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(Central) auditory processing disorder: lessons from the past and evidence for the future

Wayne J Wilson
Division of Audiology
The University of Queensland
w.wilson@uq.edu.au

OVERVIEW

(C)APD
1. Different things to different people
2. Lessons from history
3. Approaching (C)APD as a clinician: current evidence for
   a. Screening
   b. Assessment & diagnosis
   c. Re/habilitation
4. The decision is your to make as a well informed clinician and researcher
Isn’t (C)APD simply DPA(C)?

That is, isn’t (C)APD:

- a *disorder* (not just a difficulty)
- of *processing* (not necessarily perception)
- of *auditory* information (not visual, kinaesthetic, etc; not language)
- in the *central* nervous system (particularly the CANS)?

*(C)APD* put *too* simply
1. “APD means different things to different people” (Jerger, 2009, p. 10)
2. Lessons from history

History – 6 approaches (Jerger, 2009, & beyond)

- Early pioneers (late 1800s & early 1900s)
  - Link between brain injury and disturbances of receptive & expressive language (Broca, Wernicke, Jackson, Head, Freud, etc)

  6 Approaches
  
  I. The *audiological* approach
  
  II. The *psychoeducational* approach
  
  III. An approach based on the possible impact APD could have on language acquisition and learning
  
  IV. An approach based on the requirement that (C)APD be *modality specific*
  
  V. An approach based on the defining feature of (C)APD being a *deficit in auditory attention*
  
  VI. An approach based on “listening difficulties”
I. The *audiological* approach

- Based on the concept that *a person with brain injury exhibits certain behaviours; ergo, if tests reveal these same behaviours, then a link to brain injury is established*

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**History**

<table>
<thead>
<tr>
<th>Time</th>
<th>Audiological Approach</th>
</tr>
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</table>
| 1950s | Disturbed auditory perception in children with normal audiograms (Mykleburst, 1954)  
“Sensitized” word lists detect temporal lobe lesions in adults (Bocca et al., 1954-55)  
Dichotic digits (Broadbent, 1958) |
| 1960s | SSW (Katz, 1962)  
Dichotic CVs (Berlin et al., 1968) |
| 1970s | DST (Willeford, 1977)  
SSI-ICM & SSI-CCM (Jerger et al., 1974, 1975)  
TC &/or RS (Beasley et al., 1977; Kurdziel et al., 1976)  
LPFS (Lynn et al., 1977) |
| 1980s | DSI (Fifer, Jerger et al., 1983)  
FPT & DPT (Pinheiro & Musiek, 1985)  
LPFS (Keith, 1986) |
| 2000s | Gap detection (Keith, 2000; Musiek et al., 2005) |
Evidence for *audiological* approach

- E.g., SSW in adults:
  - Temporal lobectomy (Berlin, Chase, Dill & Hagepanos, 1965)
  - Tumour (Jerger & Jerger, 1975; Lynn & Gilroy, 1975)
  - Stroke (Katz & Pack, 1975)
  - Commissurotomy (Baran, Musiek & Reeves, 1986; Musiek & Wilson, 1979)
  - Degenerative disorders such as Alzheimer’s disease (Grimes, Grady, Foster, Sunderland & Patronas, 1985)

- E.g., Musiek et al. (2011). CAP test batteries & brain lesions in adults

### Table 1: Sensitivity, Specificity, and Efficiency Values for Specific Combinations of CAP Tests Using the Strict Criterion in Which a Positive Diagnosis is Made on the Basis of Failure on All Tests in the Battery

<table>
<thead>
<tr>
<th>Battery</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICC (P)</td>
<td>16/100 = 16%</td>
<td>27/30 = 90%</td>
<td>35/40 = 88%</td>
</tr>
<tr>
<td>ICC (S)</td>
<td>10/20 = 50%</td>
<td>27/30 = 90%</td>
<td>35/40 = 88%</td>
</tr>
<tr>
<td>ICC (CS)</td>
<td>14/20 = 70%</td>
<td>28/20 = 100%</td>
<td>46/100 = 88%</td>
</tr>
<tr>
<td>ICC (PS)</td>
<td>10/20 = 50%</td>
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<tr>
<td>ICC (PS)</td>
<td>8/20 = 40%</td>
<td>28/20 = 100%</td>
<td>46/100 = 88%</td>
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</tbody>
</table>

**Three test**

<table>
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<tr>
<td>ICC (P)</td>
<td>10/20 = 50%</td>
<td>24/20 = 100%</td>
<td>36/100 = 36%</td>
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<td>ICC (CS)</td>
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**Four test**

**Evidence for *audiological* approach**

- Fewer studies with confirmed lesions in *children*
  - Drake (1968)
  - Galaburda and Kemper (1979)
  - Musiek et al. (1985)
  - Musiek and Gollegly (1988)
  - Boscariol et al. (2009, 2010)
II. The *psychoeducational* approach

- Based on the concept of *a set of primary (discrete) auditory abilities that can be tested by appropriate techniques*

- Target children for (C)AP evaluation because of assumed *learning problems*

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### History

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<td>1940s</td>
<td>Construct: disturbances in perception, thinking &amp; emotion caused by brain injury in children can be demonstrated by testing (Strauss &amp; Lehtinen, 1947) <strong>Gf-Gc theory of cognitive abilities</strong> <em>(Cattell, 1941)</em></td>
</tr>
<tr>
<td>1970s</td>
<td>Goldman-Fristoe-Woodcock Scale <em>(1974)</em>. 4 dimensions of AP: aud. discrimination, aud. memory, aud. selective attention &amp; sound-symbol association</td>
</tr>
</tbody>
</table>
| 1990s | Three Stratum Theory of Cognitive Abilities *(Carroll, 1993)*  
Cattell-Horn & Carroll *(CHC)* Theory of Intelligence & Assessment  
**CHC theory expanded** *(McGrew, 1997; Flanagan & McGrew, 1998)*  
Aud. processing skills listed by ASHA *(1996)* |
**CHC theory expanded** *(McGrew, 2005, 2011)* |
CHC Theory of Intelligence & Assessment

- Many theoretical constructs have been developed, e.g., Cattell-Horn & Carroll (CHC) Theory of Intelligence & Assessment

- 9 broad stratum abilities (and over 70 narrow abilities):
  - Crystallized Intelligence (Gc)
  - Fluid Intelligence (Gf)
  - Quantitative Reasoning (Gq)
  - Reading & Writing Ability (Grw)
  - Short-Term Memory (Gsm)
  - Long-Term Storage and Retrieval (Glr)
  - Visual Processing (Gv)
  - Auditory Processing (Go): is the ability to analyze, synthesize, and discriminate auditory stimuli, including the ability to process and discriminate speech sounds that may be presented under distorted conditions
  - Processing Speed (Gs)

III. An approach based on the possible impact APD could have on language acquisition and learning

- It is not unreasonable to suppose that problems in auditory perceptual processing could lead to problems in language acquisition and to subsequent learning disability
### History

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<tr>
<td>1970s</td>
<td>Construct: If audition → language, &amp; language → learning, then poor audition → poor language and learning</td>
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<td>“Rapid Auditory Processing” (Tallal et al., 1973)</td>
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<td>Rees (1973) (argued against [C]APD)</td>
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### Evidence for approach based on language acquisition

- **Summary**
  - *Not all children* with language learning impairments demonstrate non-verbal auditory processing problems, and vice versa (summarized in McArthur & Bishop, 2004)
  - (C)APD may be a *synergistic risk factor* for language impairment that exerts a moderating influence when children are already at genetic risk of language disorder, but (C)APD is *neither necessary nor sufficient to explain language difficulties* (Bishop et al., 1999)
IV. An approach based on modality specificity

- Consider three groups of individuals, all of whom perform poorly on tests of (C)AP:
  1. Specific perceptual problems processing information presented auditorily (C)APD in its “purist” form
  2. Auditory perceptual problems that coexist with other processing problems
  3. No auditory processing problems per se, but other problems with motivation, attention, memory, motor skills etc

- “Thus the differential diagnosis of sensory-specific perceptual deficits can be considered a form of hypothesis testing where the goal is to determine in which of the three groups described above a given individual belongs”

(McFarland and Cacace, 1995, p. 37)

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</table>
Evidence for approach based on modality specificity

• Defines (C)APD as a “modality specific perceptual dysfunction that is not due to peripheral hearing loss” (McFarland and Cacace, 1995b; Cacace and McFarland, 2005, 2013)

• Notes that perception in general, and auditory perception in particular, is not a behaviour: it is a “theoretical construct”.

• Emphasizes the roles of convergent and divergent validity in realizing the concept of (C)AP

• Bellis, Billiet & Ross (2008) and Bellis & Ross (2011) have shown different performances on equivalent diotic and dichoptic tasks in healthy adults and children and children with (C)APD

V. An approach based on the defining feature of (C)APD being a deficit in auditory attention

• (C)APD should be defined by:
  – the features of children referred for a (C)AP assessment that …
  – most correlate with the listening problems reported by the child’s teachers, parents, etc, …
  – with auditory attention appearing to be the key feature
History

<table>
<thead>
<tr>
<th>Time</th>
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<tbody>
<tr>
<td>Late 2000s</td>
<td>Attempts to define (C)APD based on the characteristics of children referred for a (C)AP assessment and how closely these characteristics relate to the listening problems reported by the child’s teachers, parents, etc. (mostly Moore et al., 2010)</td>
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</table>

Evidence for approach *based on auditory attention*

- Nature of APD in children (Moore et al., 2010)

- Found children’s classroom performance (CCC-2 &/or CHAPS) was best predicted by:
  - intensity, frequency & temporal discrimination (AP)
  - derived intensity, frequency & temporal discrimination (“pure AP”)
  - speech-in-noise
  - visual attention
  - cognition (IQ, memory, language, and literacy)
  - auditory attention

- Suggested APD is *primarily an (auditory) attention problem* and that clinical diagnosis and management, as well as further research, should be based on that premise
VI. An approach based on “listening difficulties”

• “… deliberately not attempting to define APD”

• Instead, “focus on the diagnosis and management of listening difficulties

(Dillon et al., 2012, p. 98)

Evidence for approach based on “listening difficulties”

• “Despite several consensus and position statements, disagreement abounds over what constitutes an APD. These issues may well be just matters of arbitrary definition, incapable of resolution by any scientific experiment, though in the fullness of time, some definitions will likely be found to be more helpful than others”

(Dillon et al., 2012, p. 98)
### History - summary

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<th>Time</th>
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<td>ASHA (1996)</td>
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<td>CHC theory</td>
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### The “big 3”

1. **American** Speech-language, Hearing Association (ASHA, 2005)

2. **American** Academy of Audiology (AAA, 2010)

3. **British** Society of Audiology (BSA, 2011a,b; Moore et al., 2012)
Also ...

4. **Canadian** guidelines on auditory processing disorder in children and adults: Assessment and intervention (CISG, 2012)

5. **German** consensus statement on (C)APD (Nickish et al., 2007)


7. **Audiological Society of Australia** Central Auditory Processing Special Interest Group. In progress.

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### ASHA (2005)/AAA (2010) vs BSA (2011)


<table>
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<tr>
<th>ASHA (2005)</th>
<th>BSA (2011a)</th>
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</table>

**Definition**

APD refers to difficulties in the perceptual processing of auditory information in the central nervous system, as demonstrated by poor performance in one or more of the following skills:

- sound localization and lateralization
- auditory discrimination
- auditory pattern recognition
- temporal aspects of audition, including temporal integration, temporal discrimination (e.g., temporal gap detection)
- temporal ordering and temporal masking
- auditory performance in competing acoustic signals (including dichotic listening), and
- auditory performance with degraded acoustic signals.

**Definition**

APD is characterized by poor perception of both speech and non-speech sounds.

APD has its origins in impaired neural function.

APD impacts on everyday life primarily through a reduced ability to listen, and so respond appropriately to sounds.

APD does not result from a failure to understand simple instructions.

APD is a collection of symptoms (although the specific symptoms are not explicitly stated) that usually co-occur with other neurodevelopmental disorders.


<table>
<thead>
<tr>
<th>ASHA (2005)</th>
<th>BSA (2011)</th>
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<tbody>
<tr>
<td>Although APD may exist with, lead to, or be associated with disorders of higher order language, cognition or related factors, it is not the result of such disorders.</td>
<td>Cognitive factors such as attention, rather than being a potential confound, may make a significant contribution to APD.</td>
</tr>
</tbody>
</table>

- Individuals suspected of having (C)APD frequently present with one or more behavioral characteristics
  - List of behaviors is illustrative, not exhaustive & not exclusive to (C)APD
  - **Behaviors not specifically diagnostic of (C)APD**

- No consensus on presenting symptoms/behaviors of (C)APD
  - We should focus on core symptom or symptoms that reflect and contribute to clinical presentation
  - Carefully constructed parent/caregiver evaluations might lead to a gold standard

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3. APPROACHING (C)APD AS A CLINICIAN

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Wilson, W.J. (2013). (C)APD. A paper presented at RIDBC CPE event, 11Oct13, Sydney, Australia
Approaching (C)APD


- Recently dominated by the recommendations of ASHA (2005) & AAA (2010)

- BSA’s (2011a,b) similar to ASHA (2005) & AAA (2010), with some key differences that reflect different theoretical constructs

3. APPROACHING (C)APD AS A CLINICIAN

a. Screening
Screening for (C)APD

- **Ability to separate children with/out CAPD (mostly “ASHA-like”)** (Wilson, 2014)

- **Questionnaires & Checklists**
  - CHAPS: 4 – yes, 5 – no (Dawes et al., 2008, 2010; Ferguson et al., 2011; Illiaou et al., 2012; Moore et al., 2010; Drake et al., 2006; Lam et al., 2007; Sharma, et al., 2009; Wilson et al., 2011)
  - FAPC: 1 – no (Dawes et al., 2008)
  - LIFE: 1 – yes (2 items only) (Johnston et al, 2009)
  - SIFTER: 1 – yes (academics subscore only), 1 – no (Johnston et al., 2009; Wilson et al., 2011)

- **Tests**
  - HINT: 1 – yes, 1 – no in adults (Fuente et al., 2006, 2011); 1 – yes (HINT-quiet score only) in children (Johnston et al., 2009)
  - PSI: 2 – yes (Jerger, 1987; Jerger et al., 1988)
  - TEA-Ch: 1 – no (Lam et al., 2007)
  - UQUEST: 1 – yes (Wilson et al., in press)

- **Test batteries**
  - MAPA: 1 – yes (Domitz & Schow, 2000)
  - SCAN: 1 – no (Domitz & Schow, 2000)
  - SCAN-C: 1 – no (Madison, Hallberg, Anfinson, DeMaio, & Drake, 2005)
  - SCAN-A: 1 – yes (competing sentences subtest only) (Lam & Sanchez, 2007)
  - TAPS-R: 1 – no (Wilson et al., 2011)

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Verdict

- Evidence for screening is *equivocal* with *no single tool standing out as a best candidate for screening for (C)APD*
3. APPROACHING (C)APD AS A CLINICIAN

b. Assessment

The Auditory Skills Profile

- **Good**
- **Avg**
- **Poor**
- **Very Poor**
- **Very Poor**

**Skill:**
- Auditory perf. degraded
- Dichotic: binaural separation/
- Temporal patterning
- Binaural interaction
- Temp. resolution/Auditory discrim.

**Test:**
- LPFS
- CS/DDT
- FPT
- MLD
- RGDT/NW Pest

Right ear
- Left ear
The Auditory Skills Profile

- **Skill:**
  - Auditory perf.
  - Dichotic: binaural
  - Temporal binaural
  - Temporal resolution/
  - Binaural interaction
  - Temp. resolution/
  - Auditory discrim.

- **Test:**
  - LPFS
  - CS/DDT
  - FPT
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  - RGDT/NW Pest

Evidence - history

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6. APPROACHING (C)APD AS A CLINICIAN
c. Diagnosis

Diagnosing (C)APD – the “big 3” + others

- ASHA (2005): fail ≥2 tests by ≥2 SD, or fail ≥ 1 test by ≥3 SD, plus no inconsistencies among tests
- AAA (2010): fail in ≥1 ear on ≥2 tests by ≥2 SD, & no inconsistencies among tests
- BSA (2011): fail ≥2 tests, ≥1 involving speech sounds & ≥1 involving non-speech sounds
### Evidence - history

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### Criticism of various diagnostic criteria

- **Wilson & Arnott (2012)**
  - 9 diagnostic criteria (based on ASHA, AAA, BSA & others) applied to 150 children who had completed the same (C)APD test battery
  - Diagnosis rates ranged from 7.3% to 96%
  - Any diagnosis of (C)APD should be qualified by an explicit statement of the criteria used

- **Dillon et al. (2012)**
  - Current diagnostic criteria are arbitrary
  - How poor must the test scores be on how many tests before the person will actually have a problem in real life?

  - (C)APD is a construct, not a behaviour
  - Assessment should be a form of hypothesis testing to delineate modality specific perceptual dysfunctions from supramodal or polysensory dysfunctions
6. APPROACHING (C)APD AS A CLINICIAN
b. Re/habilitation

Reviewed by:

Environmental modifications - FM systems

- Personal FM systems
  - Lemos (2009)
    - 20 studies, 3 level III & the rest level IV; results +ve but no control groups
  - Johnson et al. (2009)
    - Level III; improved performance on AP, academic & psychosocial measures
    - But language confounds in AP measure & control group only in pre-treatment phase
  - Hanschmann et al. (2010)
    - Level III; improved sentence in noise performance for both children with APD & controls
    - Again, language confounds

Verdict: some evidence emerging but higher level evidence needed ([C]APD was mostly “ASHA-like”)

Compensatory strategies

- CSs seek to improve the listener’s ability to take control of his or her own situation, i.e. to actively try to compensate for his or her own difficulties

- As per EMs, while CSs have prima facie value, it should not be assumed that other improvements will immediately follow

Verdict: no studies directly investigating the effects (if any) of CSs on (C)APD
Direct intervention - auditory outcomes

- Fey et al. (2011): 6 studies, level IIb & most level III
- McArthur (2009): 6 studies, Levels Ib-III
- Loo et al. (2010): 21 studies, levels Ib-III
- More recently
  - Cameron & Dillon (2011): LiSN & Learn
  - Sharma et al. (2012): env. mods + comp. strat. + direct int.

Verdict: The evidence that direct auditory interventions improve AP in school-age children with APD with or without spoken language, reading, or learning difficulties, compared to no treatment or placebo treatments, is:

- suggestive-to-compelling for interventions involving nonspeech and/or simple speech stimuli (noncomputer or computer-based),
- suggestive for Earobics, and
- equivocal for Fast ForWord.

The evidence that AIT has no effect on AP is suggestive.

(In the short-term, in school aged children, where [C]APD was mostly “ASHA-like”)
If you treat the (C)APD with AP therapy (non-speech and simple speech training) ...

If a problem here leads to ...

Can we find it?

a problem here
If you treat the (C)APD with AP therapy (non-speech and simple speech training) ...

Language Outcomes

- Fey et al. (2011): 19 studies, level IIb & most level III
- McArthur (2009): 6 studies, Levels Ib-III
- Loo et al. (2010): 21 studies, levels Ib-III
- More recently
  - Sharma et al. (2012): env. mods + comp. strat. + direct int.
Language Outcomes

Verdict: The evidence is suggestive to compelling that direct auditory interventions including computer-based interventions involving nonspeech and/or simple speech training and Fast ForWord do not improve spoken language and/or reading skills in school-age children with spoken language and/or reading disorders with or without APD, compared to no treatment or placebo treatments.

The evidence is suggestive that Earobics improves phonological awareness skills in this patient population.

(In the short-term, in school aged children, where [C]APD was mostly “ASHA-like”)

If you treat the (C)APD with AP therapy (non-speech and simple speech training) ...

If we fix it?

No short-term improvement in these problems but may be better positioned to fix these problems … all is not lost (McArthur et al., 2008)
OVERVIEW

(C)APD
1. Different things to different people
2. Lessons from history
3. Managing (C)APD: current evidence for
   a. Screening for (C)APD
   b. Assessing for and diagnosing (C)APD
   c. Re/habilitating (C)APD
4. The decision is your to make as a well informed clinician and researcher

The many ways of saying

XÈNE “Thank You” SPASiBO
GRACIAS Grazie Mahalo
Merci Danke WA·DO
Arigato Thanyawaad Asante
References


References


References


References


Wilson, W. J. (2013). (C)APD. A paper presented at RIDBC CPE event, 11Oct13, Sydney, Australia