Auditory Processing Disorders and Attention Deficit Disorders: Interventions to Increase Academic Success

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OSSPEAC
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Selected References


Selected References (continued)

• Caeyenberghs, K. et al. (2012) Graph Analysis of Functional Brain Networks for Cognitive Control of Action in TBI. Brain April 1, 1293-1307
Selected References (continued)

- Nature Reviews Neuroscience. www.nature.com/reviews
- Schacter, D. et al. The Future of Memory: Remembering, Imagining, and the Brain, Neuron, 76 (4) 677-694

Selected References (continued)

- Neuron (2012) 76(1) Reviews on Neuromodulatory Mechanisms

Selected References (continued)

Let's Start from the Beginning

Brodman's area map and colored outlines by process – the search for modularity

Neurons that fire together wire together in networks
Cortical module mapping also progresses

- Typical brain function
- Disorders
New Technologies Expand Understanding

**Diffusion Tensor Imaging**

- Measures diffusion (motion) of protons in water molecules.
- The linear structure of fiber tracts constrains proton diffusion and produces **anisotropy**.
- Provides clearly defined images of white matter tracts.

Tracts mature at different rates.
Other Aspects of Development - Synaptic pruning fine-tunes *local* circuitry

Categorical speech representation in human superior temporal gyrus

Edward F Chang, Jochem W Rieger, Keith Johnson, Mitchel S Berger, Nicholas M Barbaro & Robert T Knight
Nature Neuroscience
VOLUME 13 | NUMBER 11 | NOVEMBER 2010
Updated research

- N Mesgarani et al. Science 2014;343:1006-1010
Fig. 1 Human STG cortical selectivity to speech sounds. (A) Magnetic resonance image surface reconstruction of one participant's cerebrum. Mesgarani et al. Science 2014;343:1006-1010. Published by AAAS.

Fig. S6. Spatial organization of responses in STG. (A) Location of electrodes in one subject color coded by cluster membership in Fig. 2C shows a dispersed pattern. (B) Correlation values of electrode PSIs plotted against their distance shows a small but significant relation between similarity of PSIs with distance between electrodes.

Plots of grey-matter density are based on data by Gogtay et al. 2004 and illustrate the local grey-matter density in the mid-dorsolateral prefrontal cortex in red, in the angular gyrus of the parietal cortex in blue, in the posterior superior temporal sulcus in purple, and in the occipital pole in green.
Regions of the brain that show decreases in maturity during adolescence

Which takes us to Connectomes

• How do these modular systems integrate through the white matter fiber tracts for brain efficiency and plasticity

FROM THE JANUARY-FEBRUARY 2013 ISSUE of Discover Magazine

**New Project Maps the Wiring of the Mind**

Project to trace all the brain's main neural pathways begins its first human imaging.

By Kat McGowan | Wednesday, January 23, 2013
Clinical Takeaways

• Most developmental disorders that affect attention, auditory processing and speech may best be understood by a combination of modular and connection maps (connectomes).
• Treatment hierarchies can be developed using information from these combined constructs.
• Developmental disorders of brain network organization may be partially preventable but all are amenable to cognitive interventions that enable more efficient brain processing.
Medications and how they work

- Amphetamines
  - Adderall – stimulant, once a day, can become addictive
- SSRIs – suicidal warnings
  - Prozac
  - Zoloft
  - Paxil
- Targets for bipolar disorders
  - Lithium
  - Depakote (antiseizure)
  - Zyprexa – balances serotonin and dopamine
- Stimulants
  - Ritalin – approved for children 6 and older – oldest, most reliable
- Norepinephrine enhancers
  - Concerta – increases norepinephrine and dopamine
  - Strattera – nonstimulant that enhances norepinephrine
  - Effexor – targets serotonin and norepinephrine

‘Study Drugs’ Popular Among High School Students

- Stimulant medications prescribed for children with A.D.H.D. are being abused by high school students wanting to study late into the night and stay focused during exams.
- Next slide shows characteristics of the drugs’ five most popular brands, which (along with their generic equivalents) make up the vast majority of the 21 million stimulant prescriptions dispensed in 2011 for patients aged 10 through 19

Study Drugs NYT 6/7/12
Adderall XR (amphetamine)

• The most popular “study drug” among high school students, it lasts 8 to 12 hours, and its generic equivalent is less expensive than Vyvanse.
• Small beads in capsules can be crushed and snorted.
• It increases dopamine levels in the brain but also can affect sleep patterns.

Vyvanse (amphetamine)

• A popular new drug for A.D.H.D., it is the most expensive because there is no generic available, so some insurance plans will not cover it.
• It is very similar to Adderall, but absorption can be more smooth.
• It can also suppress appetite more drastically than Adderall.

Concerta (methylphenidate)

• Very difficult to crush into powder and snort, so it is popular among psychiatrists concerned a patient might abuse or sell it.
• It can provide a short-term boost and last up to 16 hours — drastically affecting sleep.
Focalin XR (methylphenidate)

- Effects can last 8 to 12 hours.
- It is methylphenidate’s answer to Vyvanse, because no generic is available, making it more expensive.
- Different formulation can bring a mix of side effects like headache, loss of appetite and jitters.

Ritalin (methylphenidate)

- Students like its relatively temporary effects (3 to 4 hours) that typically will not interrupt sleep.
- Length of time on market makes it very inexpensive.
- Some students report worse jitters after snorting and prefer Adderall or Vyvanse for a quick, long-lasting jolt.
Attention Disorder or Not, Pills to Help in School (NYT 8/9/2012)

• CANTON, Ga. — When Dr. Michael Anderson hears about his low-income patients struggling in elementary school, he usually gives them a taste of some powerful medicine: Adderall.

MTA at 8 Years: Prospective Follow-up of Children Treated for Combined-Type ADHD in a Multisite Study

Journal of the Academy of Child and Adolescent Psychiatry 48:5 May, 2009

3 year follow-up outcome

• On three year follow-up effects of combined drug + therapy was no longer evident
• Identified three subgroups of children based on trajectory
3 year follow-up outcome

- On three year follow-up effects of combined drug + therapy was no longer evident
- Identified three subgroups of children based on trajectory

6-8 year outcome

- Type or intensity of 14 months of treatment for ADHD in childhood (at age 7.0-9.9 years) does not predict functioning 6 to 8 years later
And medications are not necessary

- Neuroscience approaches can enhance attentional skills in all children
  - Technological approaches:
    - Fast ForWord
    - CogMed
    - Brain HQ (adolescents)
  - Educators can help as well

Auditory Processing

Development and Disorders
Organization of cortical responses to spoken language in 3 m old infants.

Dehaene-Lambertz, et. al, 2006

Normal A1 development

Four ways to degrade sensory cortex (aural language and somatosensory cortex) development

• structured noise Zhang et al (2004) PNAS
• perinatal anoxia Strata et al (2005) PNAS
A1 does not mature in infants raised in continuous noise

• In continuous noise reared rats, the critical period remains open indefinitely

A1 does NOT mature in rats raised in CONTINUOUS noise.

A1 processing is “specialized” as the infant rat is exposed to specific sound stimuli

A learning context is NOT required — it is after the end of the critical period.

Chang et al. (2003) ms submitted for publication

Zhang, Bao & Merzenich, Nature Neuroscience, 2001
Perinatally generated representational distortions in A1 tonotopy and input selectivity persist into adulthood.

Zhang, Bao & Merzenich, Nature Neuroscience, 2001

PCB poisoning radically alters cortical map development

Normal

PCB exposed animals

Exactly the same bizarre typography seen in autism
PCB exposure in pregnant mothers .87 correlation with % of autism – some regions of Texas – Merzenich, 2006

Turken and Dronkers (2011) in press – White Matter tracts underlying auditory speech processing
Raschle et al., PNAS Feb. 7, 2012

Fig. 1. Statistical parametric maps showing brain activation during phonological processing (PM > VM) for children with (A) and without (B) a familial risk for DD, as well as group differences between children with compared to without (FHD > FHD) a familial risk for DD (C). FHD show significantly greater activation compared to FHD, children in bilateral occipitotemporal and left temporo-parietal brain regions, as well as left and right cerebellar regions.

CAPD Management – traditional approaches

- Signal enhancement
- Auditory training
- Environmental modifications
- Metacognitive [executive] strategies
- Linguistic strategies
- Metalinguistic strategies
- Collaboration
- Learning strategies
Research on works with Auditory Processing Disorders  (Kraus, N. (2012))

- **Classroom amplification devices** – In a study on children in a Chicago school for children with learning problems
  - Half of a group of children wore FM assistive listening devices (PhonakEduLink)
  - Compared with controls the FM-device wearers significantly improved on measures of reading and phonological awareness
  - cABR measure of response consistency–intra-session response replicability – was also improved in the FM device wearers
  - the children in the experimental group who had the least consistent cABRs prior to the year of FM device usage showed the largest improvements in reading measures

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Independent Research on Auditory Processing

- A small cohort of ASD children participated in 5–10 weeks of “FastForWord” training (Scientific Learning Corp.).
- A marked reduction in pitch error – the deviation of the response from the stimulus – was observed in one of the participants.
- Another aspect of the cABR, specifically timing to the syllable “da”, was improved in three participants relative to the non-trained controls (Russo, Hornickel, Nicol, Zecker, & Kraus, 2010).

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*Independent research on use of FFWD Language with Dyslexia and Auditory Processing (Temple et al., 2001; Gaab, 2008)*

**Normal readers**

**Dyslexics before training**
Effects of Fast ForWord Language on Brain Processes

(Dehaene, Reading in the Brain, pp 260)

Difference before and after training

What else works with Auditory Processing Disorders, cont. (Kraus, N. 2012)

- **Long term experience (music)**
  - Memorization of sounds, visual patterns and auditory sequences
  - Strengthens the ability to remember, manipulate (e.g., reorder), and recite lists of words, numbers or sentences
  - Improved memory affects transfers to other communication skills such as hearing in noise
  - This, in turn, improves auditory centers in the cortex resulting in a more finely tuned auditory brainstem.

Auditory processing component of ASD

- Russo, Nicol, Trommer, Zecker, & Kraus, 2009; Russo, Skoe, Trommer, Nicol, Zecker, Bradlow, & Kraus, 2008
Impaired brainstem processing of speech and prosody in some children with ASD

- Children ages 7-13 y.o (mean=9.9 yrs)
  - Children with ASD (n=21; 19 males, 2 females)
  - Typically-developing control children (TD) (n=21; 13 males, 8 females)
- Mental ability within normal limits, normal hearing, no confounding neurological impairment

Russo, Nicol, Trommer, Zecker, & Kraus, 2009; Russo, Skoe, Trommer, Nicol, Zecker, Bradlow, & Kraus, 2008

Encoding of F0 is deficient in children with ASD

Investigating the effects of Fast ForWord training

- 5-10 weeks of training with Fast ForWord
- Participants
  - Self-selected from previous studies
  - Average intellect, normal peripheral hearing (audiogram & click-evoked ABR), language score >80
  - Trained group: 5 children with ASD
    - mean age=9.4 yrs, SD=1.52
  - Control group: 6 children with ASD
    - mean age=9.0 yrs, SD=1.54

Methods

- /da/ and /ya/-evoked brainstem responses
- /da/-evoked cortical responses
- Change = post test – pretest
  - /da/: earlier is better
  - /ya/: lower frequency error is better, increased phase locking is better
- Compared responses to degree of change in control group, improvements ≥ 1.6 SD criterion deemed significant

Russo, Hornickel, Nicol, Zecker, & Kraus, 2010

Pitch tracking to the harmonics improved

Summary

- Training with Fast ForWord produced measurable improvements in auditory function in some children with ASD
  - Brainstem (/da/) – 3 kids
  - Brainstem (/ya/) – 1 child
  - Cortex (/da/) – 5 kids
- Cortical changes may precede behavioral and/or brainstem changes

Russo, Hornickel, Nicol, Zecker, & Kraus, 2010
What else works with reading problems?

Working memory training improves reading processes in typically developing children

Sandra V. Loosli
Martin Buschkuehl
Walter J. Perrig
Susanne M. Jaeggi
Volume 18, Issue 1, 2012

Attention

Core component of Cognitive Control (Executive Function) – Development and Disorders

Frontal Lobe Development

- Dorsolateral prefrontal cortex
  - Executive functions (organization, goal setting, planning, flexibility, cognitive control, working memory)

- Ventromedial prefrontal cortex
  - Mentalizing (theory of mind), self awareness, compassion

- Orbital prefrontal cortex
  - Outcome monitoring, evaluation of risk versus reward
Dorsolateral Pre-frontal lobe

Fig. 2 Attentional modulation of functional connectivity. (A) The guided activation theory of cognitive control posits that prefrontal cortex (PFC) sends feedback to posterior cortex to switch connectivity between cortex and establish task-relevant pathways (22).

Attentional Networks (Connectomes)

- Attention as a core component of cognitive control
- Deficits include distractibility and impulsivity
  - Wide distributed networks with frontal lobe providing top-down control
  - Two primary attentional networks:
    - Frontal parietal – ignoring distractions and working memory
    - Frontal striatal – lack of flexibility and impulsivity
Response inhibition – Stroop-like test

Response inhibition – Stroop-like Test
Different dimensions of adult cortical plasticity are enabled by the behaviorally-context-dependent release of:

- acetylcholine (focused attention/reward) (Kilgard, Bao)
- dopamine (reward, novelty) (Bao)
- norepinephrine (novelty) (Bollinger)
- serotonin (Bollinger)
- et alia

In infants, exposure-based plasticity is relatively uniform. In older children, learning-induced changes are complexly "nuanced" by differences in behavioral context that result in the differential release of 6 or 7 modulatory neurotransmitters.

Using genetic data in cognitive neuroscience: from growing pains to genuine insights

Adam E. Green, Marcus R. Munafò, Colin G. DeYoung, John A. Fossella, Jin Fan and Jeremy R. Gray
NRNS, September 2008 | volume 9

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ADHD and ADD

Normal brain development versus ADHD

• Note that in ADHD development, especially of the prefrontal lobes (and perhaps right hemisphere significantly lag behind) — especially during adolescence
Participants in the National Institute of Mental Health Multimodal Treatment study for attention-deficit hyperactivity disorder (ADHD) reflect the complex mental health profiles of US children with ADHD. Only a third of the children in the study had a diagnosis of ADHD alone. More than half of the children had conduct or oppositional defiant diagnoses in addition to having ADHD, and a significant proportion of those with conduct and oppositional diagnoses also had an anxiety disorder.

Differential Diagnosis (Chermak, et al, 1998)

- Rank order ADHD
  - inattentive
  - distracted
  - hyperactive
  - fidgety/restless
  - hasty/impulsive
  - interrupts/intrudes

- Rank order CAPD
  - difficulty hearing in background noise
  - difficulty following oral directions
  - poor listening skills
  - academic difficulties
  - poor auditory assoc.
  - Distracted
  - inattentive

Attentional vs. Memory or Auditory Processing Problems

- Poor listener or tunes out (could be an auditory processing problem)
- Frequently asks – Huh? or What? when given instructions – working memory
- Looks around to see what others are doing when teacher provides instructions – working memory or APD
- Fidgets, impulsive, intrusive, yells out answers, lack of self control -- ADHD
Neurobiology of ADHD Vs. ADD

- Core problem in ADD is in working memory
  - Complex span and dual task dichotic listening can detect this
  - Rather than being distractible they may be easily bored, their problem more in underarousal than inhibitory control
  - Primary disturbance in the frontal-striatal loop of ADHD
  - Primary disturbance in ADD is a frontal-parietal loop

### ADHD Vs ADD (Diamond, 2005)

<table>
<thead>
<tr>
<th>ADHD</th>
<th>ADD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperactive, always on the go, impulsive</td>
<td>A significant subset are hypoactive and sluggish and have slow response speeds</td>
</tr>
<tr>
<td>Primary deficit in response inhibition</td>
<td>Primary deficit in working memory, especially prominent in auditory processing because of the demands it places on working memory</td>
</tr>
</tbody>
</table>

### ADHD VS ADD (2)

<table>
<thead>
<tr>
<th>ADHD</th>
<th>ADD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Often insufficiently self-conscious</td>
<td>Tend to be overly self-conscious</td>
</tr>
<tr>
<td>Social problems because too assertive and impulsive: intrusive, take things belonging to others, fail to wait their turn, and act without first considering the feelings of others</td>
<td>Social problems because too passive, shy, or withdrawn</td>
</tr>
</tbody>
</table>
ADHD vs ADD (3)

ADHD
• Tend to be extroverted
• Externalizing behaviors, such as conduct disorder, aggressivity, disruptive behavior, and even oppositional defiant disorder are far more commonly comorbid with ADHD than with ADD.

ADD
• More likely to be introverted
• Internalizing disorders, such as anxiety or depression, are somewhat more common in children with ADD than those with ADHD. ADD children tend to be socially isolated or withdrawn.
• Reading and language deficits and problems with mental mathematical calculations are more commonly comorbid with ADD than with ADHD.

Understanding the top-down and bottom-up interventions

But did you know new neuroscience research indicates that the most effective interventions......

• Exercise bottom-up and top-down systems concurrently to maximize outcomes efficiently
• Resulting in short term gains but also maximize long terms outcomes
The focus of Neuroscience now....

- Blending top-down and bottom-up exercises to maximize the power of the outcomes

**So What Does This Mean?**

Activity dependent neuroplasticity  
(Vinogradav, 2012)

- “The prefrontal cortical association areas are uncommitted at birth, programmed to be shaped over the lifetime by the individual’s unique perceptual, cognitive, and affective experiences.”

Tracts mature at different rates
Changes in Brain Structure in Maturing Young People

Plots of grey-matter density are based on data by Gogtay et al. 2004 and illustrate the local grey-matter density in the mid-dorsolateral prefrontal cortex in red, in the angular gyrus of the parietal cortex in blue, in the posterior superior temporal sulcus of the temporal cortex in purple, and in the occipital pole in green.

Why focus on perceptual problems? They create unstable states in the brain

- Irrelevant stimuli capture attentional resources
- They are incorrectly coded as salient or novel
- They enter into working memory, and increase activity in subcortical noradrenergic and dopaminergic systems.
- This creates an unstable state in the brain, leading to further inappropriate learning (see Mercado et al., 2001; Kilgard, 2002)
Why focus on perceptual problems? They create unstable states in the brain

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In order for prefrontal cortical operations to engage in efficient decision-making and adaptive behavior, the brain must be able to continuously make accurate predictions about the near future. These predictions rely on rapidly and accurately comparing high-fidelity perceptions of our current internal and external environments with past experiences. Vinogradav, et al 2012

Activity dependent neuroplasticity (Vinogradav, 2012)

- “The high degree of learning-dependent brain plasticity—combined with the availability of advanced computerized technology allows us to deliver well-defined and constrained learning events to the brain.”
The balance is between low level, mid level is even more critical for impaired brains (adapted and modified from Ahissar et al [2009]).

- In an impaired brain, distortions or limitations at any level will create bottlenecks for learning-induced widespread adaptive changes.

- If training of sufficient intensity and duration progresses on specific sets of informative lower-level and middle-level stimuli and tasks,
  - plastic changes feed forward to improve the representational fidelity of information at higher levels
  - Learning is then partially transferred to higher-level contexts that use the trained lower-level features.

Critical active ingredients of neuroscience-informed approach to cognitive intervention

1. Precise engineering of stimuli and tasks in order to improve the speed and accuracy of relevant information processing throughout the targeted neural system(s), including lower and higher levels of processing (Ahissar, 2009)

2. Highly intensive training schedules of carefully controlled and constrained learning events along with individualized adaptation of task difficulty to drive learning and preserve reward schedules.

- The relevant ‘skills’ must be identified, isolated, then practiced through hundreds if not thousands of trials on an intensive (i.e., quasi-daily) schedule (Roelfsema 2010)
Critical active ingredients of neuroscience-informed approach to cognitive intervention

3. In order to maximize enduring plastic changes in cortex, the learner must attend to each trial or learning event on a trial-by-trial basis and a very high proportion of the learning trials must be rewarded immediately (rather than at the end of a block of trials or on a trial-and-error basis) (Roelfsema 2010)

In addition, mechanisms and effects of myelin reduction in FA is just starting to be understood

Vinogradov (2012)

• These studies in children show that repetitive training (implicit learning) that focuses on relatively lower-level impairments can result in clinically meaningful generalized improvements in real-world behavior and affect.
• There is also extremely high clinical potential of carefully constructed higher level cognitive training that is based on an understanding of systems neuroscience.
Ways to enhance classroom (listening) attention

- Listening activities
  - Audio books (without the written book to follow along) with periodic comprehension questions
- Following oral directions
- During book reports or oral classroom presentations provide a post-activity prize for specific details students recall

Ways to enhance classroom (listening) attention

- Continuous performance tasks - Vigilance
  - Tap your finger for the letter ‘d’
  - Tap your finger when ‘d’ is preceded by the letter ‘n’
  - Tap your finger when ‘d’ is preceded by the letters ‘f’ and ‘g’

Activities that build selective attention

- Younger students – “Simon Says”
- Continuous performance activities – demo
- Listening for specific details such as how many times is the word _____ used; in a news cast, audio book, video
- “Where’s Waldo” type visual search activities
- During book reports or oral classroom presentations provide a post-activity prize for specific details students recall
Ways to enhance classroom (listening) attention outside of the classroom

- Listening activities
  - Audio books (without the written book to follow along) with periodic comprehension questions
- Following complex oral directions

Working memory

- Working memory is your RAM
- It is closely tied to and can build fluid intelligence (ability to solve novel problems you have never seen before)
- It is a core component of executive function

Brain Fitness: Word List Challenge

Now write down as many words as you can recall. You have one minute.

<table>
<thead>
<tr>
<th>Word List Challenge</th>
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<tbody>
<tr>
<td>pill</td>
</tr>
<tr>
<td>epic</td>
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<tr>
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<tr>
<td>natural</td>
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<tr>
<td>photo</td>
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Working memory training improves reading processes in typically developing children

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How working memory problems present in the classroom

• Slow on multiple choice tests even though they know the material
• Re-read passages frequently
• Trouble with memorization activities but get the key ideas
• Take much longer to complete homework and in class assignments
• Word-finding problems
• Problems with spelling
Classroom activities that build working memory

- Language Arts teachers
  - Reading comprehension as long as the student cannot review the text
  - Demo Book Monkeys
- Math teachers
  - Sudoku (without notes)
  - Ken Ken
  - Word problems
- History teachers
  - Timelines (use timelines for short-term discussion and solving what-if questions)
- Science teachers
  - All lab experiments involve working memory

The key to building working memory skills is not to emphasize the outcome, but rather the process. So, don’t penalize students who struggle with working memory – rather give them opportunities to practice and be successful.

Neural mechanisms of selective auditory attention are enhanced by computerized training:
Electrophysiological evidence from language-impaired and typically developing children

- Courtney Stevens, Jessica Fanning, Donna Coch, Lisa Sanders, Helen Neville

**Brain Research** 1205 (2008) 55–69
Cog Med Research with ADHD


Working memory, attention, receptive language and verbal expression

- Fast ForWord and BrainPro programs
  - Attention, Auditory Working Memory, Language and Processing Speed
- Reading Assistant
  - Oral/Reading fluency and expression – excellent for children with CAS and (C)APD
- Classroom amplification systems – Auditory Processing and Reading
- PROMPT and other motor speech approaches like KSLP – excellent for children with CAS in conjunction with interventions to address other issues, (APD, Language)
- Musical Training – auditory processing, working memory