VANDERBILT UNIVERSITY
MEDICAL CENTER

Objective Assessments of Fatigue in School Age Children with Hearing Loss

Samantha Gustafson, AuD

ASHA Convention

November 12-14, 2015

VANDERBILT UNIVERSITY
MEDICAL CENTER

Acknowledgements

- Faculty Investigators
  - Fred H. Bess
  - Stephen Camarata
  - Ben W.Y. Hornsby
  - Alexandra Key
- Lab Members (previous and current)
  - Nicholas Bennett
  - Angela Chen
  - Hilary Davis
  - Tonia Davis
  - Stone Dawson
  - Andy DeLong
  - Caralie Focht
  - Emily Fustos
  - Elizabeth Geller
  - Olivia Gutierrez
  - Amanda Headley
  - Dorita Jones
  - Ralph Leverett
  - Lindsey Rentmeester
  - Quela Royster
  - Rebecca Schoon
  - Sara Seckman
  - Amelia Shuster
  - Beth Suba
  - Krystal Werfel
- Project/Staff Funding
  - Institute of Education Sciences, U.S. Department of Education through grant R324A110266 (Bess, PI) to Vanderbilt University
  - Dan and Margaret Maddox Charitable Trust
  - American Speech Language and Hearing Association

VANDERBILT UNIVERSITY
MEDICAL CENTER

What is Fatigue?

- Occurs in the physical and mental/ cognitive domains
- Subjectively- fatigue is a mood or feeling of tiredness, exhaustion, or lack of energy
- Behaviorally- fatigue affects focus, concentration, alertness, and/or mental efficiency

Fatigue is Common!

Transient fatigue

- Common, even in healthy populations

Recurrent, severe fatigue

- Uncommon in healthy populations, but common in many chronic health conditions
  - Cancer, HIV AIDs, Parkinson's, Multiple Sclerosis

VANDERBILT UNIVERSITY
MEDICAL CENTER

Consequences of Fatigue

Adults

- stress, inattention, concentration, mental processing, and decision-making
- less productive and more prone to accidents
- less active, more isolated, less able to monitor own self-care

Children with chronic illnesses

- inattention, concentration, distractibility
- poorer school achievement, higher absenteeism

Amato, et al. 2001; van der Linden et al. 2003; DeLuca, 2005; Eddy and Cruz, 2007; Ricci et al. 2007

VANDERBILT UNIVERSITY
MEDICAL CENTER

Fatigue and Hearing Loss

"...since I lost most of my hearing..., I've had periodic bouts of tiredness that are deeper and of a different quality than I ever experienced before."

– David Copithorne, 2006

"First thing I do when I get home is take my hearing aids out. I just need a break."

- Student with hearing loss

"Processing and constructing meaning out of half-heard words and sentences. Making guesses and figuring out context. And then thinking of something intelligent to say in response to an invariably random question. It's like doing jigsaws, Suduku and Scrabble all at the same time."

– Ian Noon, 2013

"My child stayed only five minutes at a recent social event. He tends to withdraw and get overwhelmed in big groups of people. He's seeming more frustrated by these experiences."

- Mother of a child with hearing loss

VANDERBILT UNIVERSITY
MEDICAL CENTER

Is fatigue associated with effortful listening?

<ins>Listening effort</ins> refers to the allocation of attentional and cognitive resources toward auditory tasks.

Greater listening effort → increased demands on top-down processing

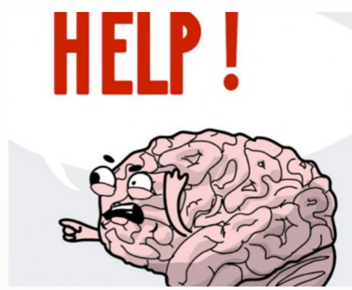
Downs 1982; Pichora-Fuller et al., 1995

VANDERBILT UNIVERSITY MEDICAL CENTER

Is fatigue associated with effortful listening?

Degraded Listening Conditions → **Increased Listening Effort** → **Decline in Available Top-Down Processing Resources** → **Increased Stress** → **Fatigue**






Bess and Hornsby (2014)

VANDERBILT UNIVERSITY MEDICAL CENTER

Measuring Listening-Related Fatigue

Subjective measures include surveys, rating scales and questionnaires that ask about mood or feelings

- No currently-available tool focuses on fatigue related to listening
- Subjective measures alone provide an incomplete assessment of fatigue
  - The physiologic mechanisms responsible for the rating may be variable or unknown
  - Often uncorrelated with severity of conditions associated with the fatigue

Measuring Listening-Related Fatigue

Subjective measures include surveys, rating scales and questionnaires that ask about mood or feelings

Objective measures do not require the listener to make judgment of their fatigue

- Behavioral
  - Measures of performance decrement
  - A decline in (cognitive) task performance in conjunction with sustained (mental) demands

VANDERBILT UNIVERSITY
MEDICAL CENTER

Measuring Listening-Related Fatigue

Subjective measures include surveys, rating scales and questionnaires that ask about mood or feelings

Objective measures do not require the listener to make judgment of their fatigue

- Behavioral
- Physiologic
  - Physiologic changes or biomarkers associated with mental effort

Cortisol measures
Hicks and Tharpe, 2002; Tops et al., 2006

EEG measures
Murata et al., 2005; Trejo et al., 2004

Skin Conductance
Darrow and Solomon, 1934; Segerstrom and Nes, 2007

fMRI measures
Caseras et al., 2006; Caldwell et al., 2010

VANDERBILT UNIVERSITY
MEDICAL CENTER

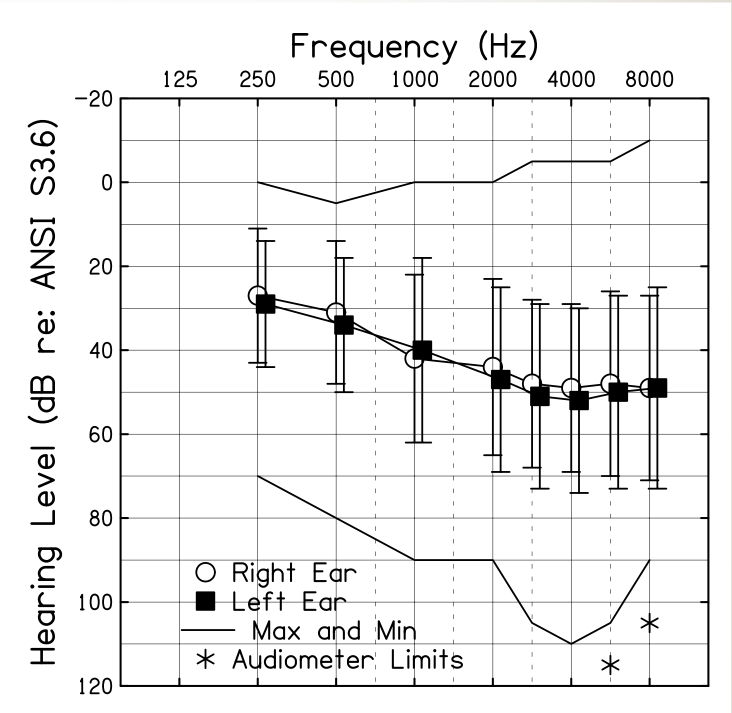
Vanderbilt Study on Listening Effort & Fatigue

Goals:

1. **Characterize a physiologic marker of stress**
2. **Induce listening-related fatigue in the laboratory**
   a. Measure it using behavioral and subjective assessments
   b. **Determine if physiologic assessments can characterize the effects of fatigue**
3. Examine the effect of daily listening fatigue on literacy performance

Vanderbilt Study on Listening Effort & Fatigue

- 6-12 year old children
  - Bilateral, mild to moderately-severe, permanent hearing loss
- Inclusion/Exclusion:
  - No cochlear implant users
  - General education classroom
  - Monolingual English speakers
  - No diagnosis of cognitive impairment, autism, or other developmental disorder



- Experimental group (n=59)
  - 30 males, 29 females
  - Age = 9.93 (1.92) years
- Control Group (n=42)
  - 25 males, 17 females
  - Age = 9.16 (2.32) years

Vanderbilt Study on Listening Effort & Fatigue

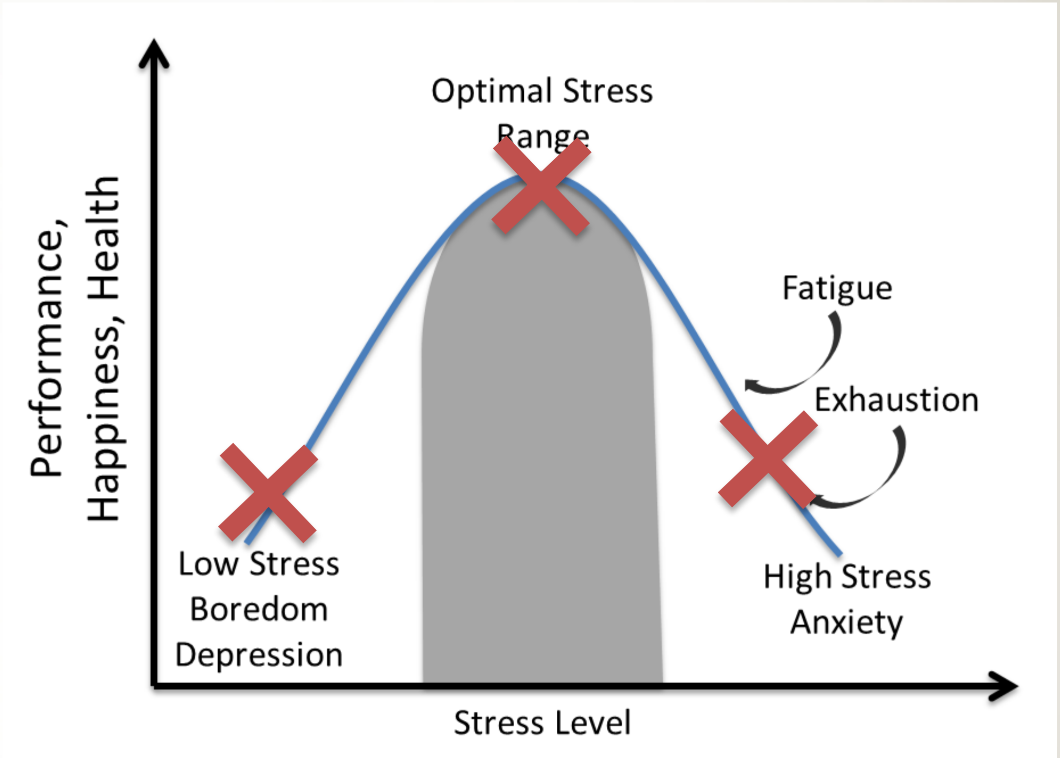
Goals:

1. **Characterize a physiologic marker of stress**
2. Induce listening-related fatigue in the laboratory
   a. Measure it using behavioral and subjective assessments
   b. **Determine if physiologic assessments can characterize the effects of fatigue**
3. Examine the effect of daily listening fatigue on literacy performance

VANDERBILT UNIVERSITY
MEDICAL CENTER

Stress, Cortisol, and Fatigue

- Stress is the body's reaction to change that requires a physical, mental, or emotional response
  - Stress is caused by good and bad experiences



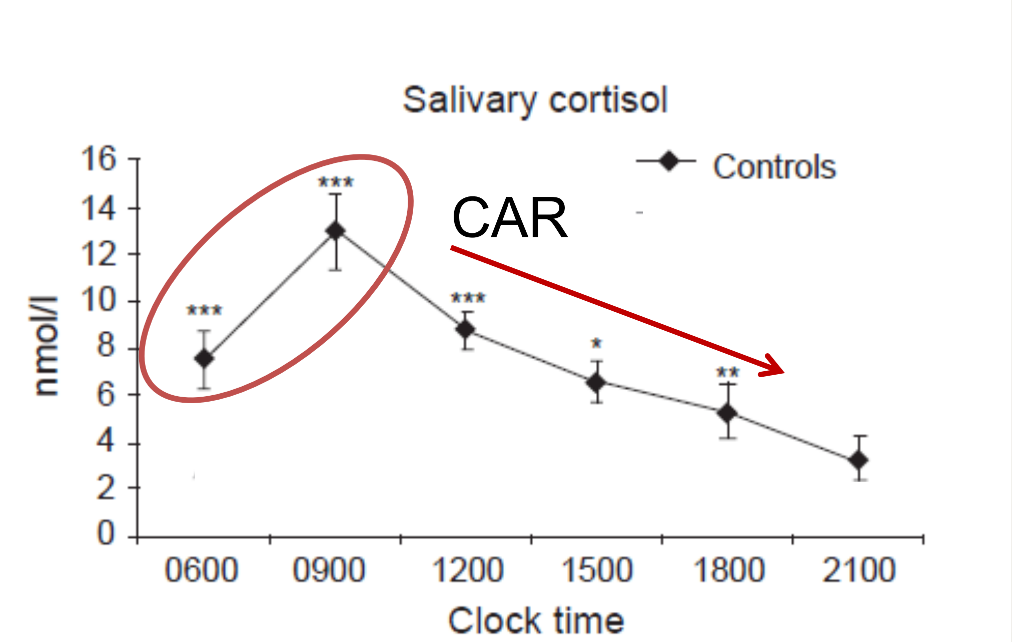
- **Cortisol** levels provide a physiologic measure of stress
  - Regulated by the hypothalamic-pituitary-adrenal (HPA) axis
  - Related to sugar levels in the blood that fluctuate based on the need to mobilize energy

VANDERBILT UNIVERSITY MEDICAL CENTER

"Typical" Cortisol Patterns

In non-fatigued individuals, cortisol levels have a typical diurnal pattern

- Build-up of cortisol during sleep
- Rapid rise upon awakening
  - Cortisol Awakening Response; CAR



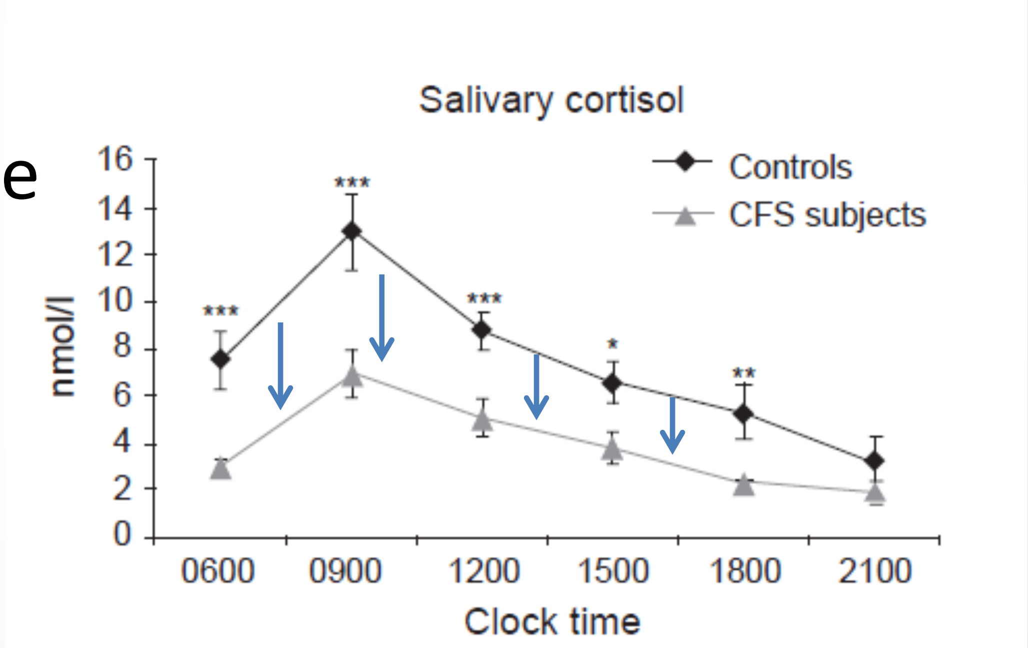
- Slow decline in cortisol throughout the day

Jerjes, et al., (2005).

VANDERBILT UNIVERSITY MEDICAL CENTER

"Atypical" Cortisol Patterns

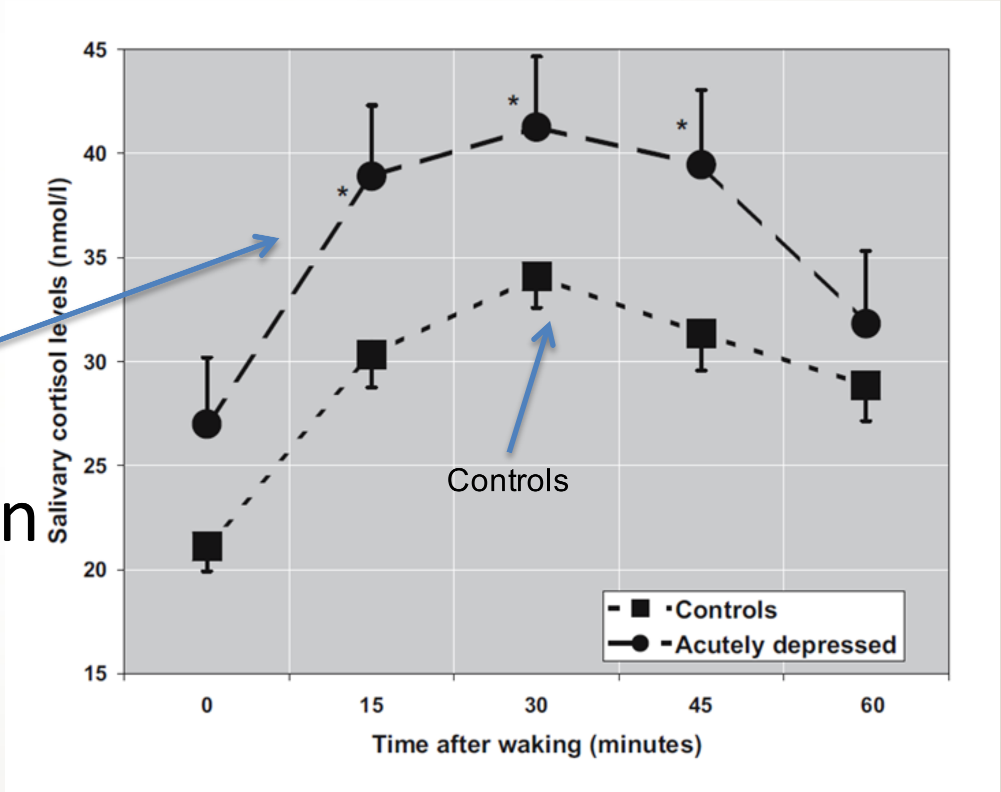
- Sustained stress or fatigue can lead to abnormal diurnal cortisol patterns
  - Reduced response with "Chronic Fatigue Syndrome"



Jerjes, et al., (2005).

"Atypical" Cortisol Patterns

- Sustained stress or fatigue can lead to abnormal diurnal cortisol patterns
  - Reduced response with "Chronic Fatigue Syndrome"
  - "Elevated" CAR in patients with depression



Bhagwagar, Z., Hafizi, S., & Cowen, P. J. (2005).

VANDERBILT UNIVERSITY
MEDICAL CENTER

Do children with hearing loss show differences in cortisol when compared to peers with normal hearing?

VANDERBILT UNIVERSITY MEDICAL CENTER

Cortisol Patterns in Children with Hearing Loss

Hicks and Tharpe (2002)

- Children with mild to moderate hearing loss (n=10) and a control group (n=10)
- 5-11 years old
- Salivary cortisol at 9am and 2pm

No significant difference in cortisol levels between children with hearing loss and controls

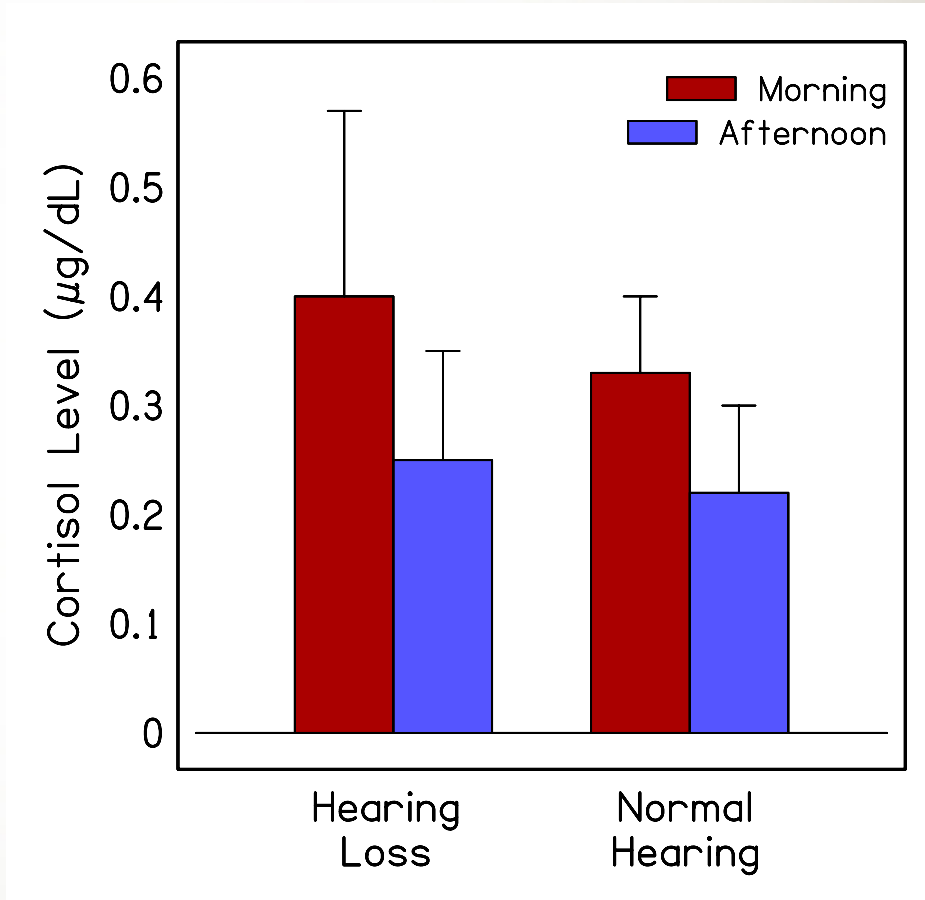
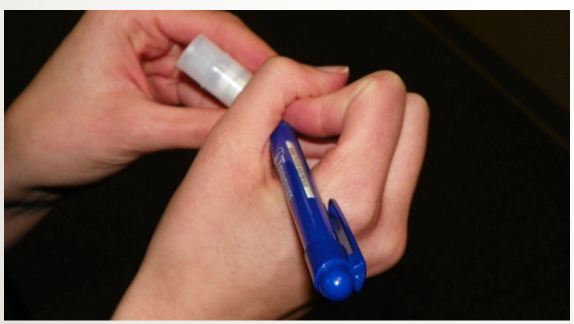


Figure adapted from original publication

VANDERBILT UNIVERSITY
MEDICAL CENTER

Measuring Salivary Cortisol Levels



- Participants
  - Children with hearing Loss (n=32)
  - Control group (n=28)

- Six samples per day
  1. Awakening*
  2. 30 min post-wake up*
  3. 60 min post-wake up*
  4. 10:00 am
  5. 2:00 pm
  6. 8:00 pm*

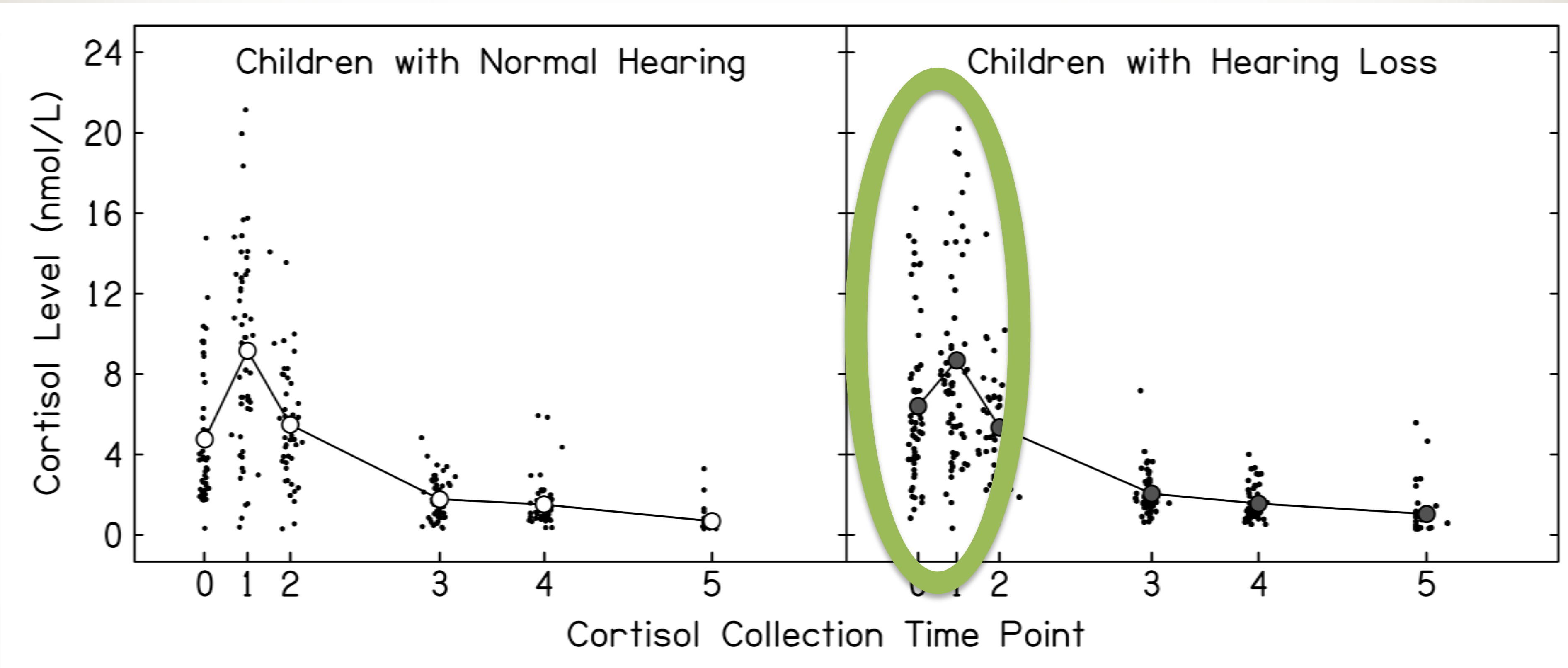
- Sampled on two separate school days

*Samples taken by parents at home

Bess, Gustafson, Corbett, Lambert, Camarata, and Hornsby, (in press)

Comparing Measured Cortisol Levels

Modeling analysis revealed significant differences between group slopes – differences localized to the morning.



Bess, Gustafson, Corbett, Lambert, Camarata, and Hornsby, (in press)

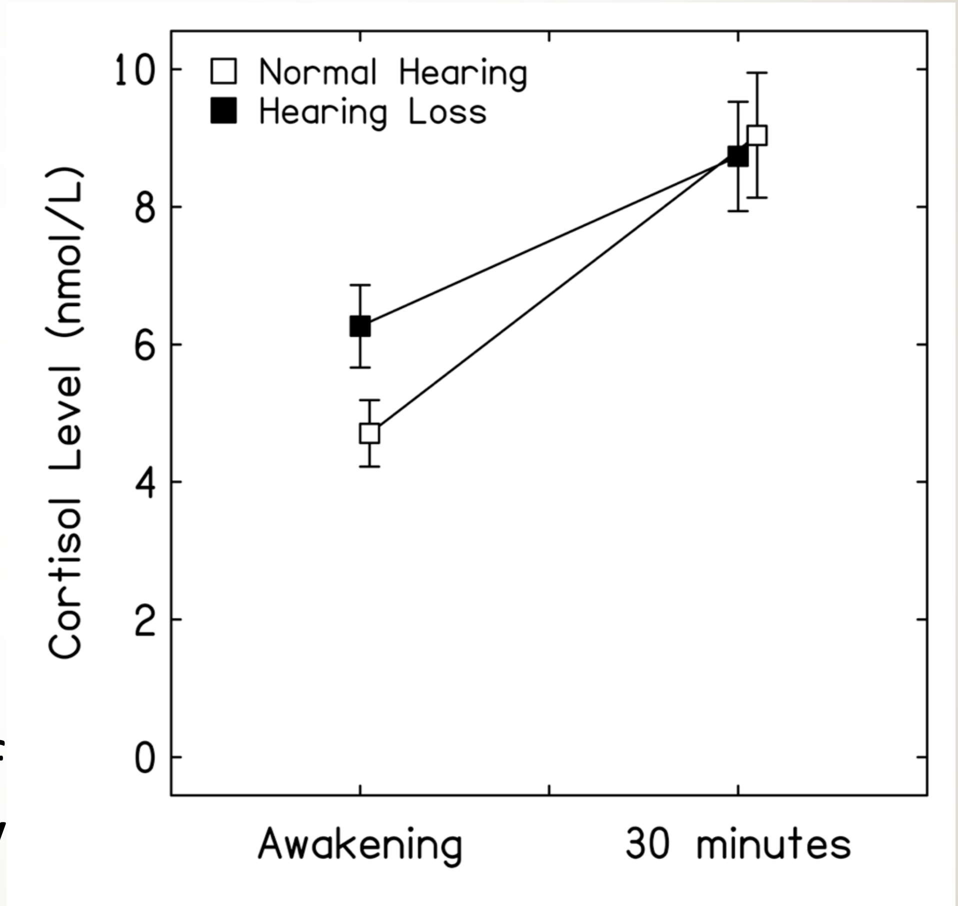
VANDERBILT UNIVERSITY MEDICAL CENTER

Comparing Measured Cortisol Levels

Children with hearing loss have higher cortisol levels at awakening than controls

Children with hearing loss have a reduced CAR compared to controls

Suggests children with hearing loss are experiencing perceived stress and an increased burden of worrying about the upcoming day



Bess, Gustafson, Corbett, Lambert, Camarata, and Hornsby, (in press)

VANDERBILT UNIVERSITY
MEDICAL CENTER

Are there cumulative effects of chronic stress for children with hearing loss?



VANDERBILT UNIVERSITY
MEDICAL CENTER

Chronicity of Stress

Hyperactive HPA axis

Hypoactive HPA axis

- Increased productions of cortisol
- HPA axis responds by reducing cortisol output over time
- Flattened cortisol profiles

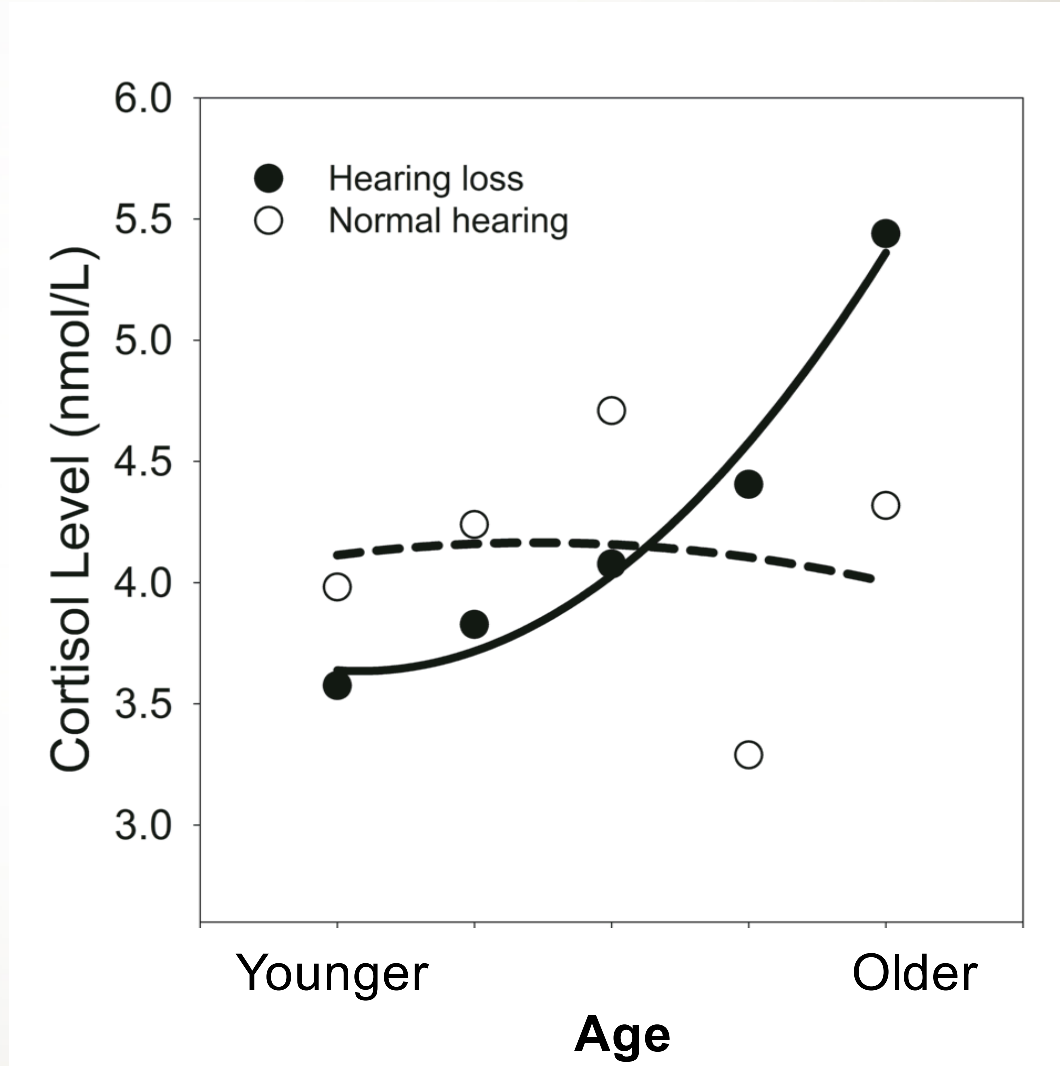
De Vente et al., 2003; Fries, et al., 2005; Kudielka et al., 2009; Miller et al., 2007

VANDERBILT UNIVERSITY MEDICAL CENTER

Child Age and Cortisol

Overall cortisol levels increase with increasing age for children with hearing loss, but not for the control group

Sustained stress due to hearing loss **might** be affecting their HPA system, potentially increasing the risk for fatigue over time



Bess, Gustafson, Corbett, Lambert, Camarata, and Hornsby, (in press)

VANDERBILT UNIVERSITY
MEDICAL CENTER

Vanderbilt Study on Listening Effort & Fatigue

Goals:

1.Characterize a physiologic marker of stress

Findings:

Diurnal cortisol patterns in children with hearing loss are not "typical"

– Elevated levels at awakening and reduced CAR may suggest increased stress
    - Similar to adults with high "burnout"
    - Indicative of a dysregulation in HPA-axis activity

Vanderbilt Study on Listening Effort & Fatigue

Goals:

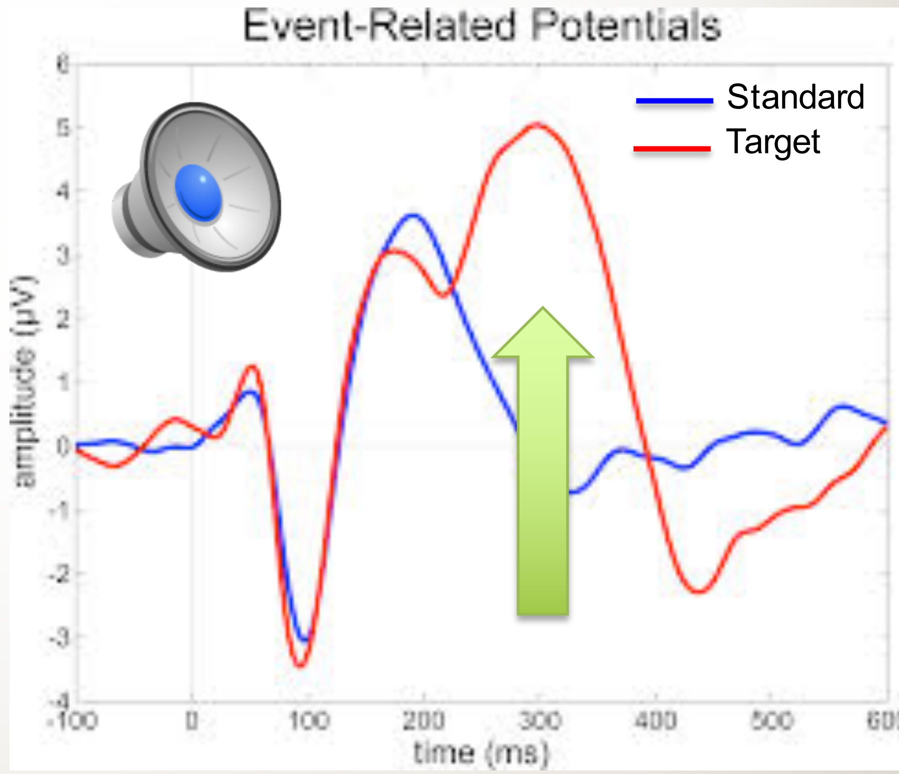
1. Characterize a physiologic marker of stress
2. **Induce listening-related fatigue in the laboratory**
   a. Measure it using behavioral and subjective assessments
   b. **Determine if physiologic assessments can characterize the effects of fatigue**
3. Examine the effect of daily listening fatigue on literacy performance

VANDERBILT UNIVERSITY
MEDICAL CENTER

Measuring Fatigue with ERP

Event-related potentials (ERP) are changes in ongoing EEG activity that are time-locked to the onset of the auditory event

- Reflects change in brain activity associated with the processing of that stimulus



Centro-parietal P300 response

- Sensitive to fatigue due to cognitive processing (Murata, Uetake, & Takasawa, 2005; Uetake & Murata, 2000)

More fatigue → reduced amplitude

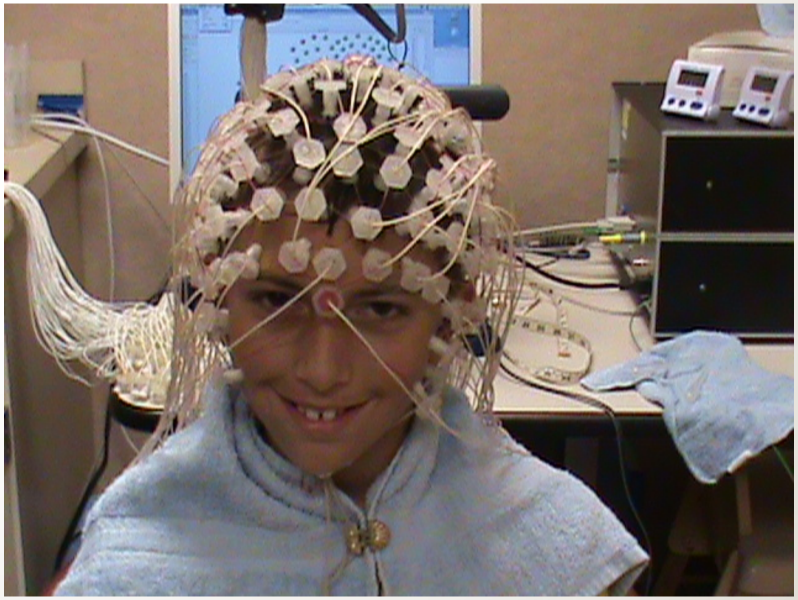
VANDERBILT UNIVERSITY MEDICAL CENTER

Assessing Fatigue in the Lab

3 hours

ERP 1 → Speech Processing Tasks → ERP 2

- Participants
  - Children with hearing Loss (n=33)
  - Control group (n=29)
- Stimuli
  - Oddball paradigm (70/30)
  - Speech syllables ("gi" and "gu") at 65 dB SPL
  - Multi-talker babble at +10 dB SNR
- Procedure
  - 128-channel Geodesic sensor net
  - Passive task



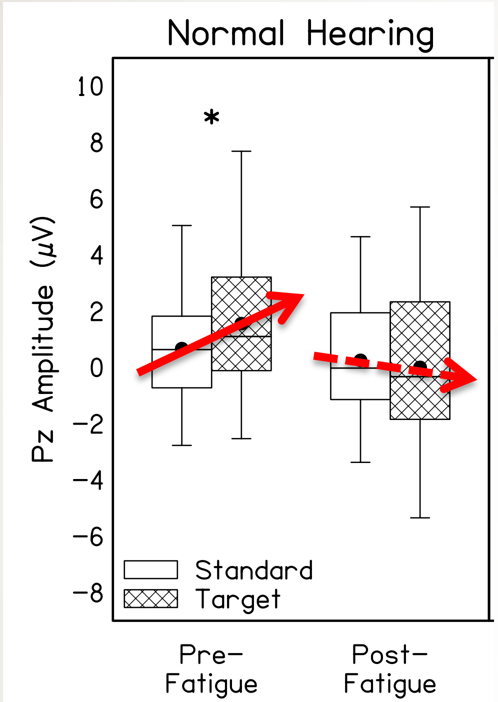
VANDERBILT UNIVERSITY MEDICAL CENTER

Assessing Fatigue in the Lab

$$\underbrace{\text{ERP 1} \rightarrow \text{Speech Processing Tasks} \rightarrow \text{ERP 2}}_{\text{3 hours}}$$

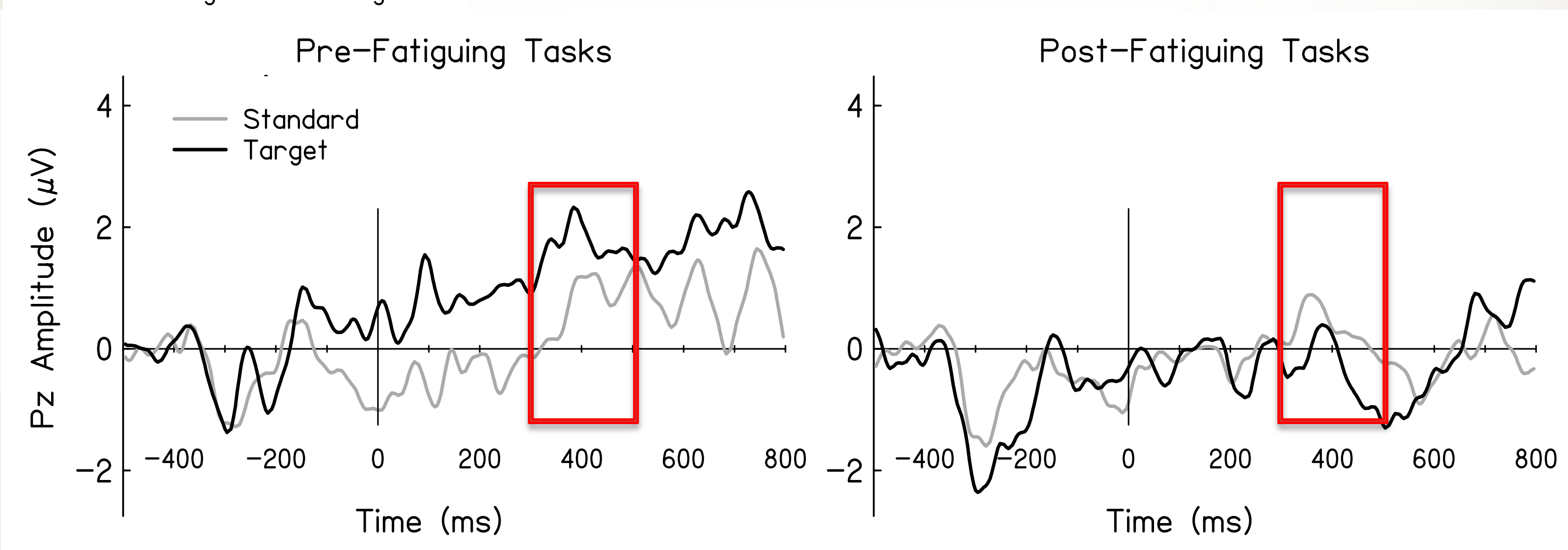
Series of activities focused on the recognition of speech in noise during tasks that required shared and sustained attention.

Physiologic Markers of Fatigue



Children with normal hearing show reduced cognitive processing following sustained speech-processing tasks.

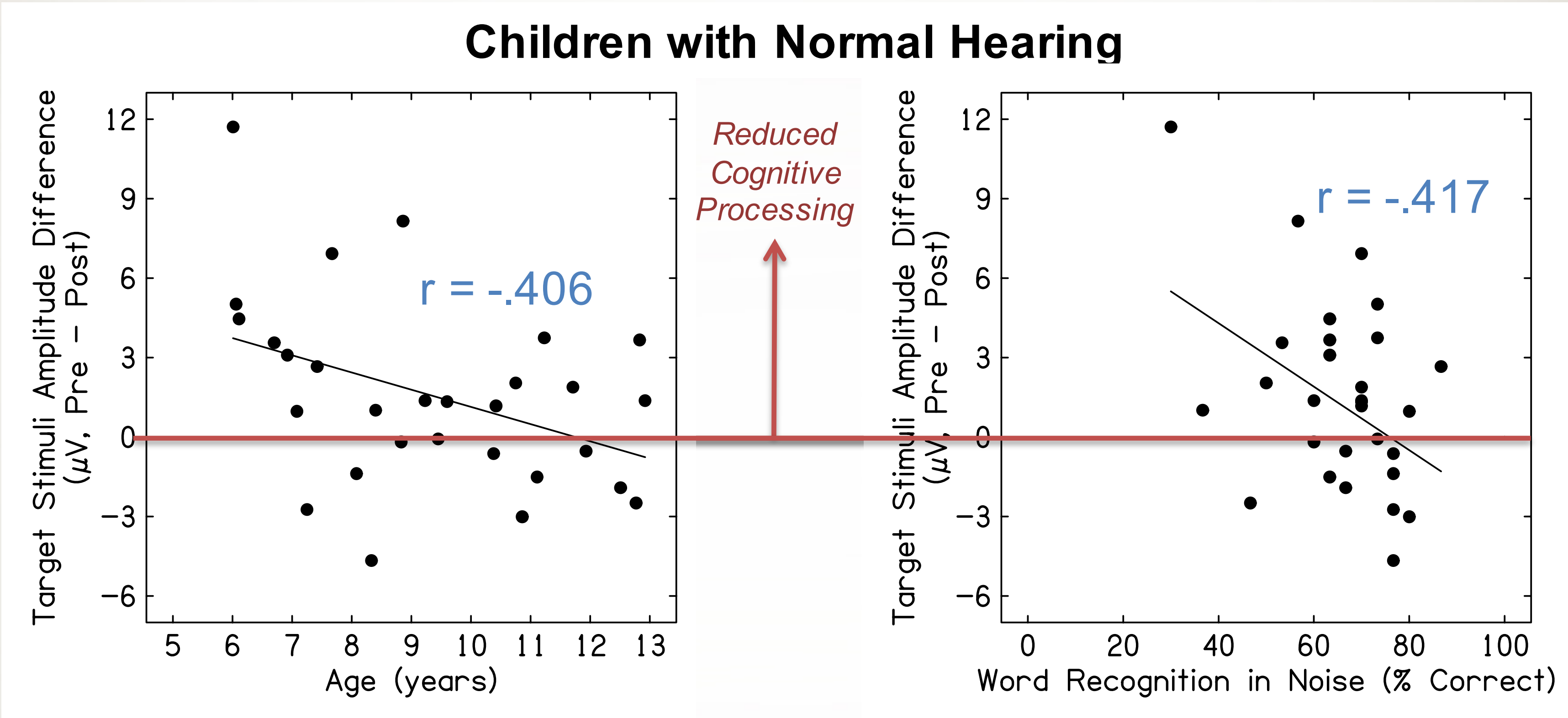
Changes are consistent with increased reports of fatigue on subjective assessments completed before and after speech-processing tasks (p<.05).



Key, Gustafson, Rentmeester, Hornsby, and Bess, (in prep)

VANDERBILT UNIVERSITY
MEDICAL CENTER

Who's at risk?



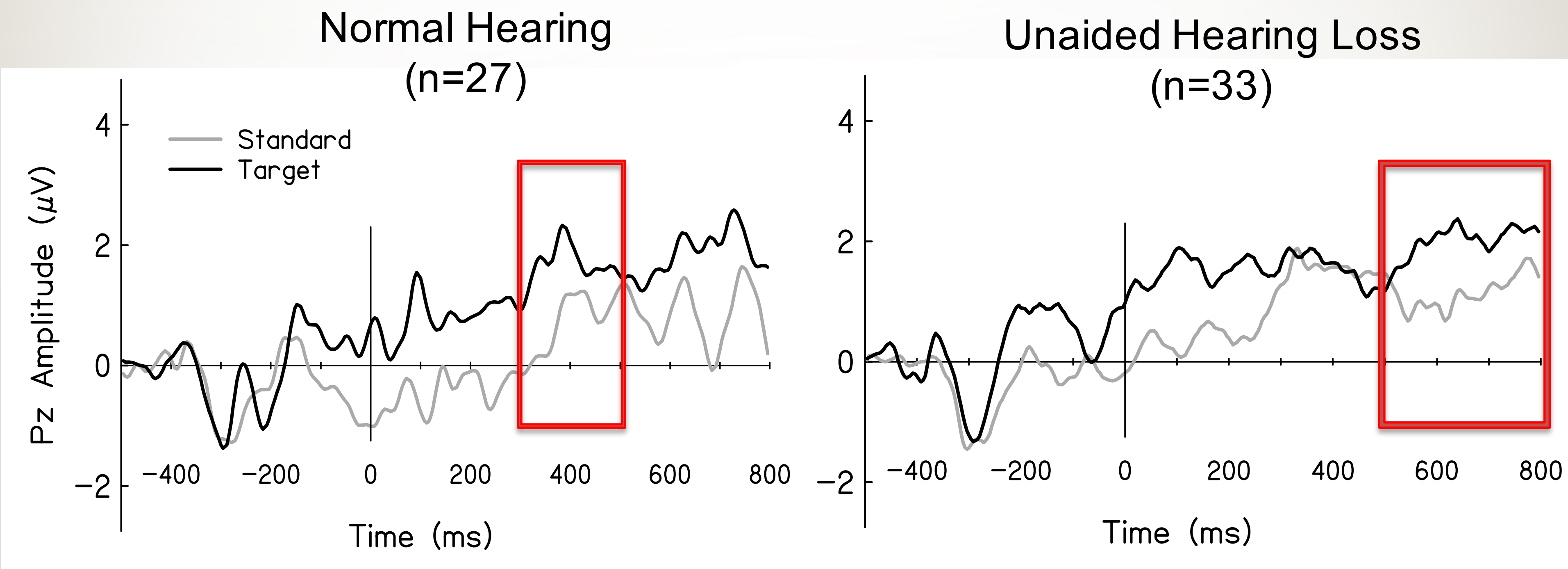
For children with normal hearing, **younger children** and those who have **poorer speech recognition** in noise were more likely to show reductions in cognitive processing due to speech-processing related fatigue.

VANDERBILT UNIVERSITY
MEDICAL CENTER

Is cognitive processing of speech in noise different for children with hearing loss?

Are they more affected by sustained speech processing?

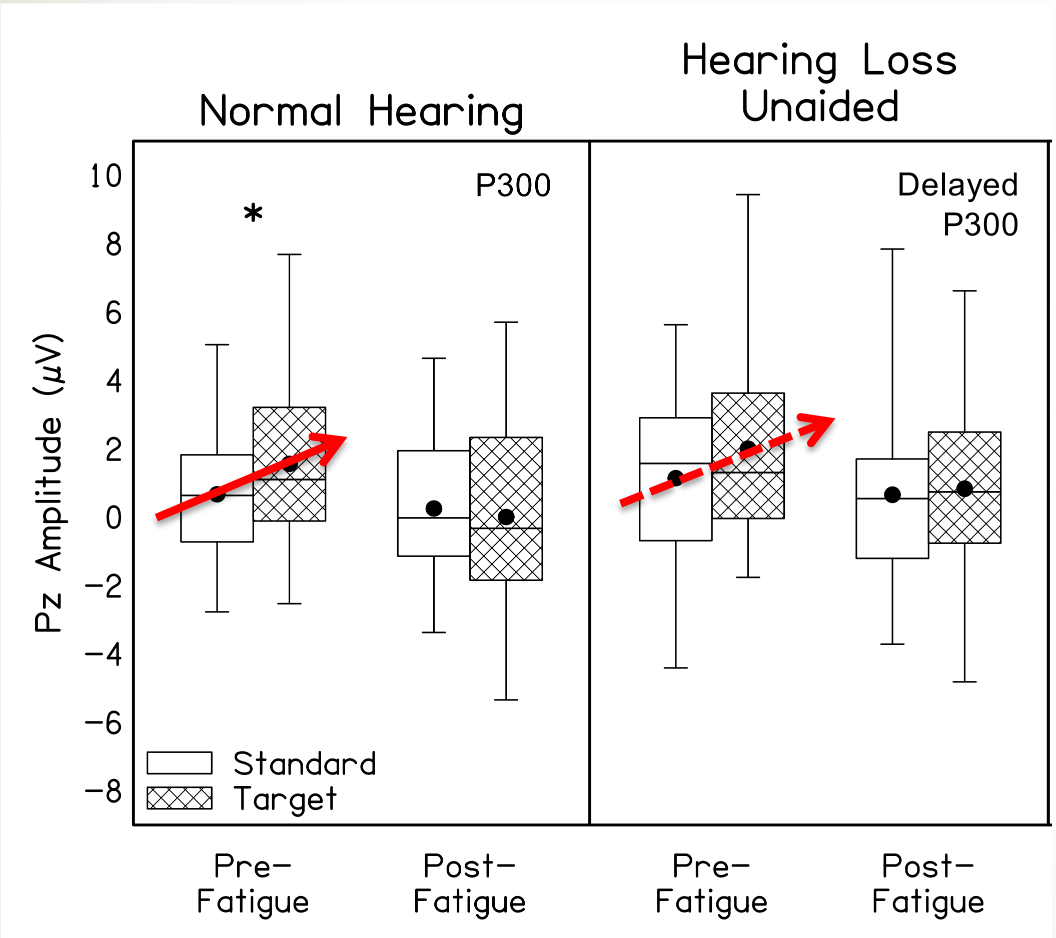
Hearing Loss and Cortical Speech in Noise Processing



Children with hearing loss show delays in cognitive processing when compared to children with normal hearing.

VANDERBILT UNIVERSITY MEDICAL CENTER

Physiologic Markers of Speech in Noise Processing



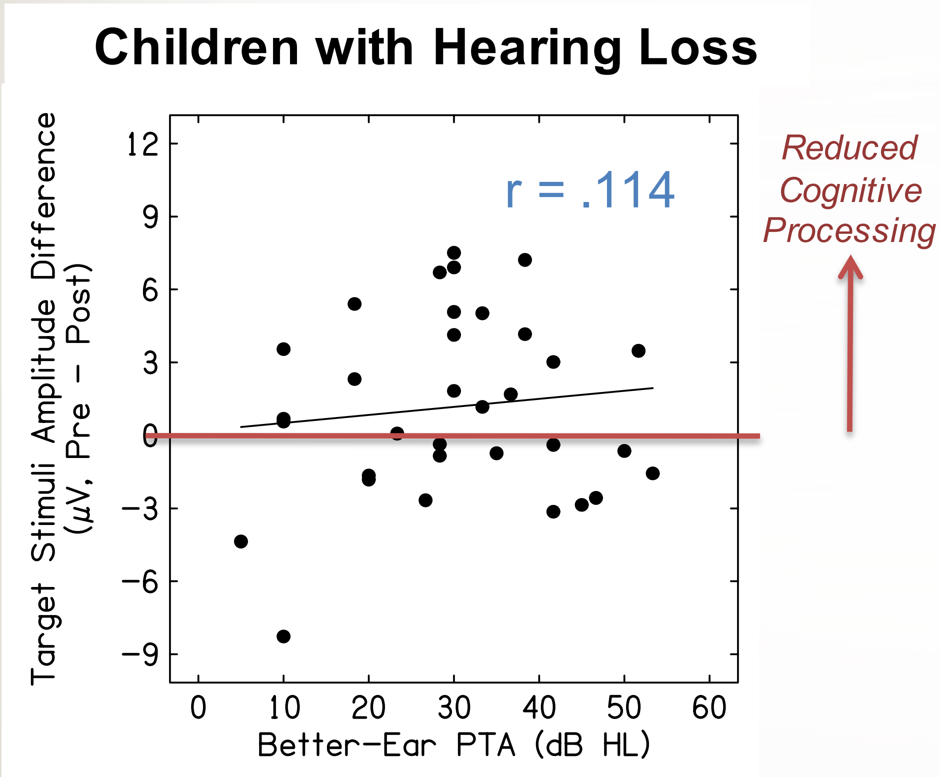
Unaided children with hearing loss show similar trends towards processing of speech in noise ($p=.10$) as children with normal hearing.

Children with hearing loss also show reductions in P3 response after speech-processing tasks.

Children with hearing loss also reported increased of fatigue on subjective assessments completed before and after speech-processing tasks ($p=.07$).

VANDERBILT UNIVERSITY MEDICAL CENTER

Who's at risk?



This lack of relationship with degree of hearing loss is consistent with subjective fatigue data and suggests that children with even mild hearing loss are at increased risk for fatigue.

Age, Language, Nonverbal Intelligence, and Speech in Noise Recognition did not significantly accounted for variability in cognitive processing changes associated with listening-related fatigue.

VANDERBILT UNIVERSITY MEDICAL CENTER

Vanderbilt Study on Listening Effort & Fatigue

Goals:

2. Induce listening-related fatigue in the laboratory
   b. Determine if physiologic assessments can characterize the effects of fatigue

Findings:

- Laboratory testing can induce listening-related fatigue.
  - Auditory-evoked P300 can be used to measure changes in cognitive processing associated with listening-related fatigue.
- Compared to children with normal hearing, children with mild- to- moderately-severe hearing loss:
  - demonstrate delayed cognitive processing time during active discrimination of speech in babble noise.
  - show similar consequences (i.e., reduced cognitive processing) of speech-processing related fatigue.

VANDERBILT UNIVERSITY MEDICAL CENTER

Take-Home of Study Findings

Physiologic markers of stress can be reliably measured in children with hearing loss.

- Cortisol patterns in children with hearing loss are not “typical” and suggest increased stress.

Fatigue due to effortful listening can be induced in the laboratory and its effect on cognitive processing can be measured using auditory-evoked ERP.

- Children with hearing loss show delays in cognitive processing of speech in noise discrimination.
- Children with and without hearing loss show reductions in cognitive processing secondary to speech-processing related fatigue.

VANDERBILT UNIVERSITY
MEDICAL CENTER

Implications for Practice

Be on the lookout for fatigue!

- Symptoms associated with fatigue include tiredness, sleepiness in the morning, inattentiveness, mood changes, and changes in play activity.

Help us educate the community

- Discuss with families, general education teachers, and other service providers that children with hearing loss are at increased risk for fatigue
- Promote strategies to cope with the increased stress of children with hearing loss
  - Relaxation, avoidance of high-fat diets, and regular exercise can all help reduce the negative effects of stress (McEwen, 1998; Ratey, 2008)

VANDERBILT UNIVERSITY
MEDICAL CENTER

Implications for Practice

There are several "good practice" suggestions for management of fatigue in children with hearing loss.

- Monitor use of amplification
  - Evidence in adults suggests that properly fitted hearing aids can reduce listening effort and cognitive fatigue (Hornsby, 2013)
  - Children with lesser degrees of hearing loss and those who are in grades 5-7 are at increased risk for reduced hearing aid use (Gustafson et al., 2015)
- Classroom Strategies
  - Improving classroom acoustics should be an initial step in efforts to reduce listening effort in the classroom
  - Preferential seating can minimize environmental distractors
  - Slowing the pace of a lesson and utilizing breaks between activities can allow for additional processing time
  - Daily content can be rearranged so demanding listening tasks occur earlier when the child has more available cognitive resources

VANDERBILT UNIVERSITY
MEDICAL CENTER

Visit the Listening and Learning Lab's website at
http://my.vanderbilt.edu/listeninglearninglab

Samantha.Gustafson@Vanderbilt.edu