Executive Functioning and Language Development in Children with Cochlear Implants

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Handouts: [http://www.indiana.edu/~drk/](http://www.indiana.edu/~drk/)
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Where It All Begins: Hearing, Speech, and Language

- Benefits of cochlear implantation for hearing, speech, and language in children with early deafness are well-established

More to the Story: “Downstream Effects” of Early Deafness and Language Delay

- “Hearing loss is primarily a brain issue, not an ear issue.” (Flexer, 2011, Cochlear Implants International)
- “…deaf children are not simply hearing children who cannot hear.” (Marschark & Knoors, 2012, Deafness & Education International)
- “…sensory loss has distal effects that extend well beyond the sensory system and related brain functions, with pronounced effects on central neurological and higher order neurocognitive functioning.” (Kral et al., 2016, Lancet Neurology)
- “The type of neural reorganization caused by auditory deprivation before implantaion is valuable for predicting post-CI language outcomes for young children” (Feng et al., 2018, PNAS)
Downstream Neurocognitive Effects: Executive Functioning, Hearing, and Language

- Auditory and language experience appear to be particularly important for the development of a set of neurocognitive functions collectively referred to as executive functioning (EF).
- Executive functioning: the active regulation of cognitive, behavioral, and emotional processes in the service of planned, organized, controlled, goal-driven thinking and behavior.
  - Planned, purposeful, effortful self-regulation
  - Multiple components: working memory, inhibition, flexibility-shifting, controlled attention, planning, organization.

EF Has Many Parts

Auditory Experience and EF Practice

How Would Deafness Affect EF in CI Users? The Auditory-Neurocognitive Model

Language and EF Self-Regulation

- Therefore, the risk of EF delays in children with hearing loss is a result of reduced auditory and language experiences.
- Assistive devices such as CIs and hearing aids do not cause the delay and in fact may improve long-term development of EF.
Executive Functioning in Children with Cochlear Implants:
Research Findings

- EF delays in children with CIs are found:
  - Even with no audibility or speech production demands
  - Even when groups are matched on nonverbal IQ
  - Even when measures with varying verbal mediation are used
  - Longitudinally throughout childhood

How Does EF Support Spoken Language in Children and Adolescents with CIs?

- Language processing is more effortful and less automatic for children with CIs compared to NH children
  - Underspecified, degraded auditory input
  - Reduced exposure to spoken language
  - Searching for words in memory is harder
- Many children with CIs have to put in more work (focus and concentration) when using language in order to make up for challenges in speech perception and reduced experience with spoken language in early development

EF, Speech, and Language: Dual-Channel/EF-Compensatory Models of S-L Processing

- EF-Compensatory Models of Speech-Language Processing Under Challenging Conditions (ELU [Ronnberg et al., 2013], FUEL [Pichora-Fuller et al., 2016], ANM [Kronenberger & Pisoni, 2017])
  - Basic/simple language stimuli (e.g., speech perception under ideal conditions by NH listeners, rapid access to familiar words in the mental lexicon) are processed using fast-automatic channels that take little effort, focus, or active processing
  - Challenging language stimuli (e.g., speech perception under challenging conditions, effortful search of the mental lexicon) are processed using slow-effortful, active-controlled processes (executive functioning)
**EF and Language in Children with CIs: Better FOCUS means Better LANGUAGE**

- Compensatory focus and concentration during language processing for children with CIs
  - When processing language, children with CIs, on average, draw on their EF resources more than NH children – they have to concentrate harder
  - Therefore, children with CIs who have better EF have better basic language skills
    - This puts more pressure on the EF of children with CIs
    - Research suggests that EF is less important for basic language skills in NH children

**EF-Compensatory Language Processing in Children with CIs: Cross-Sectional/Correlational Research**

- Children with CIs who have better EF have better speech and language outcomes
  - Verbal WM and Controlled Cognitive Fluency
- EF is more strongly related to language skills and knowledge in CI users than NH peers
- EF is more strongly related to speech perception in CI users than NH peers

**EF-Compensatory Language Processing in Children with CIs: Longitudinal Research**

- Children with CIs who have better EF earlier in development have better speech-language outcomes later in development
  - Verbal WM and Controlled Cognitive Fluency
- EF is more strongly related to later speech-language outcomes in CI users than NH peers

**EF-Compensatory Language Processing in Children with CIs: Experimental Manipulation**

- 2 Conditions
  - Single Task: Lexical Decision Task only (speed of identifying whether an auditory stimulus is a word or nonword) – measures efficiency of search of mental lexicon
  - Dual Task: LDT with Additional Verbal Working Memory task – occupies/depletes verbal WM resources and allows you to see how much verbal WM is used when finding common words in the mental lexicon
- ELU, ANM predict that single task and dual task performance will be equivalent for NH peers because they are using fast-automatic processes for word search
  - But CI users engage in more slow-effortful processes that are more dependent on verbal WM and therefore, their dual-task performance will be poorer

**EF Provides Resources for Language Processing**

- Verbal working memory – Actively controlled processing of verbal information in immediate memory: hold more language in mind as the language is operated on by mental processes
- Controlled cognitive fluency – Focused, efficient, effortful concentration so that information can be processed rapidly, comprehensively, and accurately – allows more language to be processed effortfully in a short period of time

**Verbal WM Skills Support Word Search in Children with CIs but Not in NH Peers**

Note: N=9 CI users and 9 NH peers. From Kronenberger et al. (under review)
EF and Speech-Language Skills in Children with CIs: Translating Research to Practice

- Some subdomains of EF are significantly delayed in 30-50% of children with CIs (2-5x risk of NH)
- Children with CIs depend on EF more than NH children when processing language
- Implications for Practice
  - Assess for risk of EF delay; intervene if warranted
    • EF delay carries broad functional risks
  - Improve EF as a way to enhance speech-language functioning
    • Conversely, improve language as a way of enhancing EF

Implications for Practice

- A s s e s s  f o r  r i s k  o f  E F  d e l a y ;  i n t e r v e n t i o n  i f  w a r r a n t e d

- E F  d e l a y  c a r r i e s  b r o a d  f u n c t i o n a l  r i s k s

- I m p r o v e  E F  a s  a  w a y  t o  e n h a n c e  s p e e c h - l a n g u a g e  f u n c t i o n i n g

  - Conversely, improve language as a way of enhancing EF

CAN WE IMPROVE EF?

Strategies to Develop and Improve EF in Children

- Parents and Families
  - Computer programs
  - Activity/discipline programs (martial arts)
  - developingchild.harvard.edu

- Teachers/Therapists
  - www.toolsofthemind.org

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Improving EF: Medication

- Research shows that some types of medication improve working memory, inhibition, and attention
- If EF delays are markedly interfering with functioning in spite of other interventions, medication might be considered
The End

• Thank You!!
• Questions?
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