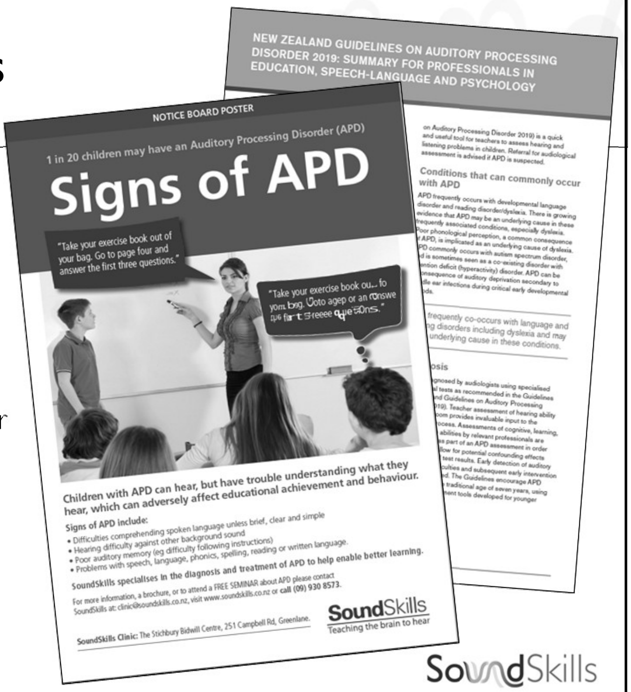
Screening tips for teachers

- for teachers, an abbreviated list of APD symptoms likely to be observed in school is shown on the SoundSkills A4 School Notice Board Poster
- download from Resources/Materials at soundskills.co.nz
- more comprehensive APD information for teachers can be found in the NZ APD Guidelines Summary: Education
- download NZ APD Guidelines Summary: Education from Resources/Guidelines on APD at soundskills.co.nz



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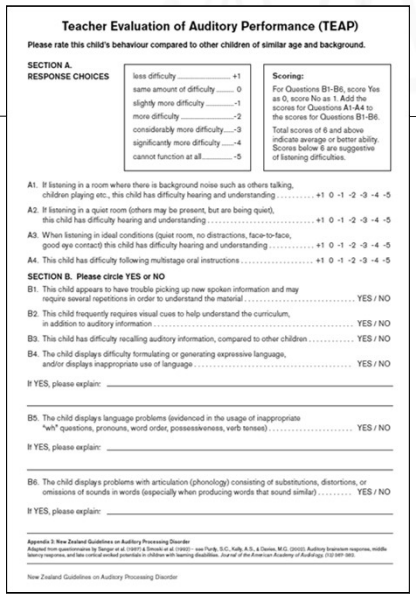
Questionnaires

- there are several good teacher, parent and self-report questionnaires that assist in identifying auditory difficulties
- the Teacher Evaluation of Auditory Performance (TEAP) is an example of a questionnaire recommended for teachers
- scores below 6 are suggestive of hearing or listening difficulties
- download fillable pdf of TEAP with auto scoring from Resources/Materials at soundskills.co.nz



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 questionnaire 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*(2) 367-382.

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Assessment of related developmental abilities

- a diagnosis of APD should not be made without considering related developmental abilities – cognition, language, phonological awareness, teacher observations
- audiologists may administer screening assessments of related developmental abilities when pre-assessment information is not available

> *"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"*
> *NZ Guidelines on APD*

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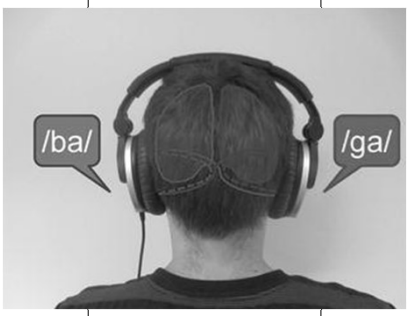
Diagnostic testing

- audiologists test for APD using a battery of tests that stress the auditory system, eg:
  - understanding of speech against background noise
  - understanding distorted speech (e.g., compressed in time or with low or high pitch parts removed)
  - recognition of brief acoustic events (less than 20 thousandths of a second)
  - dichotic tests: understanding competing speech messages to the two ears simultaneously
  - auditory memory
  - perceiving and recalling short musical phrases



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Diagnosis

- APD is diagnosed by audiologists taking into consideration the results of the basic and APD hearing tests; the pre-assessment information about language, cognitive ability, and other related developmental abilities; the case history; and parent and teacher observations
- the audiologist might diagnose auditory processing disorder, or weaknesses in auditory processing, or auditory processing deficits secondary to another diagnosed condition (e.g., ASD)
- APD in children can usually be diagnosed from age 6, and sometimes at age 5
- at ages 4 and 5 some useful information can be obtained, a provisional diagnosis may be possible, and appropriate treatment may be started before final diagnosis at a later stage
- when APD is diagnosed it is the responsibility of the diagnosing audiologist to prepare a management plan

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When the brain doesn't hear
Part 3: Hearing technologies for APD

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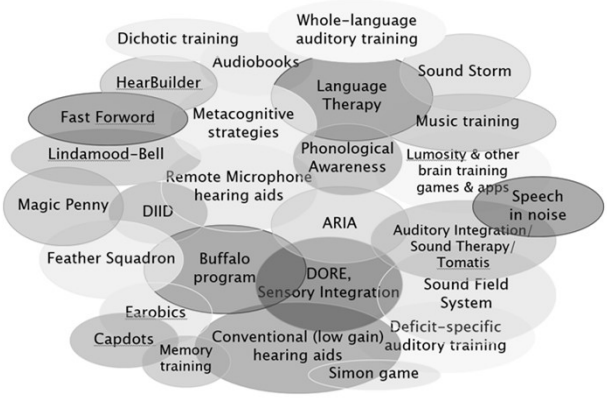
Treatments for APD

- because of the neuroplasticity of the brain, APD is very responsive to treatment
- there are many treatments promoted for APD
- not all are supported by scientific evidence
- SoundSkills carries out research into APD treatments, keeps up to date with advances in APD, and uses the best proven treatments



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The three key treatments for APD

- hearing technologies
- auditory skills training

Audiologist

- language and literacy therapies

SLT, Teachers, Learning Support specialists, SPELD

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Hearing technologies

- remote microphones are microphones that transmit wirelessly to hearing aids worn behind the ears
- the transmitter microphone is worn by the key person speaking, e.g., teacher, parent, grandparent, coach, friend
- remote microphone hearing aid (RMHA) systems only work with the remote microphone
- some conventional hearing aids can be used both with or without an accessory remote microphone
- remote microphones dramatically improve hearing in noise which is particularly helpful in many classrooms (noise levels average 75dBA in Innovative Learning Environments)

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Hearing technologies

- both systems provide mild amplification which also helps people with APD, even if their pure tone audiogram is normal
- younger children are generally best suited by RMHA systems
- adolescents and adults may prefer the flexibility of conventional hearing aids with features such as Bluetooth connectivity, plus the ability to use the remote microphone selectively
- both technologies are helpful in multiple life situations

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Audio demonstration of RMHA system

- during the following slides you will hear an audio demonstration of the ability of RMHA systems to elevate a speaker's voice above background noise in a classroom
- listen to the differences and watch the speech understanding scores as the soundtrack switches between:
  - no hearing assistance (No RM)
  - a first-generation remote microphone hearing aid system (Traditional RM)
  - a modern "dynamic" RM hearing aid system that adapts its output according to the noise level

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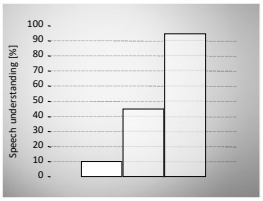

- No RM
- Traditional RM
- Dynamic RM

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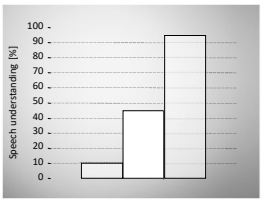

- No RM
- Traditional RM
- Dynamic RM

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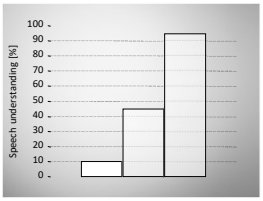

- No RM
- Traditional RM
- Dynamic RM

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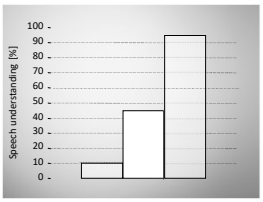

- No RM
- Traditional RM
- Dynamic RM

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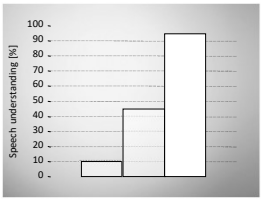

No RM

Traditional RM

▷ Dynamic RM

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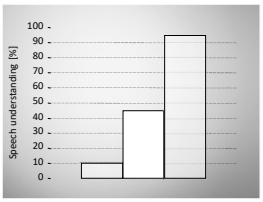

No RM

▷ Traditional RM

Dynamic RM

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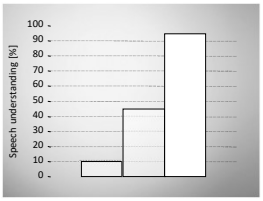

No RM

Traditional RM

Dynamic RM

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Audio demonstration

- in practice RMHA systems are fitted with open eartips or earmoulds, for comfort, and so people close by who aren't wearing the remote microphone can still be heard
- background noise will still be audible, but no longer bothersome

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RMHA systems for children

- there is strong evidence that RMHA systems benefit most if not all children with APD (and many with ASD, dyslexia, and other learning disorders)
- there is a double benefit – both assistive (immediately assisting hearing), and therapeutic (permanent improvement in hearing skills over time) – making RMHA systems a powerful treatment for APD in children
- children may not need RMHA systems long term – our research shows average duration of use is 2 years and 9 months but there is much individual variation

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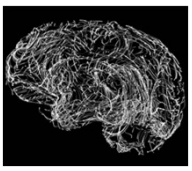
RMHA system benefits:
Assistive, therapeutic

Assistive	• attention, participation and academic performance • phonological awareness, language, reading • psychosocial development, confidence, self-esteem • reduced classroom stress • less tired
Neuroplastic, permanent	• bioelectric responses to sound in the brain • multiple aspects of sound perception e.g., pitch, brief sound changes and sound patterns • auditory working memory • speech perception in quiet and in noise



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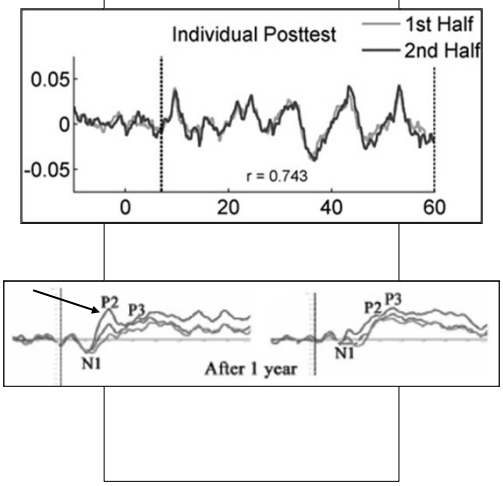
Evidence of neuroplasticity
Changes in brain responses after RMHA system use

- neurophysiological responses from the brain (brainwaves) show better processing of sounds at the brainstem and auditory cortex of the brain after one year of RMHA system use in school
- accompanied by improvements in hearing, language, academic and social skills



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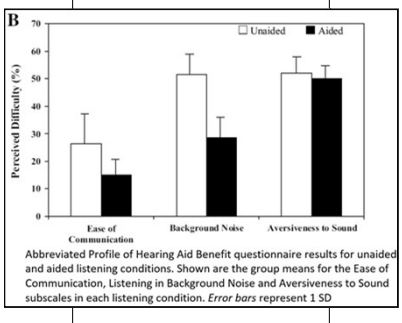
RMHA systems for autism spectrum disorder

- various studies show hearing and communication benefits for children and adolescents with ASD e.g.,
- improved speech perception in noise
- less communication difficulty
- no increase in aversiveness to noise
- reduced stress (measured via salivary cortisol) during listening tasks when wearing an RMHA system



Abbreviated Profile of Hearing Aid Benefit questionnaire results for unaided and aided listening conditions. Shown are the group means for the Ease of Communication, Listening in Background Noise and Aversiveness to Sound subscales in each listening condition. *Error bars* represent 1 SD

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Funding, fitting and trial of RMHA systems

- RMHA systems need to be fitted by audiologists
- SoundSkills' Education Advisers assist client families and the child's school through the fitting and trial process
- a minority of children with APD qualify for Ministry of Education assistive technology funding support for RMHA systems
  http://www.education.govt.nz/school/student-support/special-education/assistive-technology
- SoundSkills can advise on funding, fitting and trial options for both private and government-funded fittings

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When the brain doesn't hear

Part 4: Training and therapy treatments for APD

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The three key treatments for APD

- hearing technologies
- auditory skills training

Audiologist

- language and literacy therapies

SLT, Teachers, Learning Support specialists, SPELD

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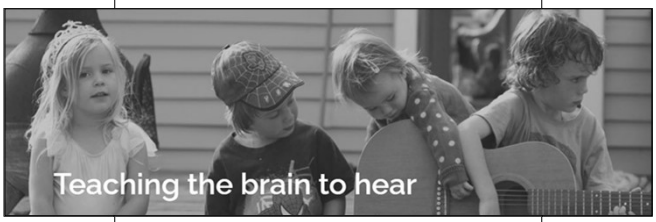
Auditory skills training
Teaching the brain to hear

- in-clinic training sessions
- home-based training with software programmes including auditory training games
- audiobook listening
- musical training



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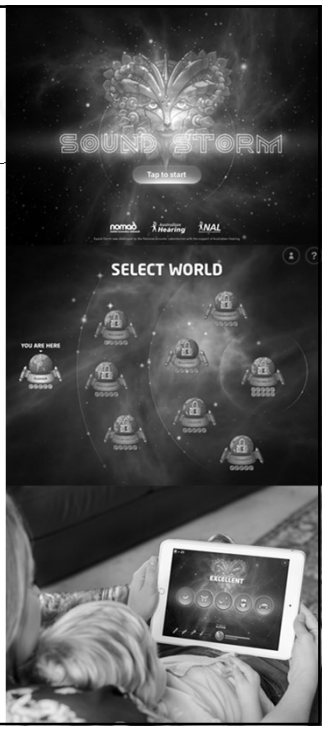
Auditory skills training
Home-based game format training software

- Sound Storm auditory training game
- improves hearing in noise
- evidence-based
- developed by Australian Government research group



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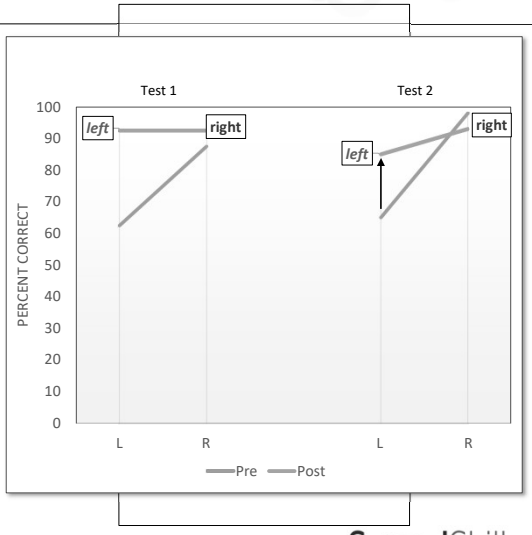
Auditory skills training
In-clinic auditory training

- ARIA - dichotic training for amblyaudia
- minimum of 4 sessions over 4 weeks
- strengthens weak ear
- improves hearing in situations with multiple speakers at once



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Auditory skills training
Audiobook listening

- auditory enrichment with mildly amplified whole language
- evidence is inferred from RMHA evidence and results with other groups
- listen at upper part of comfortable range, earphones or headphones, no visual or other distractions, sufficiently interesting to engage and maintain attention

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Auditory skills training
Musical training

- learning and playing music boosts brain and cognitive functions
- musical skills help hearing skills, and speech and language development
- music training improves educational outcomes including graduation rates
- less tangible benefits of music education include improved focus, discipline, confidence and even friendships

  - Music listening programmes such as Auditory Integration Therapy, Tomatis, are not recommended.by clinical professionals. Listening to music does not provide similar benefits to music training and does not treat APD.

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Language and literacy therapies
Language

Hearing problems affect language development. Language therapy, provided by speech-language therapists, is often required to treat various effects of auditory processing disorders including the following.

- language impairment
- deficient phoneme recognition and discrimination, deficient phonemic and phonological awareness, and consequent effects on spelling, vocabulary, and reading
- abnormal appreciation of prosody (pitch, stress, rhythm, and melodic pattern or intonation)

  Poor prosody perception can result in misunderstanding whether spoken language is intended to convey subtleties such as a demand, a question or humour.

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Language and literacy therapies
Literacy

- literacy (reading) therapy using a phonics approach may also be needed for some children with APD

  Speech-language therapists, teachers, learning support specialists, SPELD teachers and others may be involved in literacy/remedial reading tutoring.

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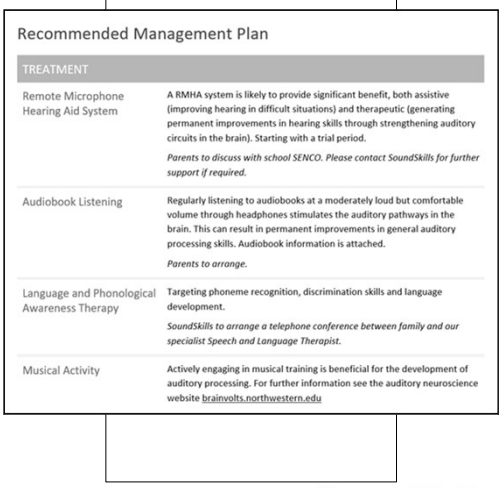
Management of APD

- the diagnosing audiologist is responsible for preparing a management plan customised to the needs of the individual, and for making any necessary further referrals
- many people may be involved in managing cases – parents, teachers, audiologists, speech-language therapists, paediatricians, psychologists, learning support specialists, SPELD teachers and more
- the SoundSkills multi-disciplinary team includes audiologists, a speech-language therapist, education advisers, and an autism specialist



Recommended Management Plan

TREATMENT	
Remote Microphone Hearing Aid System	A RMHA system is likely to provide significant benefit, both assistive (improving hearing in difficult situations) and therapeutic (generating permanent improvements in hearing skills through strengthening auditory circuits in the brain). Starting with a trial period. *Parents to discuss with school SENCO. Please contact SoundSkills for further support if required.*
Audiobook Listening	Regularly listening to audiobooks at a moderately loud but comfortable volume through headphones stimulates the auditory pathways in the brain. This can result in permanent improvements in general auditory processing skills. Audiobook information is attached. *Parents to arrange.*
Language and Phonological Awareness Therapy	Targeting phoneme recognition, discrimination skills and language development. *SoundSkills to arrange a telephone conference between family and our specialist Speech and Language Therapist.*
Musical Activity	Actively engaging in musical training is beneficial for the development of auditory processing. For further information see the auditory neuroscience website brainvolts.northwestern.edu

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Tips for teachers
Understanding APD, and strategies to assist at school

- NZ APD Guidelines Summary: Education (download details next slide)
- see also Ministry of Education website/APD https://www.education.govt.nz/school/student-support/special-education/assistive-technology/applying-for-assistive-technology/auditory-processing-disorder-apd/

- *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 volume*
- *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*

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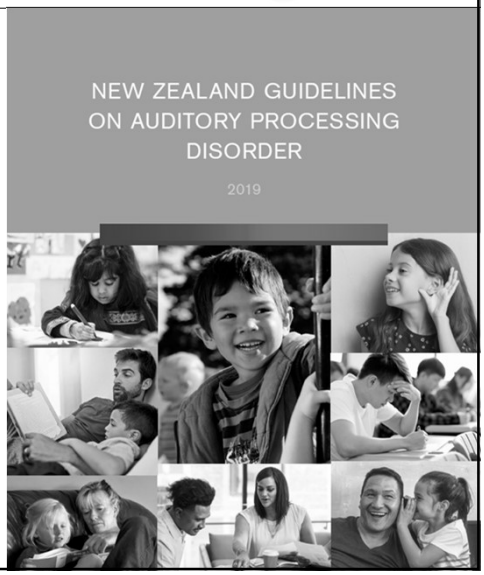
APD Guidelines and Summaries

- New Zealand Guidelines on Auditory Processing Disorder summary versions for the public and educators
- NZ APD Guidelines General Summary
  For consumers and their families
- NZ APD Guidelines Summary: Education
  For professionals in education, psychology and speech-language
- download from
  Resources/NZ Guidelines on APD at
  soundskills.co.nz



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