

# Listening Fatigue: A Problem for Students with Hearing Loss?



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# Disclosures

- Financial Disclosures:
  - I am employed by the Vanderbilt University Medical Center.
- Non-financial Disclosures:
  - None

# What is fatigue?



**EXTREME  
TIREDNESS**

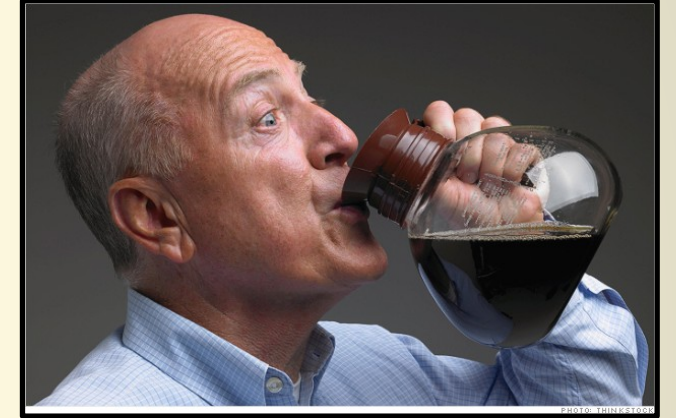
- No universal definition
- **Physical fatigue:** reduced ability or desire to perform some physical task
- **Cognitive/mental fatigue:** state of decreased optimal performance due to sustained cognitive demands
- Measured behaviorally, physiologically, and subjectively

Stress also associated with difficult listening; overlapping construct with fatigue.

# Aren't we all fatigued?

Fatigue is one of the most common complaints reported in primary care settings

- Transient fatigue is common, even in healthy populations
- <https://www.youtube.com/watch?v=POKDDleedCY>



Recurrent, severe fatigue

- **Uncommon** in healthy populations, but common in many chronic health conditions
  - Previous reports in individuals with cancer, HIV/AIDs, Parkinson's, Multiple Sclerosis
  - Very little work looking at fatigue and hearing loss, especially for children

# LISTENING FATIGUE

“I went to a great conference today. It was riveting and I was hooked on pretty much every word. And then I got home and **collapsed** on the sofa. I’ve had to **turn my ears off to rest** in silence and my eyes are burning.

..the impact of deafness doesn’t just manifest itself in communication. It’s about the **energy** involved in lipreading and **being attentive all day long**.



When I was younger, I was a little embarrassed to be so tired all the time. I would force myself to go out and be busy and out there when really all I wanted to do was crawl under the sofa and nap for a hundred years. Nobody ever really told me that being tired was “okay’.

**of something intelligent** to say in response to an invariably random question.

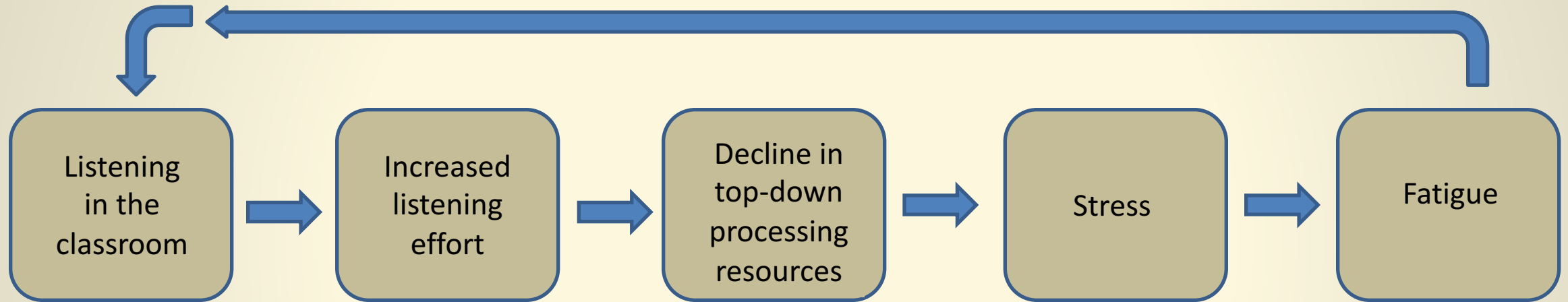


5	3		7			
6		1	9	5		
	9	8			6	
8			6			3
4		8	3			1
7			2			6
	6			2	8	
		4	1	9		5
			8		7	9

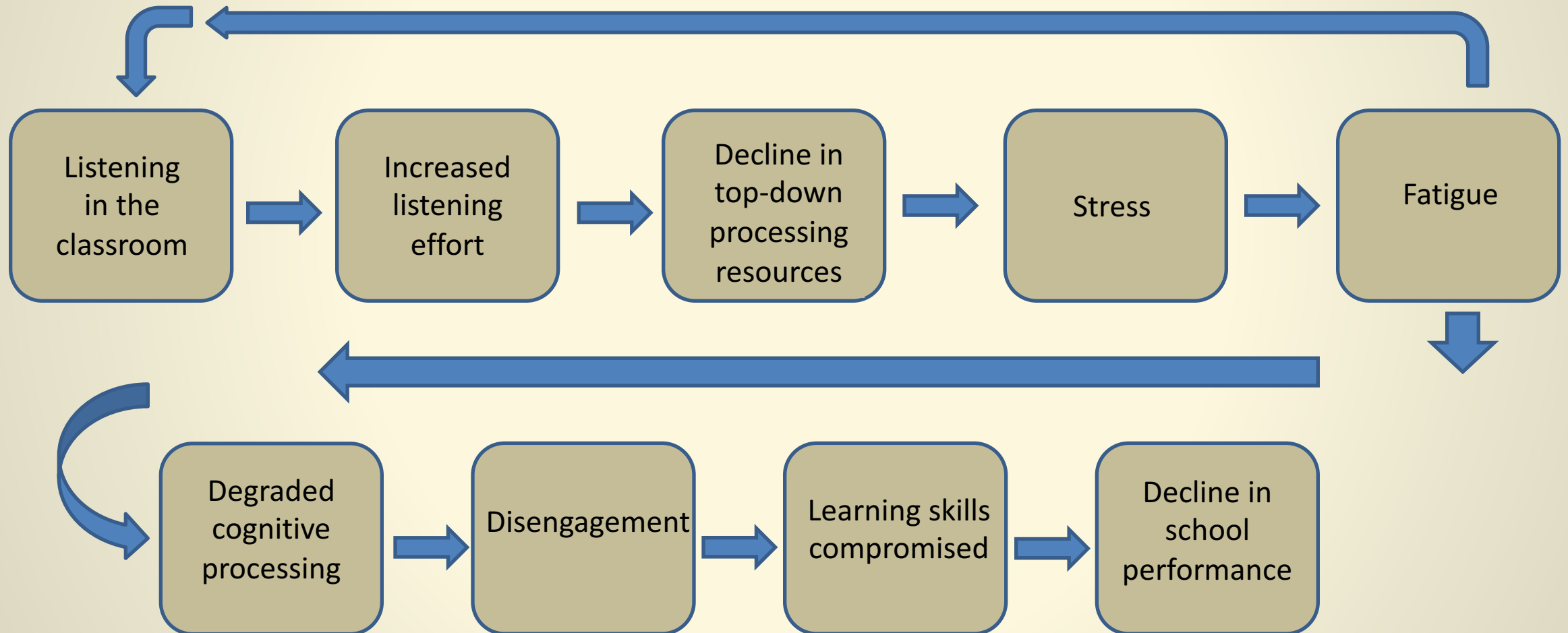


It’s like doing **jigsaws**, **Sudoku**, and **Scrabble** all at the same time.”

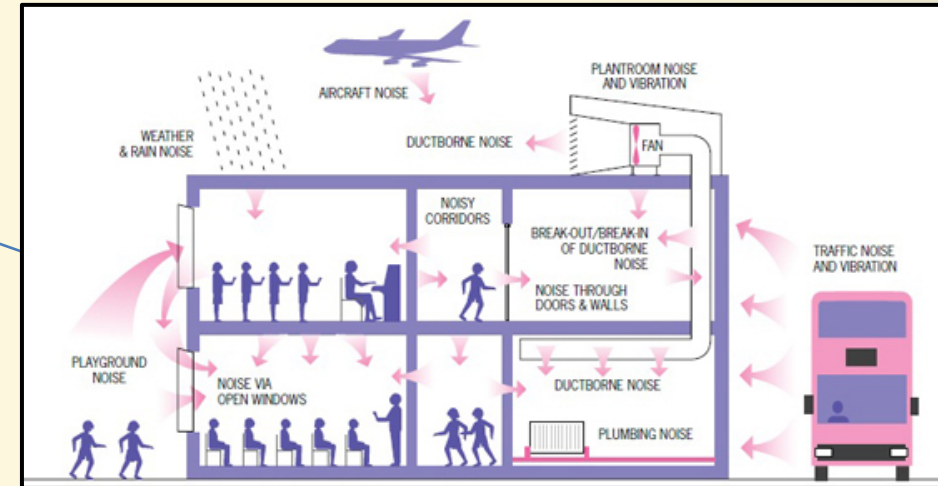
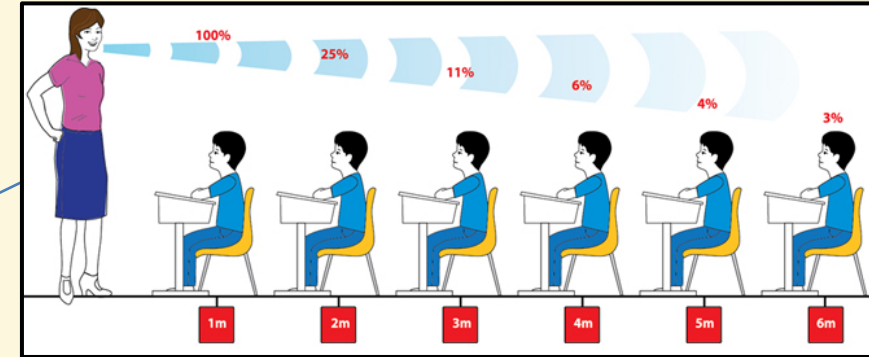
# What contributes to listening-related fatigue?



# Negative Consequences of Fatigue



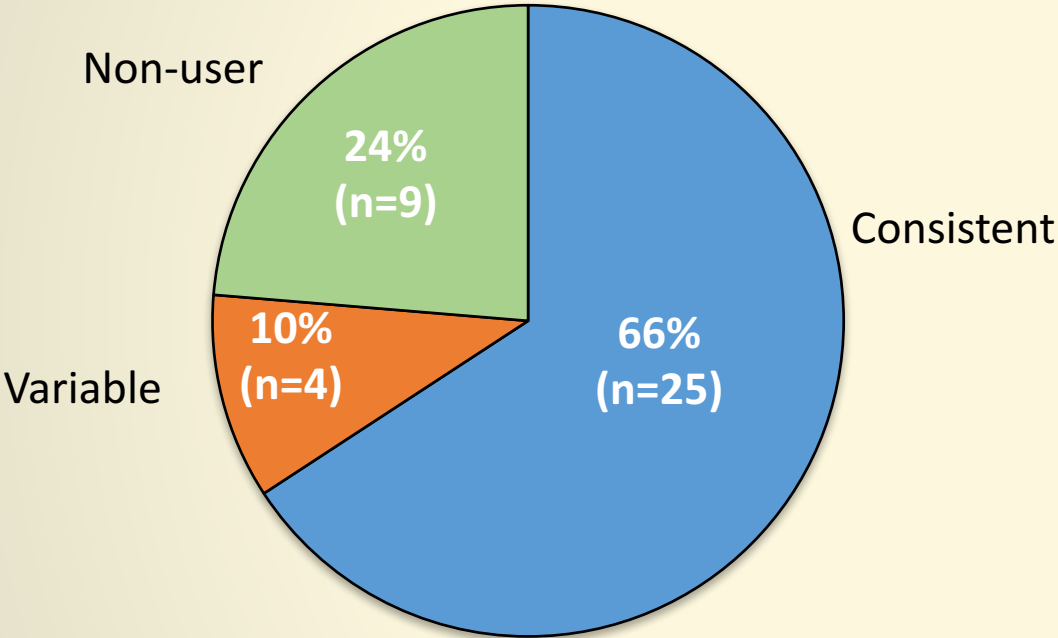
# 1. Listening in the Classroom





# Device Use in the Classroom

## Hearing Aid Use



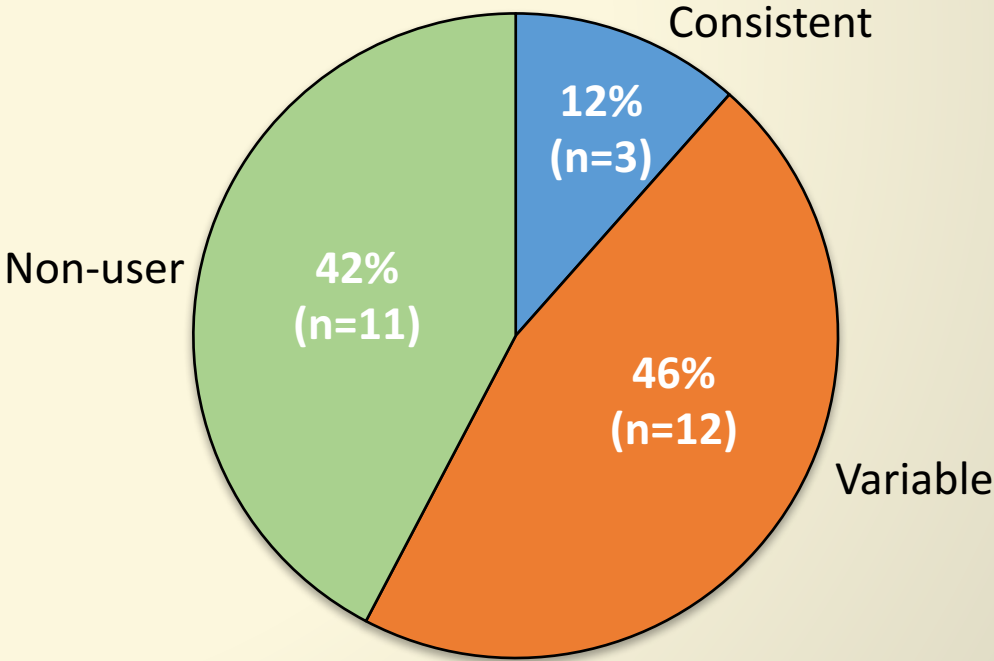
Children with less hearing loss, and those in higher grades (5<sup>th</sup>-7<sup>th</sup>) were less likely to use hearing aids in the classroom.

## FM system available?

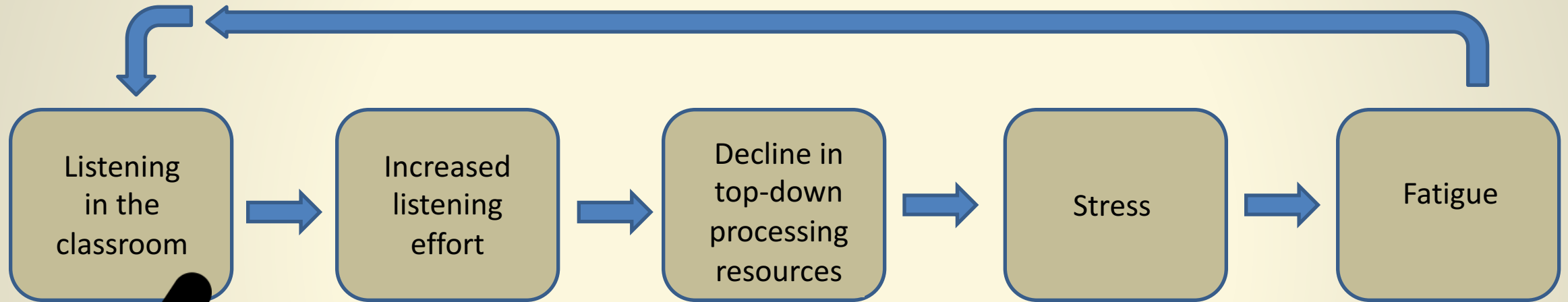
89% of 1<sup>st</sup> - 4<sup>th</sup> graders

47% of 5<sup>th</sup> -7<sup>th</sup> graders

## FM System Use

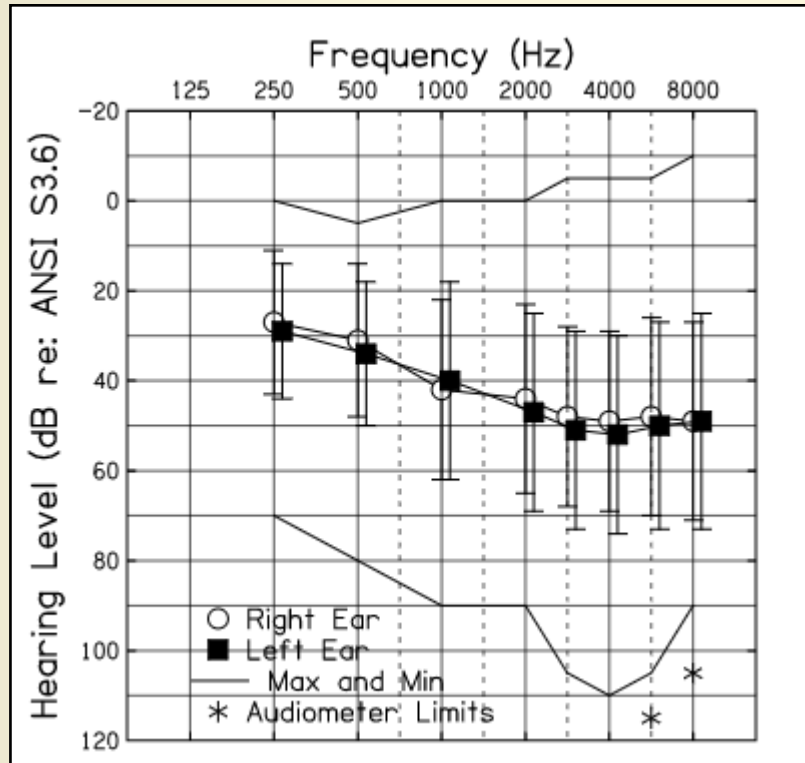


# What contributes to listening-related fatigue?



**High Noise Levels +  
Inconsistent Use of  
Technology**

# Study Participant Demographics



- Participants

- CNH and CHL (6-12 years old)
  - Parents
- Bilateral, mild to moderately-severe SNHL
- No CI users
- No diagnosis of developmental disorder or cognitive impairment

- Experimental (CHL) group (n=60) • Control (CNH) Group (n=43)
  - 31 males (52%), 29 females
  - Age = 10.0 (1.9) years
  - 26 males (60%), 17 females
  - Age = 9.1 (2.3) years

# What is listening effort?

- Allocation of attentional and cognitive resources toward auditory tasks.
- CHL and AHL must increase mental effort compared to those without HL when attempting to detect, process, and respond to auditory stimuli (Hicks and Tharpe, 2002; McCoy et al., 2005)
  - Increase in **LISTENING EFFORT** (Hornsby, 2013; Bess & Hornsby, 2014; McGarrigle et al., 2014)



5	3			7			
6			1	9	5		
	9	8					6
8				6			3
4			8		3		1
7				2			6
	6					2	8
			4	1	9		5
				8			7
							9



# Does effortful listening affect CHL?

## “Effortfulness Hypothesis”



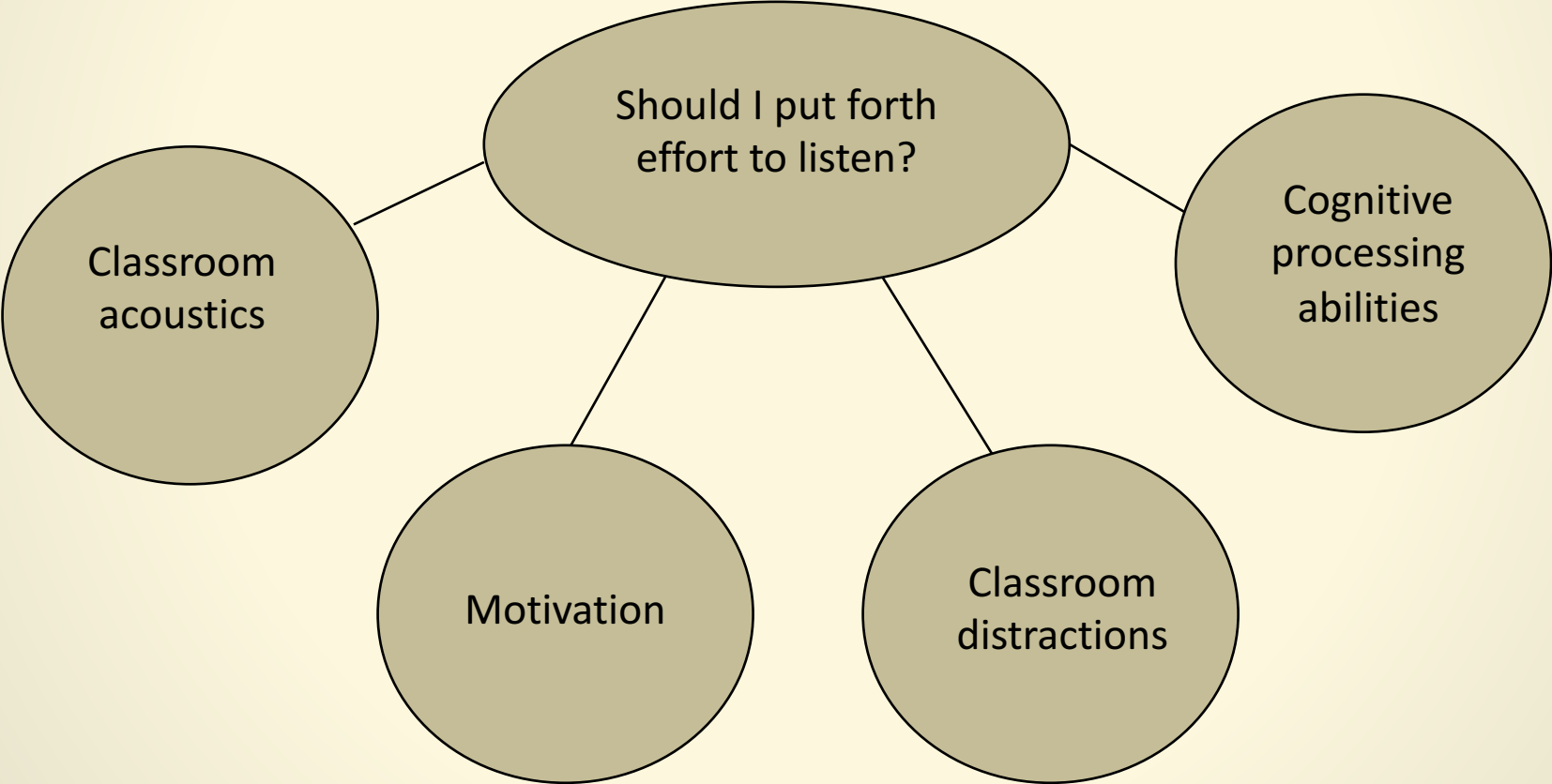
Consequences:  
listening effort, stress,  
and fatigue

COGNITIVE  
RESOURCES

EFFORTFUL  
LISTENING IN  
DIFFICULT  
SITUATION

RESOURCES LEFT  
FOR OTHER  
PROCESSING  
NEEDS  
(memorization,  
comprehension)

# Factors Influencing Listening Effort



## 2. Assessing Listening Effort

Primary task: Word Recognition

Secondary task: Visual Reaction Time

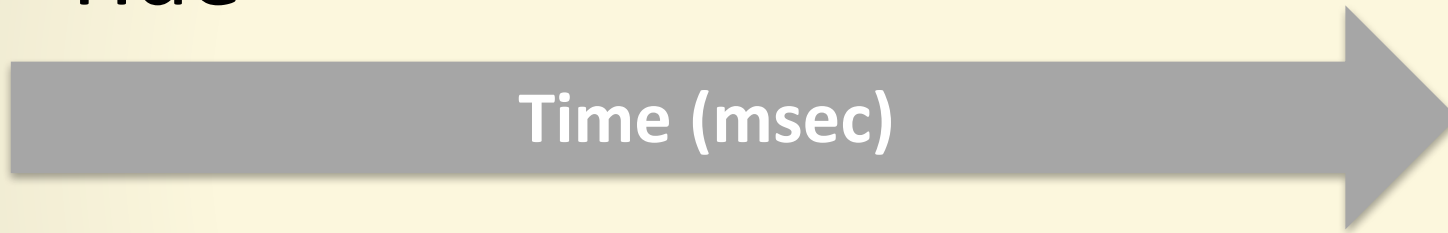
Three SNRs ranging from -4 to +12 dB in multi-talker babble



# Assessing Listening Effort: *Vocal Response Time*

Say the word....

“ride”



VRT = time delay  
between speech  
stimulus and spoken  
response

**EASY**

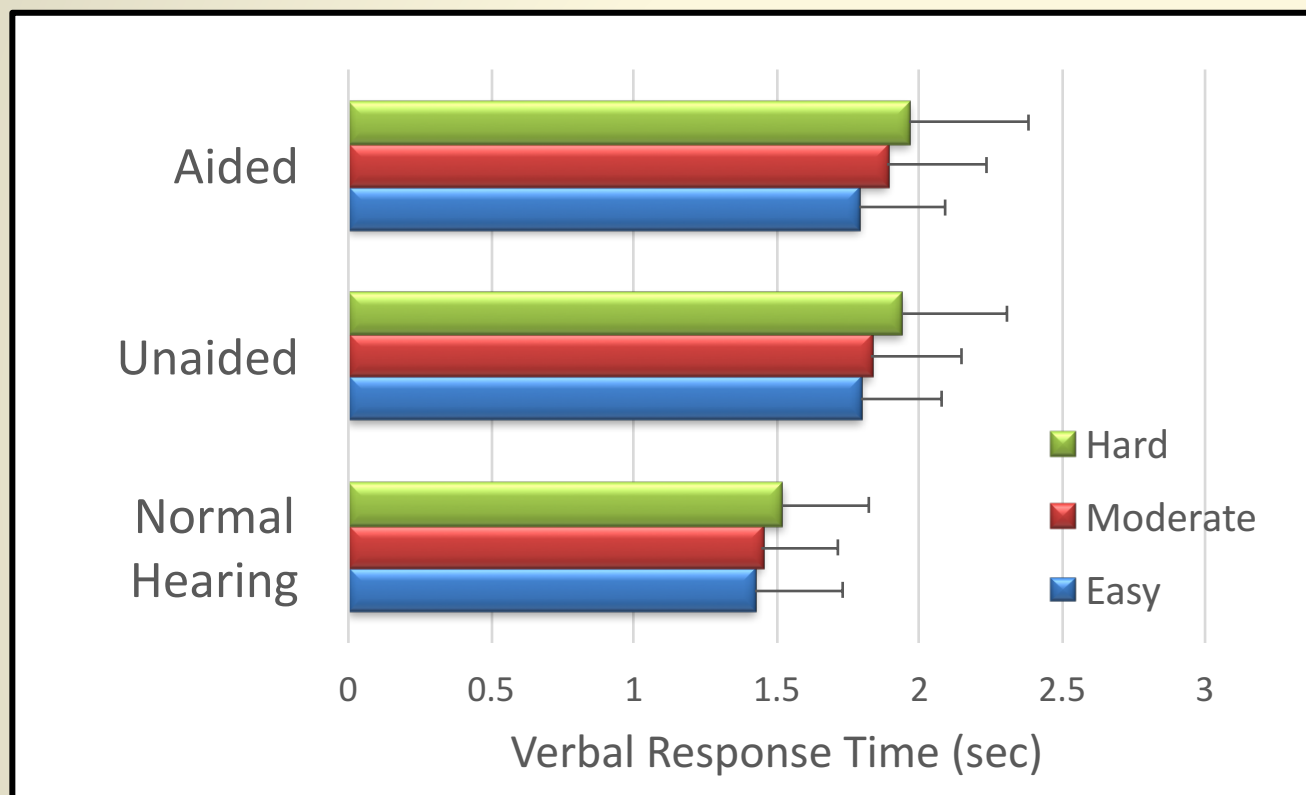
..... “ride”

**HARD**

..... “ride”



# Assessing Listening Effort: *Vocal Response Time*

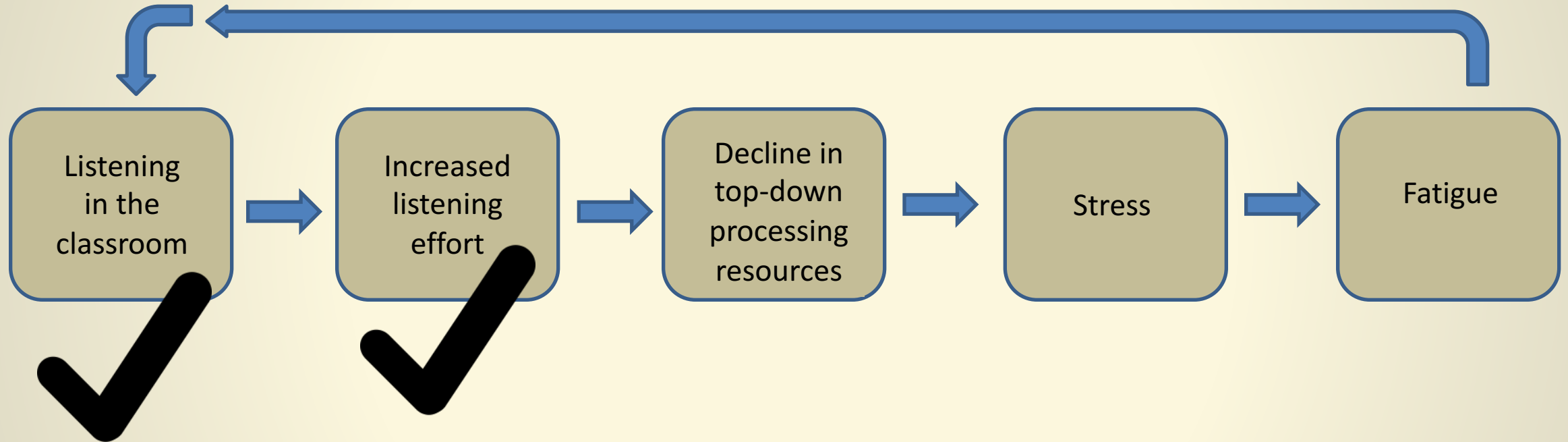


Task: word recognition in -4 to +12 dB SNR

Children with hearing loss showed longer VRT compared to children with normal hearing ( $p < .001$ ).

Children with hearing loss demonstrate greater listening effort when listening to speech in noise and reverberation.

# What contributes to listening-related fatigue?



**High Noise Levels +  
Inconsistent Use of  
Technology**

**Lab:  
Vocal Response  
Times (McGarrigle  
et al, in prep)**

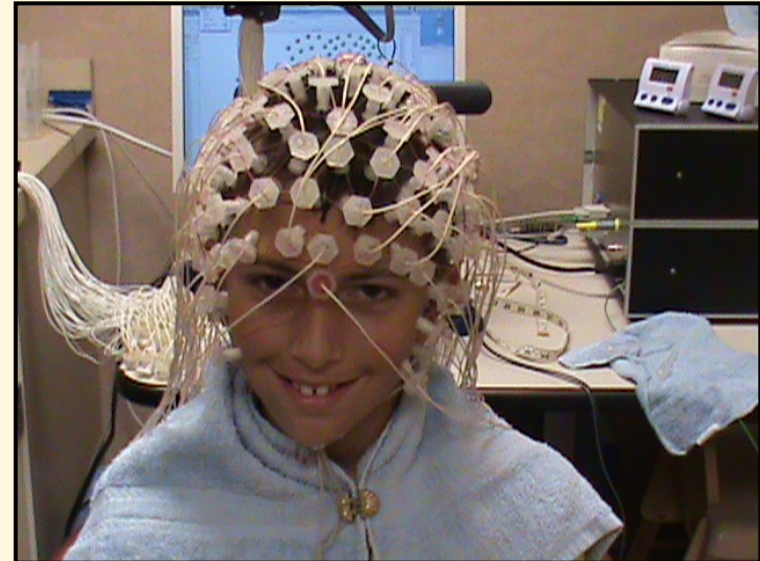
# 3. Measuring ERP

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

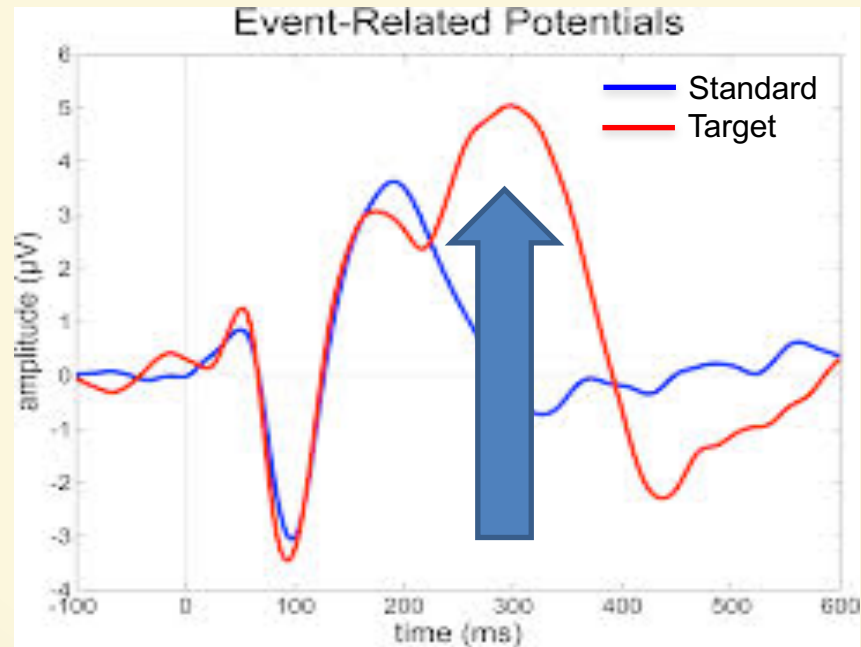
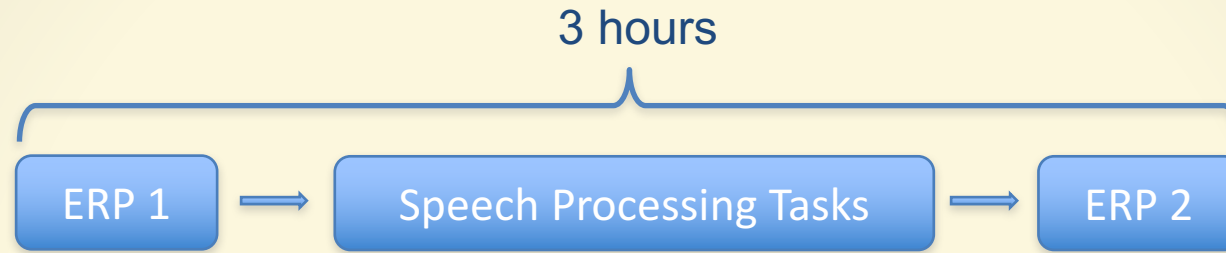
- Reflects change in brain activity associated with the processing of that stimulus

Centro-parietal P300 response

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



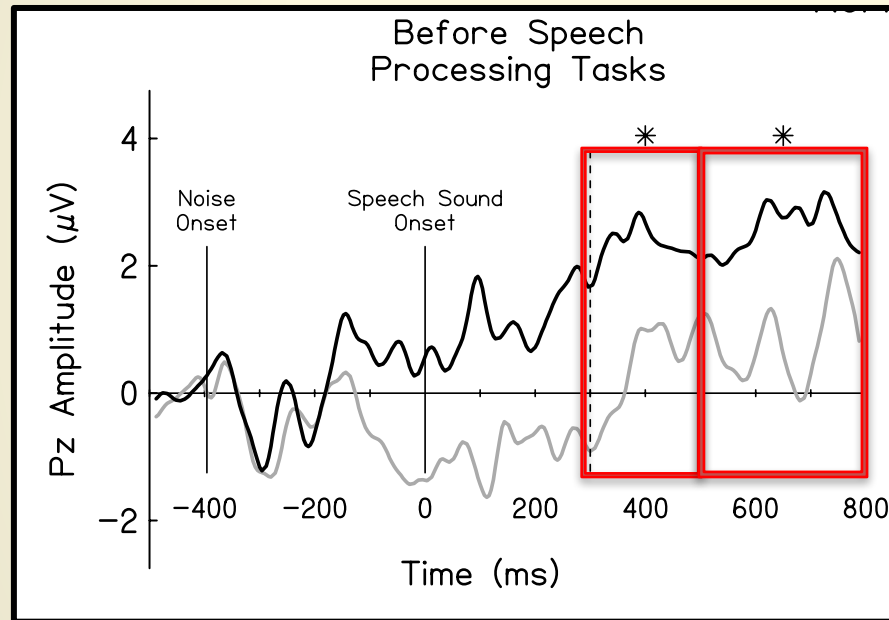
# Assessing Fatigue in the Lab



# Change in Processing Resources:

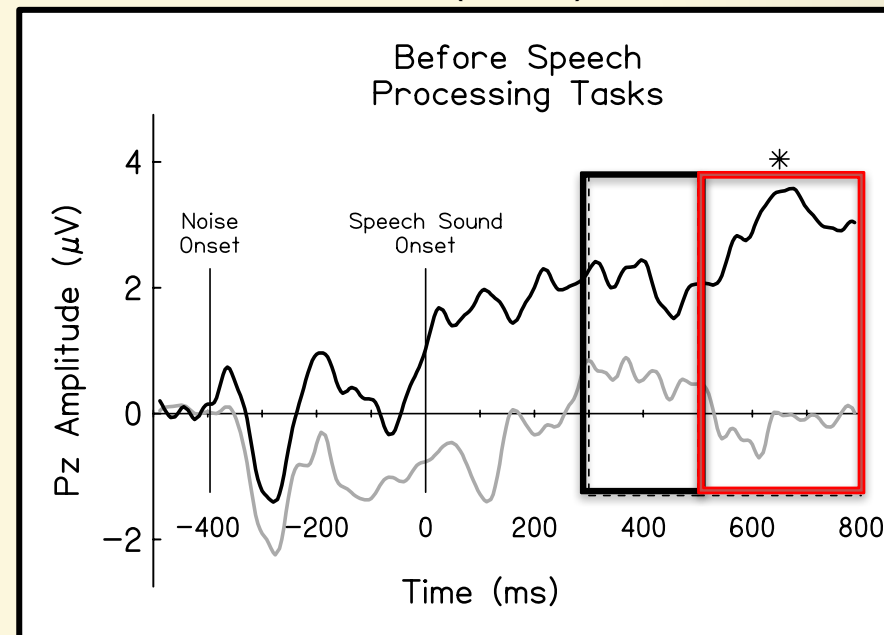
*Comparing children with and without hearing loss*

No Hearing Loss  
(n=18)



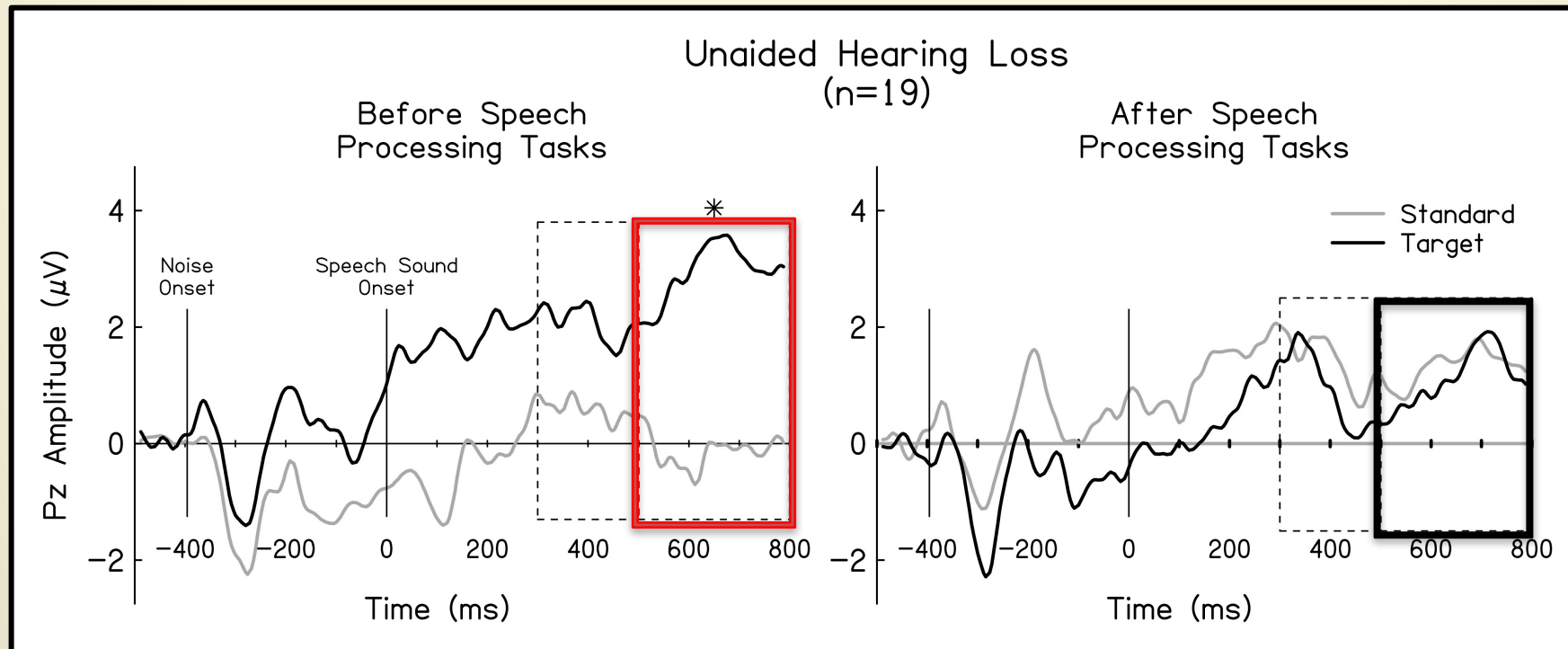
Children with hearing loss show delays in cognitive processing when compared to children with no hearing loss.

Unaided Hearing Loss  
(n=19)

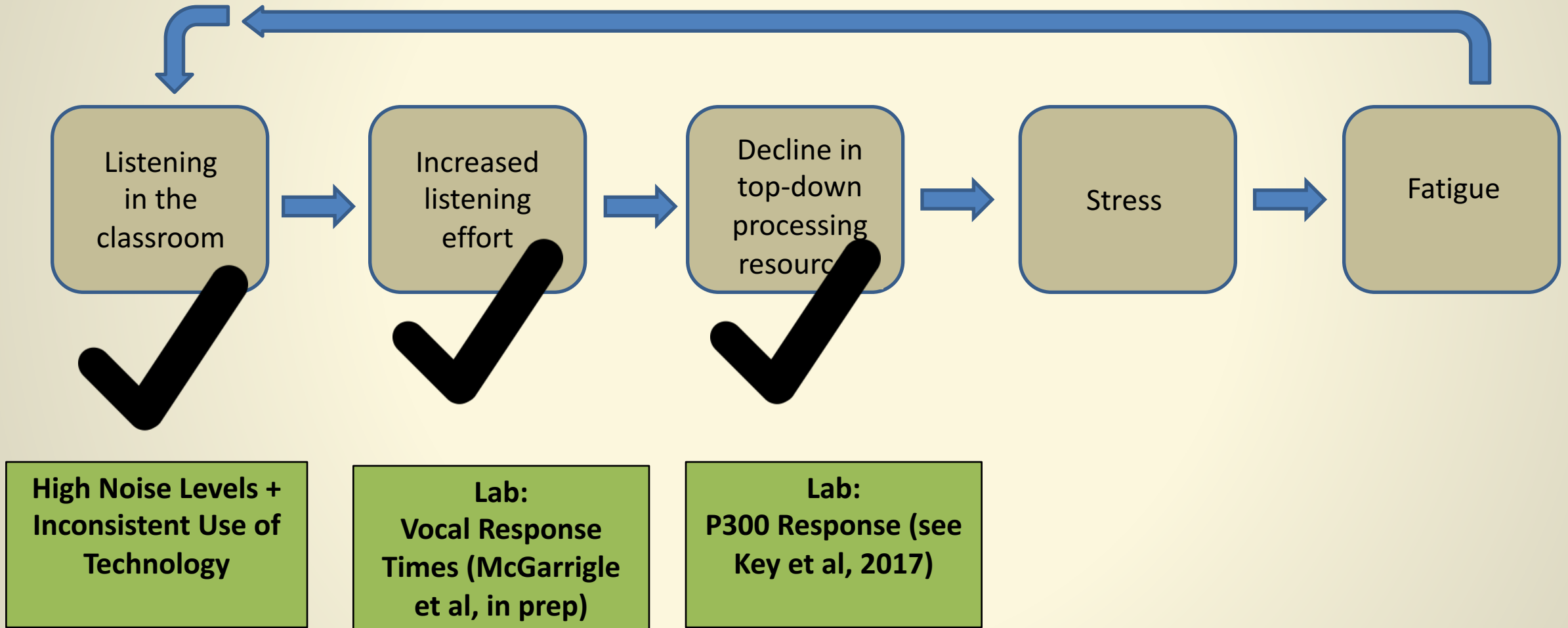


# Change in Processing Resources: *Children with Hearing Loss*

Trend for cognitive processing to be reduced following sustained speech-processing tasks ( $p=.078$ ).

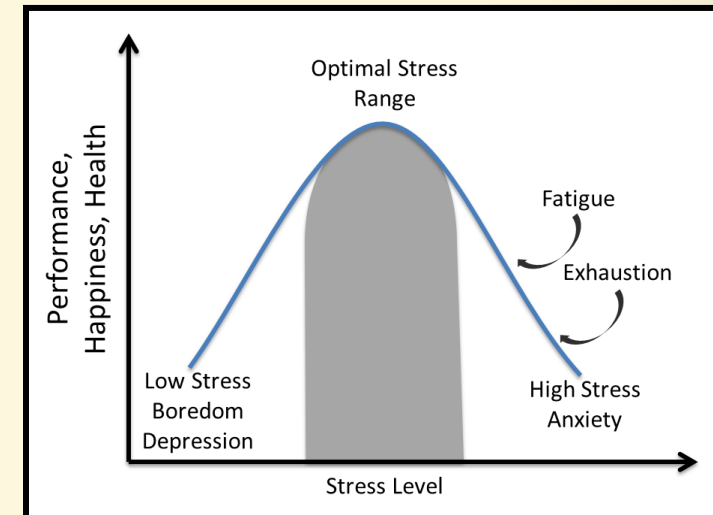
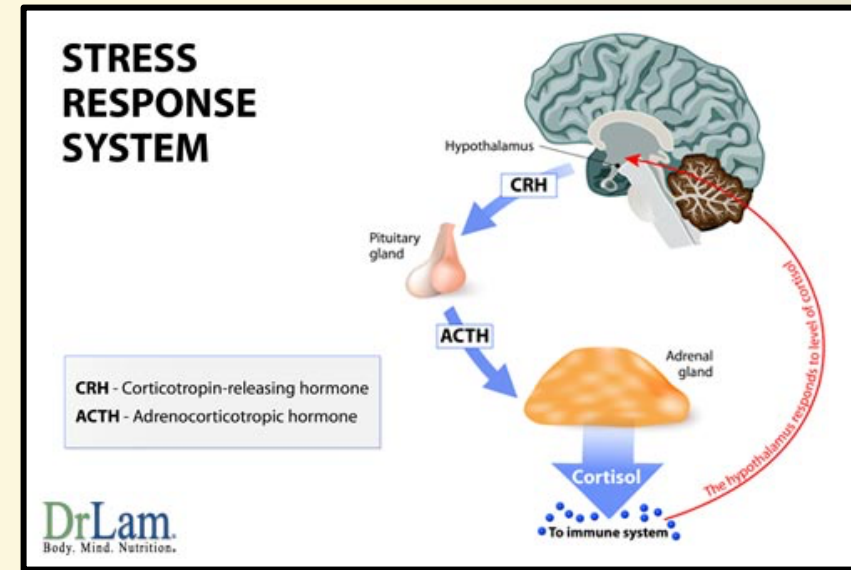


# What contributes to listening-related fatigue?



# 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



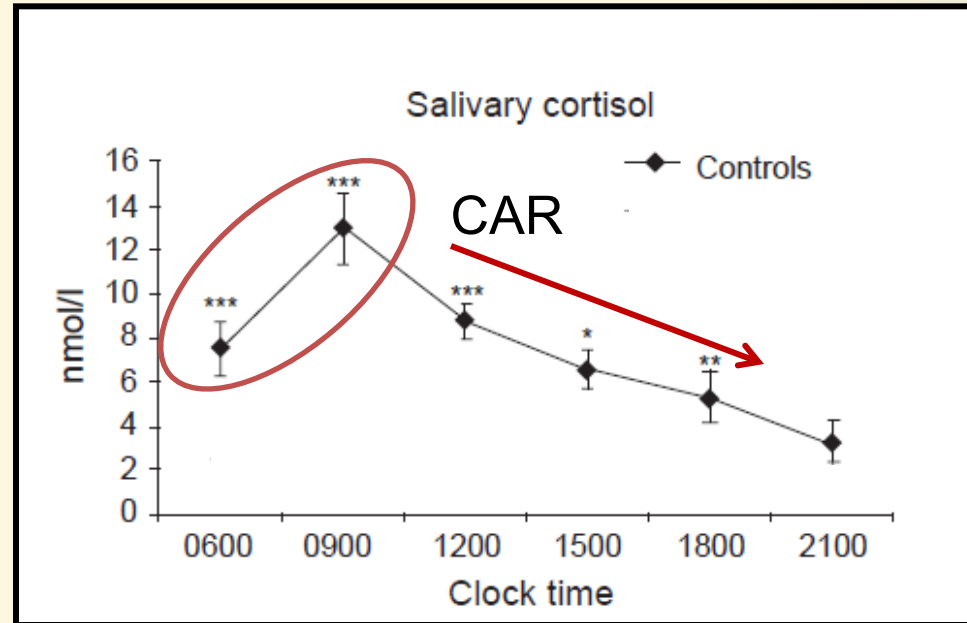


# “Typical” Cortisol Patterns

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

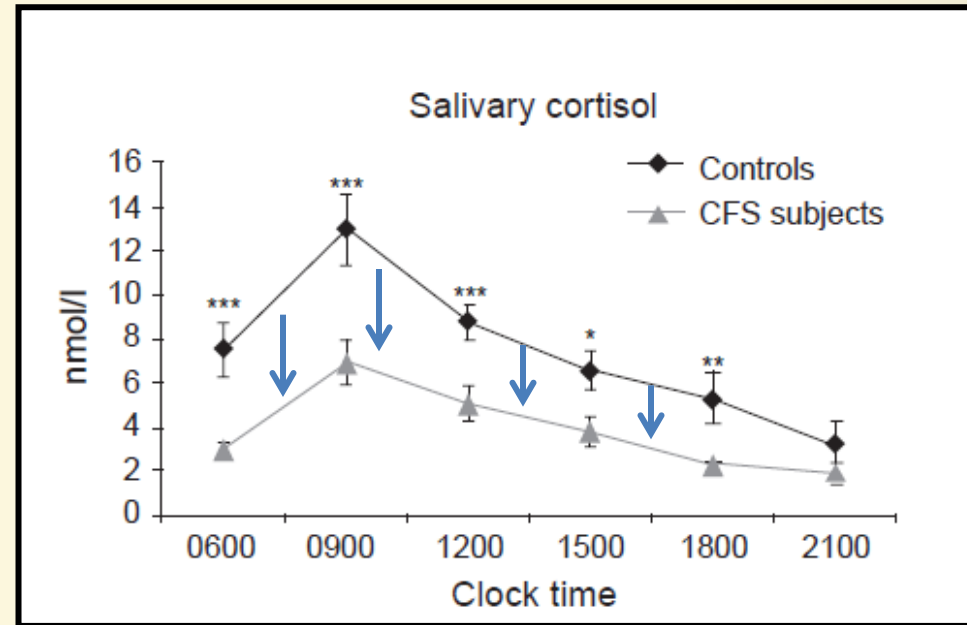
- Build-up of cortisol during sleep
- Rapid rise upon awakening
  - Cortisol Awakening Response; CAR
- Slow decline in cortisol throughout the day

Jerjes, et al., (2005).



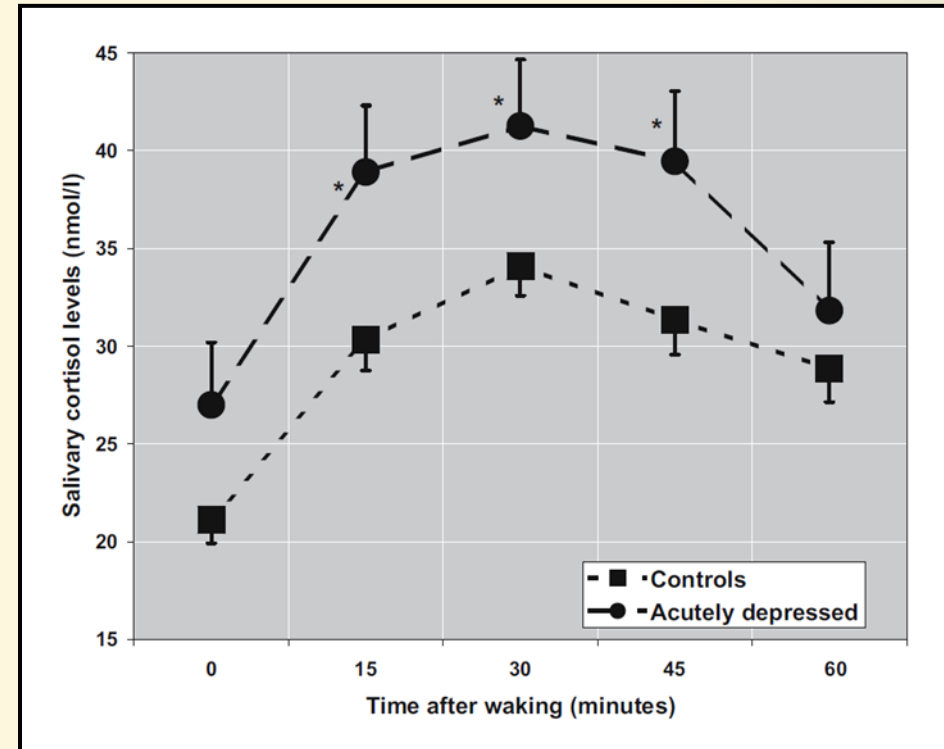
# “Atypical” Cortisol Patterns

- 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
  - “Elevated” CAR in patients with depression



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

Slide from Gustafson, 2015

# 4. Cortisol Measurement

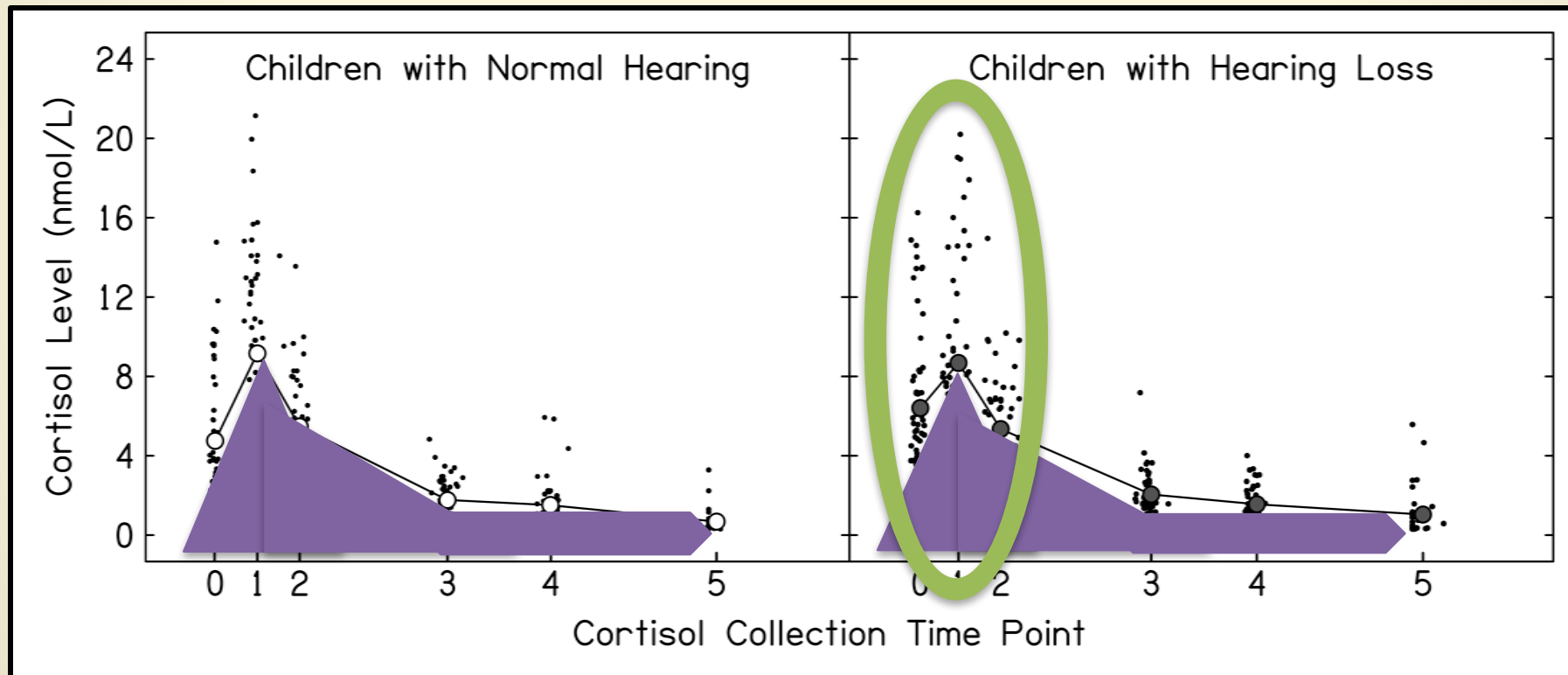


- Participants
  - Children with hearing Loss (n=32)
  - Control group (n=28)
- Six samples per day
  1. Awakening\*
  2. 30 min post-wake up\*
  3. 60 min post-wake up\*
  4. 10:00 am
  5. 2:00 pm
  6. 8:00 pm\*
- Sampled on two separate school days

\*Samples taken by parents at home

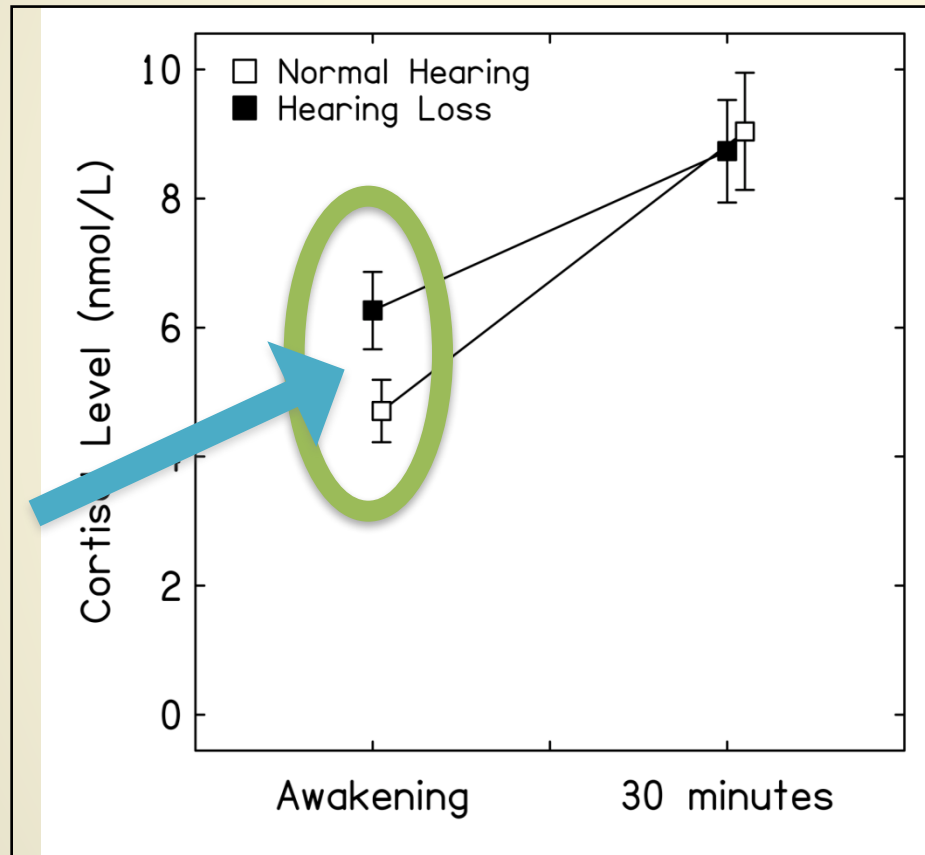
# Comparing Measured Cortisol Levels

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



Bess et al., (2015)

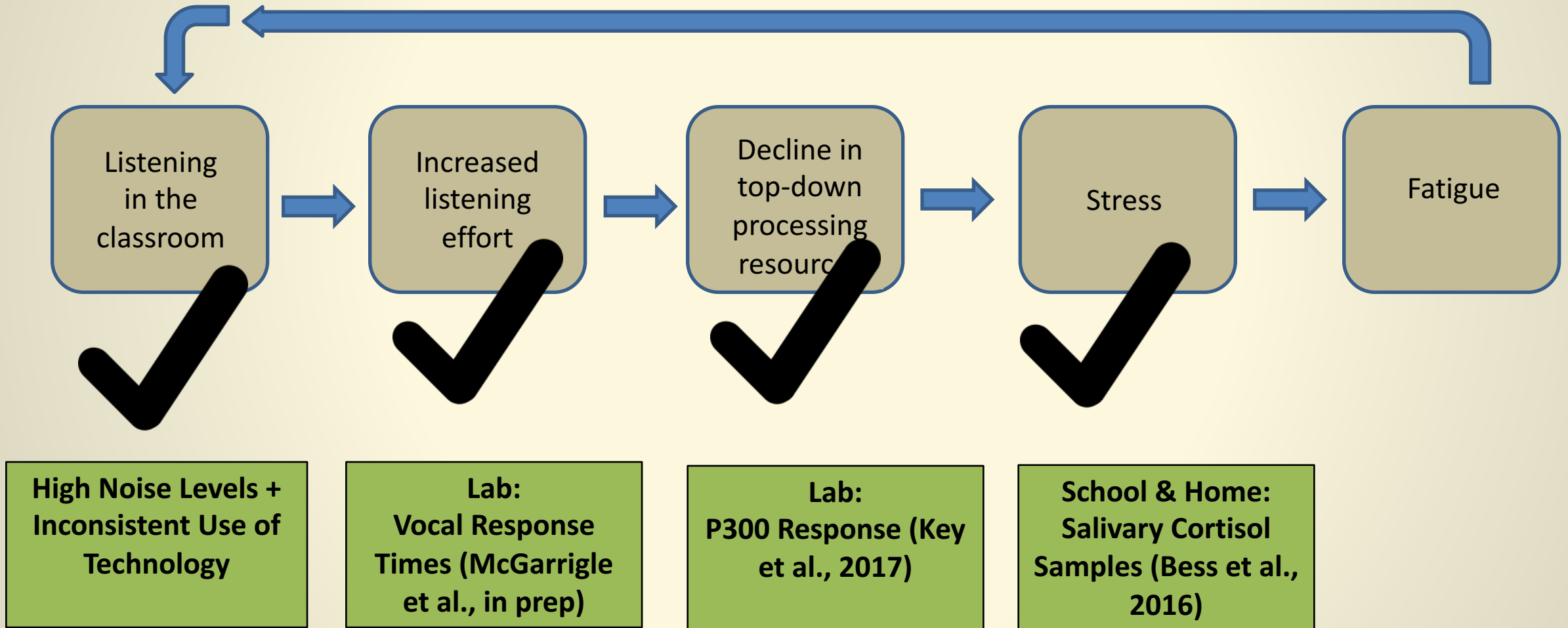
# Comparing Measured Cortisol Levels



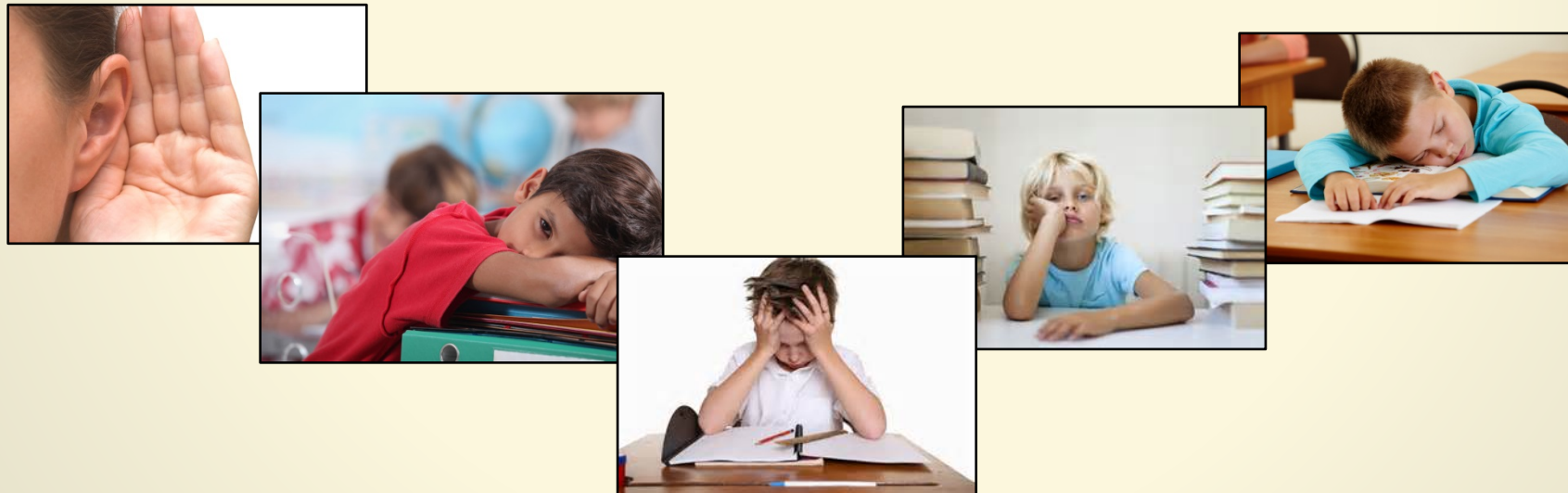
- Children with hearing loss have higher cortisol levels at awakening than controls
- Children with hearing loss have a reduced CAR compared to controls
- Suggests children with hearing loss are experiencing perceived stress and an increased burden of worrying about the upcoming day

**High workload, job strain, and burnout symptoms**

# What contributes to listening-related fatigue?



“When you are hard of hearing you struggle to hear; when you struggle to hear you get tired; when you get tired you get frustrated; when you get frustrated you get bored; when you get bored you quit.” (Pichora-Fuller, 2003)





# Subjective Measures of Fatigue

- Subjective measures include surveys, rating scales, and questionnaires that ask about mood or feelings.
  - Uni-dimensional: assess “general” fatigue (composite score)
  - Multi-dimensional: assess various dimensions fatigue

**Several scales exist to measure multiple domains of fatigue, but none are validated measures specific for hearing loss**



# Subjective Measures Study Questions

- Is subjective fatigue a problem for children with hearing loss?
  - Measure using validated measures
  - See Hornsby & Naylor, 2016 for review of subjective fatigue in adults
- If so, what factors affect their levels of fatigue?

# Measuring Subjective Fatigue

## PedsQL Multidimensional Fatigue Scale

In the past ONE month, how much of a problem has this been for you...

Subscale	Item	Never	Almost Never	Sometimes	Often	Almost Always
General	I feel tired	0	1	2	3	4
Sleep/Rest	I sleep a lot	0	1	2	3	4
Cognitive	It is hard for me to keep my attention on things	0	1	2	3	4

**SCORES: General, Sleep/Rest, Cognitive and Overall**

Varni et al., 2002

# Measuring Subjective Fatigue

## **PedsQL** Multidimensional Fatigue Scale

In the past few weeks, how much of a problem has this been for you...

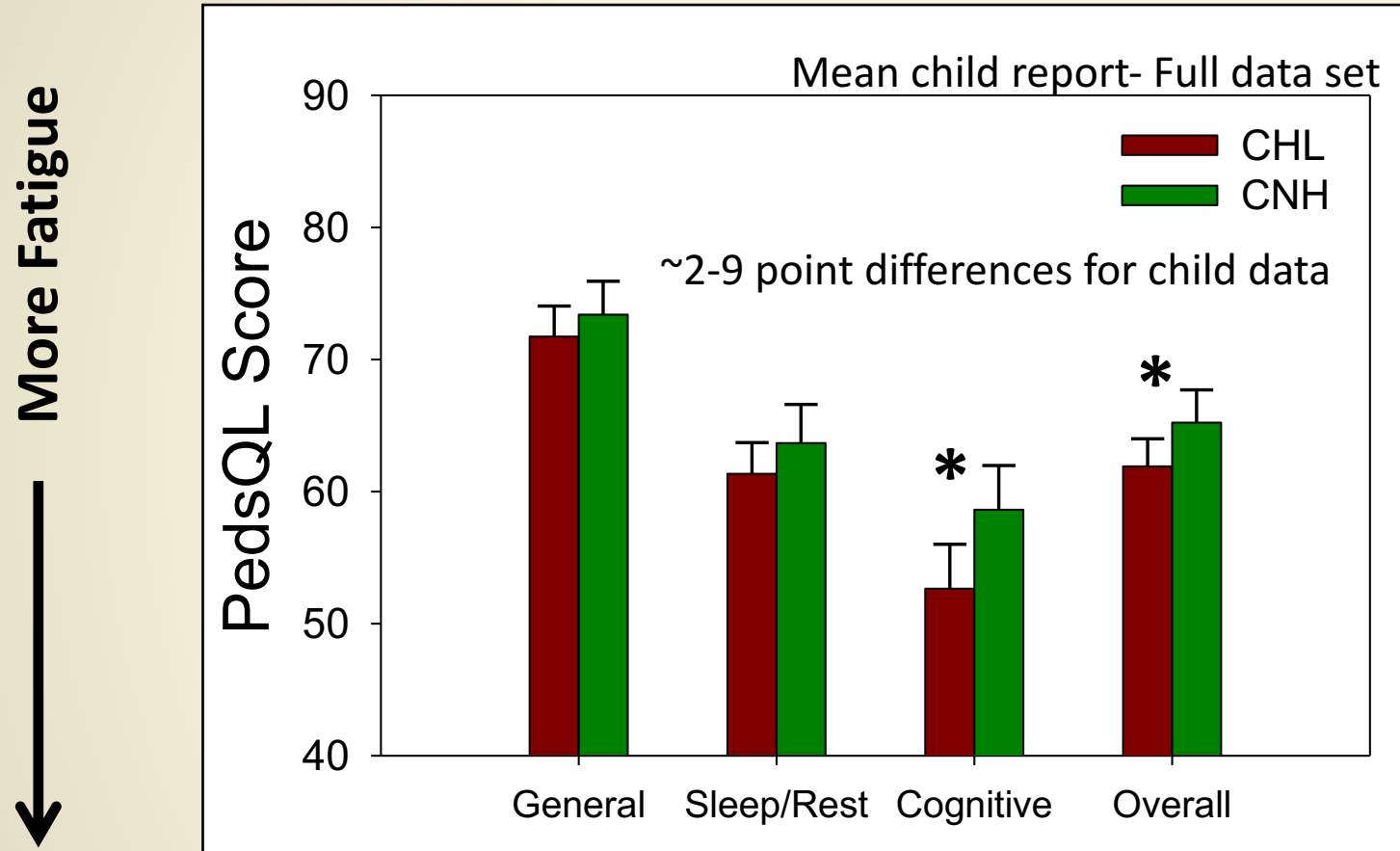
<b>Subscale</b>	<b>Item</b>	<b>Not at all</b>	<b>Sometimes</b>	<b>A lot</b>
General	Do you feel tired?	0	2	4
Sleep/Rest	Do you sleep a lot?	0	2	4
Cognitive	Is it hard for you to keep your attention on things?	0	2	4

**SCORES: General, Sleep/Rest, Cognitive and Overall**

Varni et al., 2002

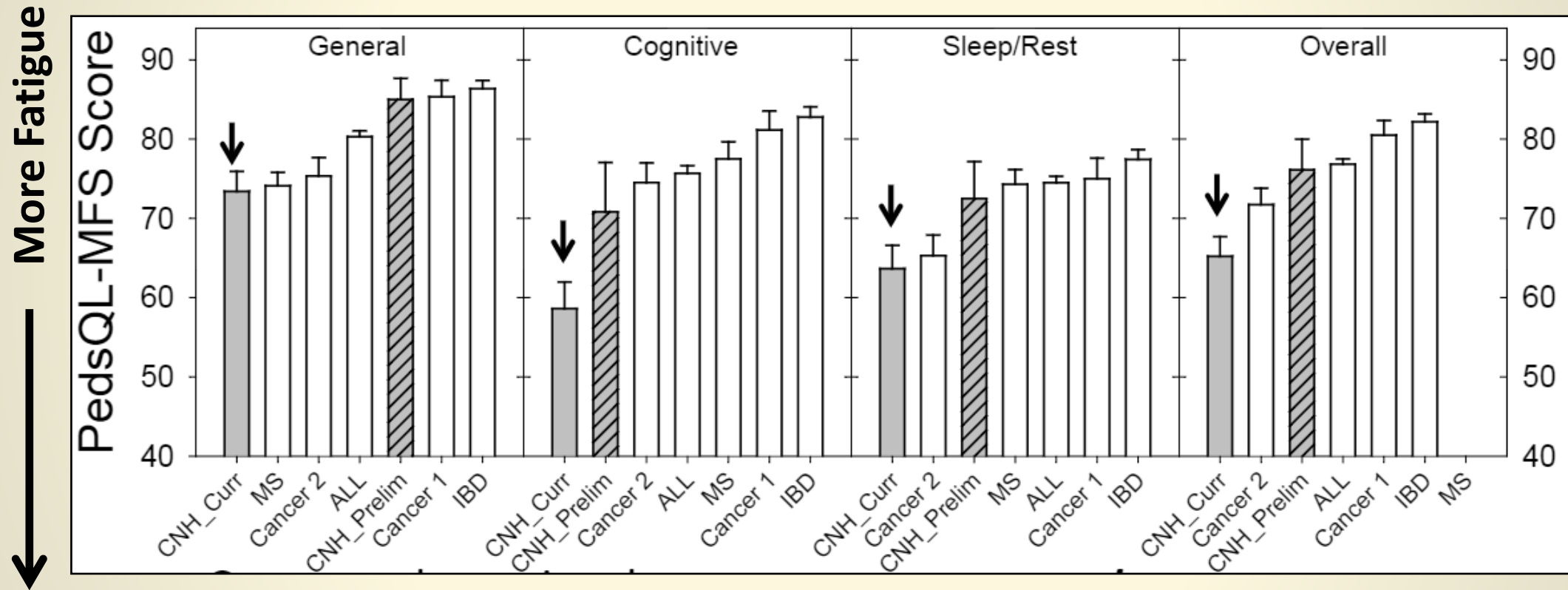
5-7 year  
old version

# Subjective fatigue in CHL



- Current data shows main effect of HL, but small effect. Why?

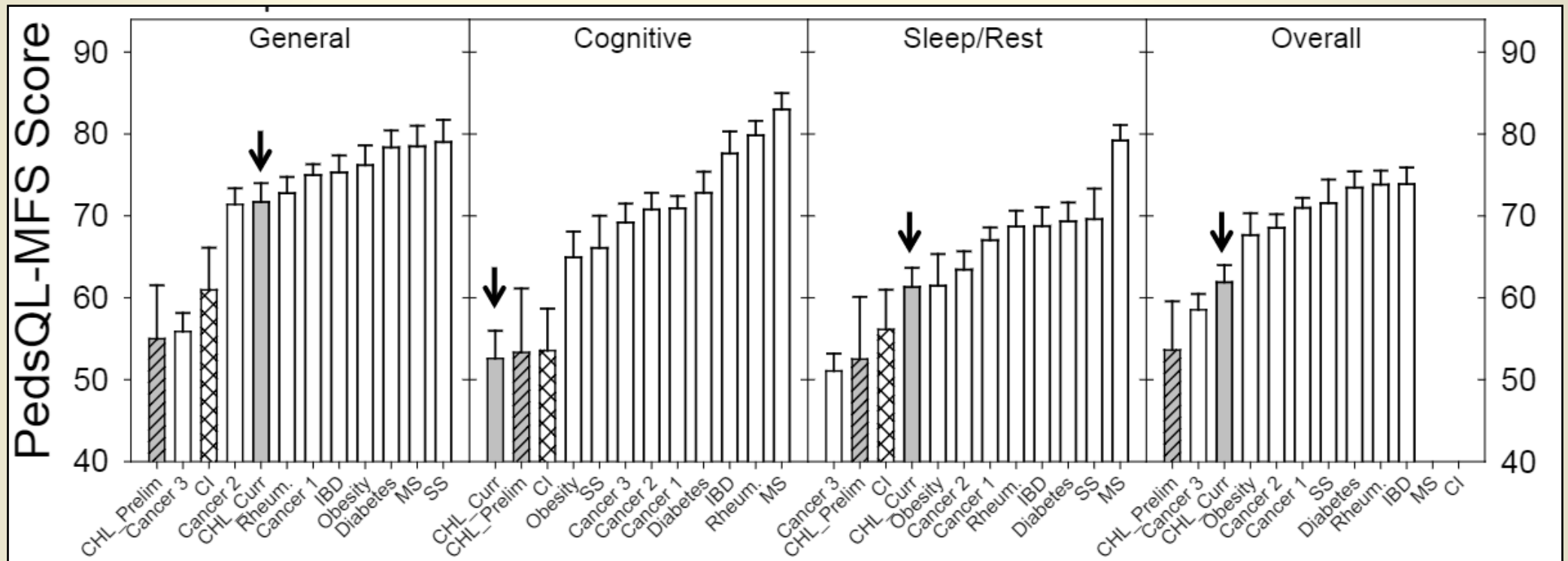
# CNH and CHL PedsQL Reports



**CNH reported higher fatigue compared to other control groups.**

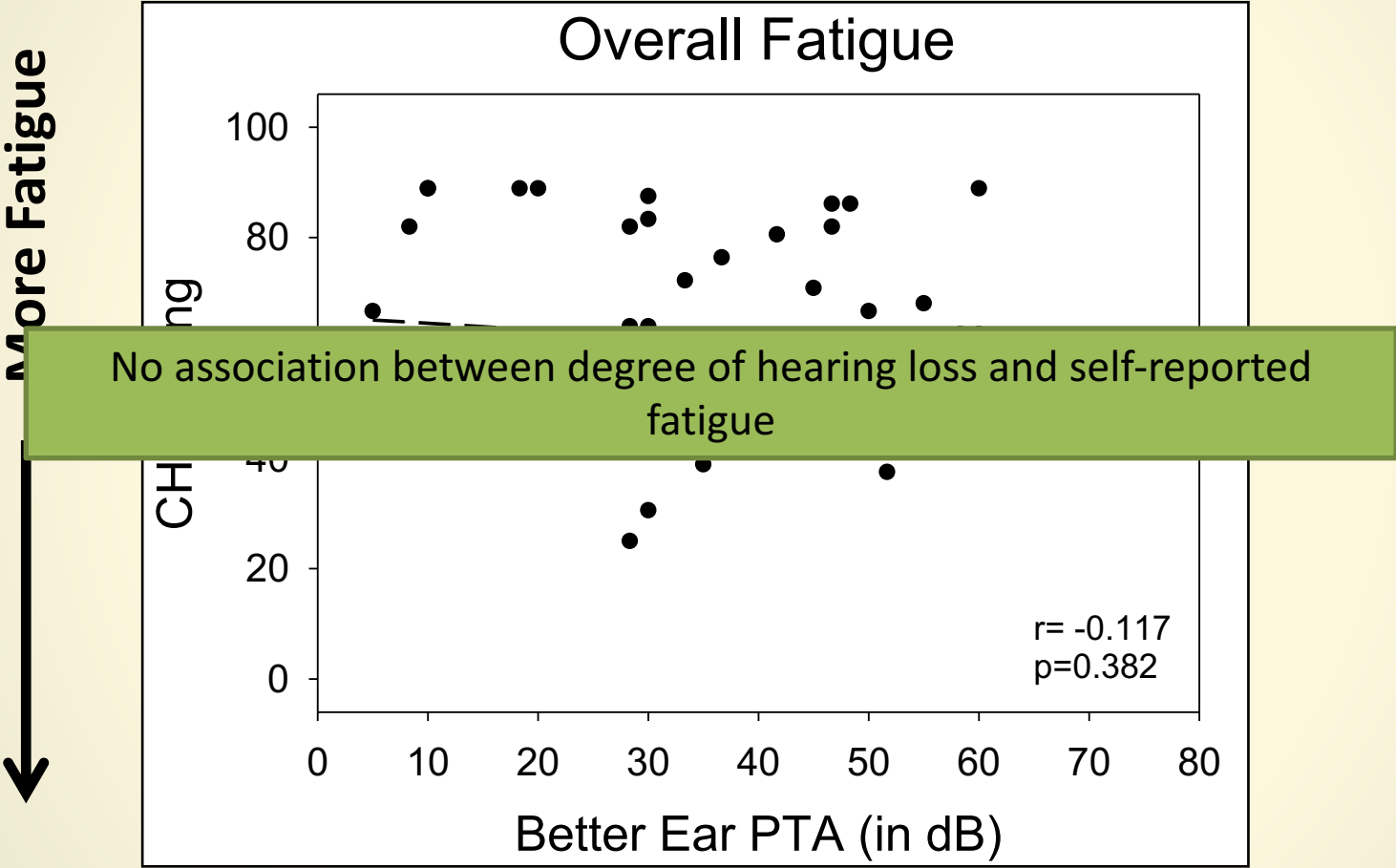
# CNH and CHL PedsQL Reports

More Fatigue  
↓



**CHL reported more, or similar, fatigue across multiple domains when compared to other control groups AND children with other chronic conditions**

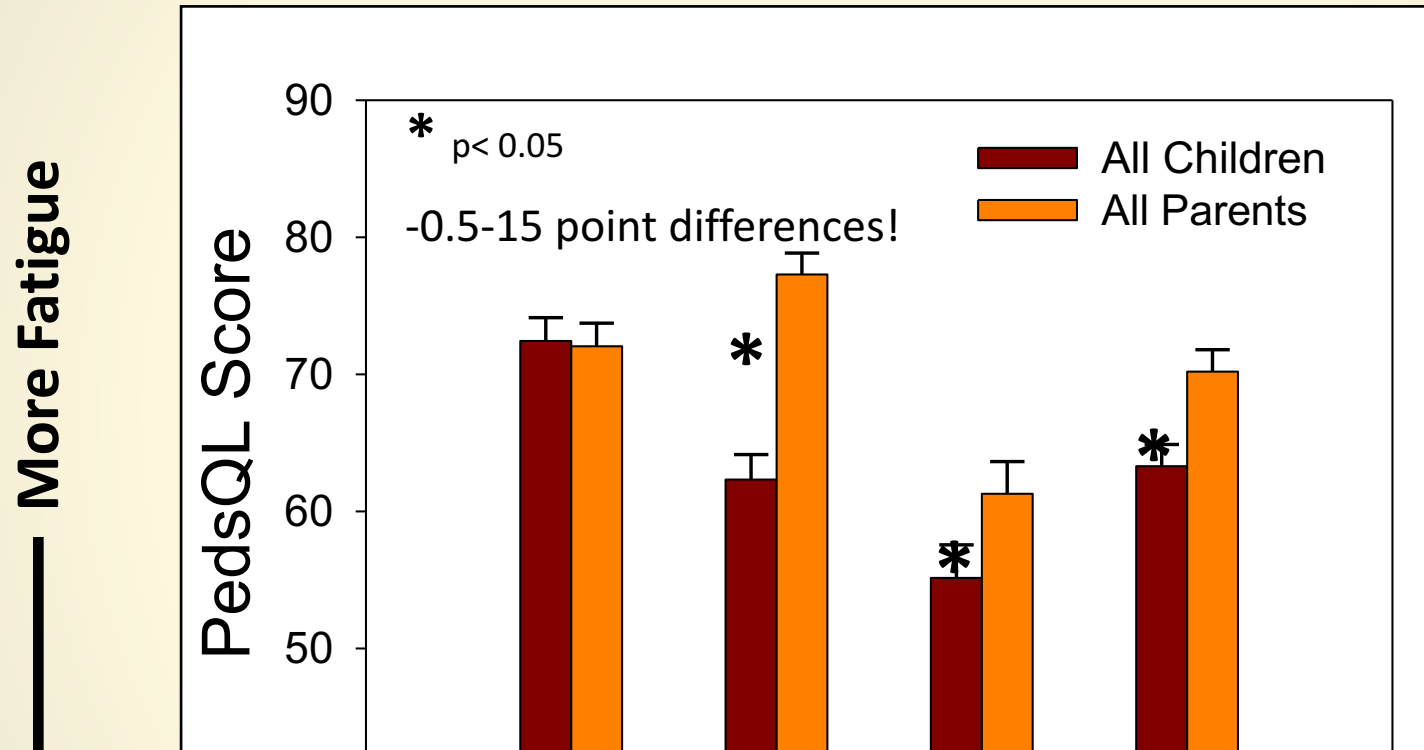
# More HL = More Fatigue?





# Parent versus Child Fatigue Report

Mean data collapsed across HL/NH groups



More Fatigue  
↓

CAN WE USE PARENT REPORT?

ON PEDSQL, NO!

ts

# Need for Hearing Loss Specific Fatigue Scale

- No significant differences noted between CHL and CNH on overall scores for PedsQL MFS.
- Fatigue is a subjective experience
  - Inter-subject and inter-group variability



What was the PedsQL measuring?  
How do you quantify fatigue?

# Listening-Related Fatigue Scales: Current Work

- Vanderbilt Fatigue Scale-AHL (Adults with Hearing Loss)
- Vanderbilt Fatigue Scale-CHL (Children with Hearing Loss)
  - Pediatric Version
  - Caregiver Version
  - Teacher/Service Provider Version

**GOAL:** create and validate a measure of fatigue in individuals with hearing loss with specific listening-related questions.

# Fatigue Scale Development Process

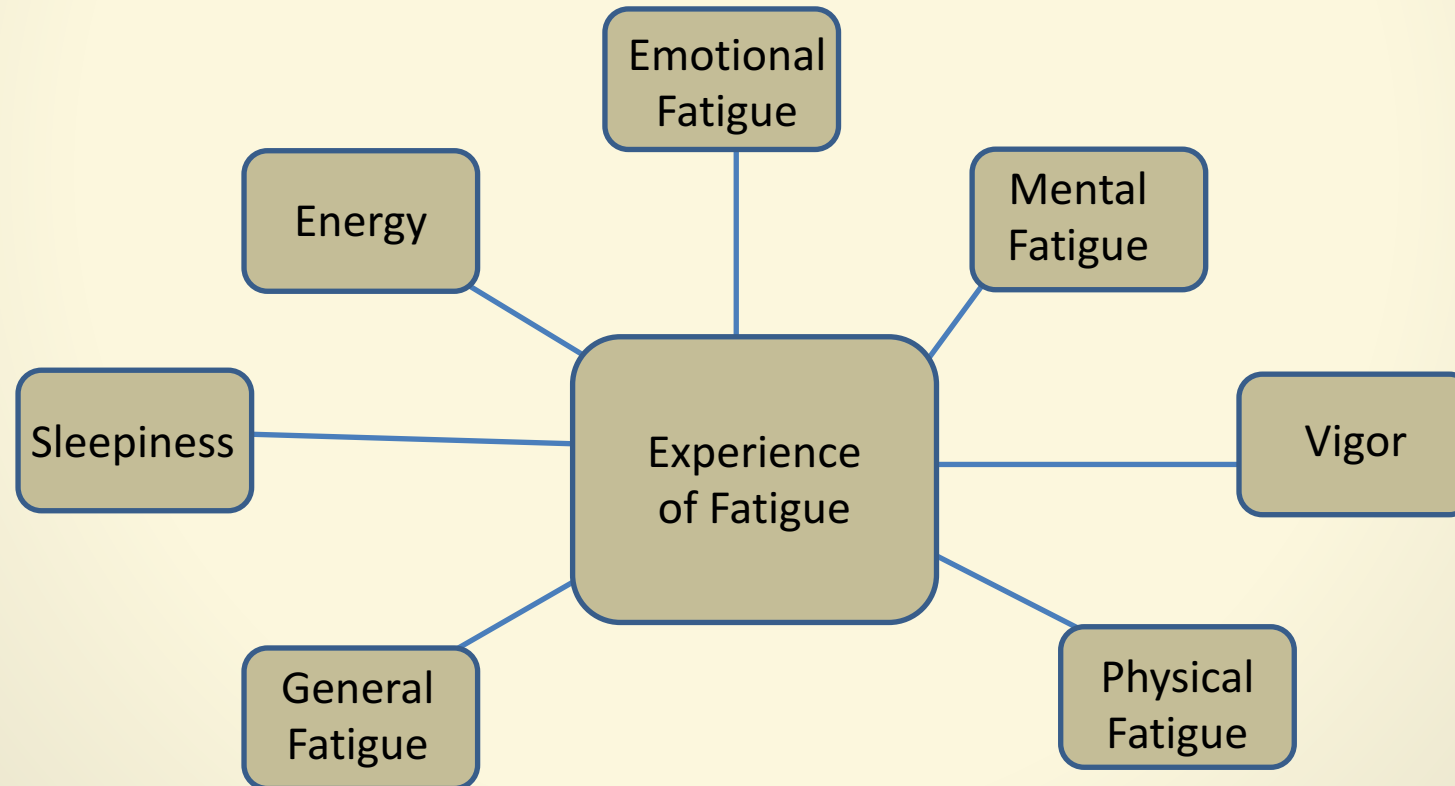
- Phase 1: Defining listening-related fatigue and issues
  - Literature Review: background theory and constructs
  - Focus Groups: individual experiences
- Phase 2: Item Development and Revisions
  - Focus group data review
  - Expert review
  - Cognitive interviews
    - AHL, CHL, parents, and teachers
- Phase 3: Initial Psychometric Evaluation
  - Adults only, child version in progress



**We need your  
help, so stay  
tuned!**

# Dimensions of Subjective Fatigue

- Fatigue dimensions and related constructs identified via literature review, surveys, interviews, and focus groups



# Focus Group Process

- Focus groups and individual interviews with parents, teachers, and children with hearing loss
- Transcribed and reviewed the focus group discussions
- Items written directly from quotes

## SCHOOL SERVICE PROVIDER MODERATOR'S GUIDE

Does your student seem to exert more energy to participate in certain activities?

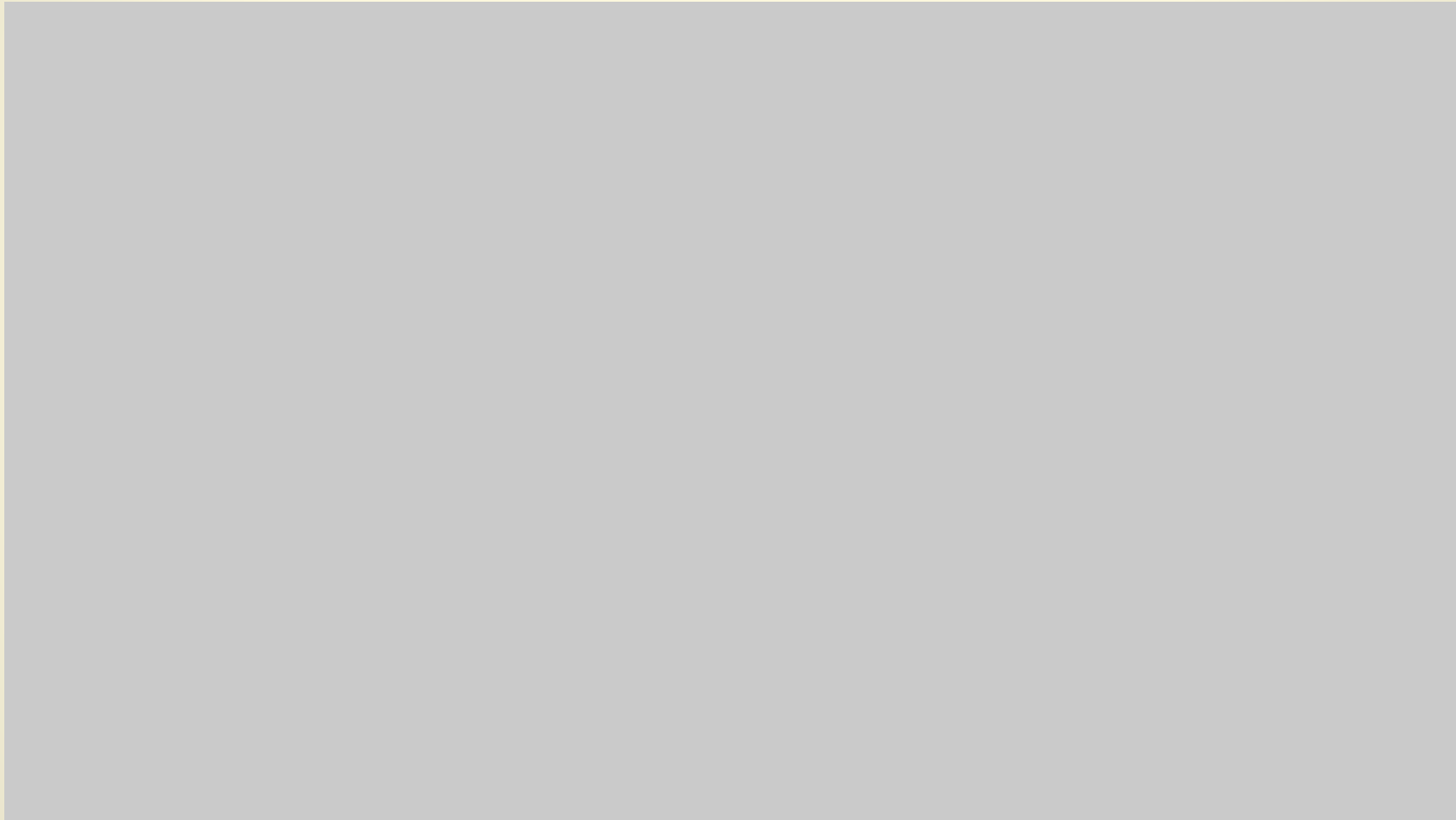
What behaviors/emotions do you note in your student that alert you that he/she may be fatigued?

What coping strategies do you/the student use to recover from fatigue?

Is fatigue from listening a problem for your student?



What do adults with HL have to say?



# Phase 1: Defining the Issues-CHL

- “Fatigue sounds like phantom, so maybe a squid?”





# Phase 1: Defining the Issues-CHL

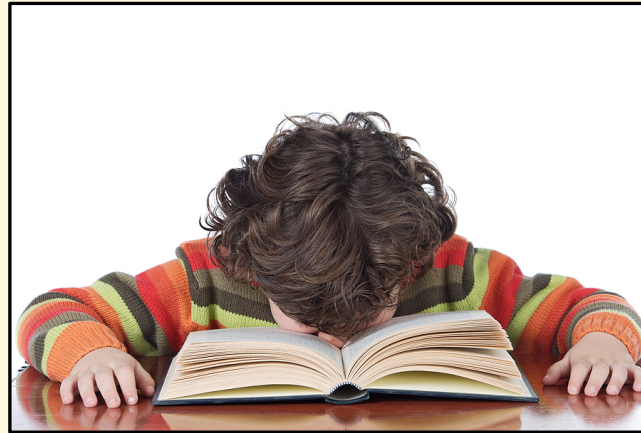
## Listening-Related Fatigue

*"...for me I feel more focused when there's a one-on-one conversation and I feel kind of more talkative when there's just a one on one conversation. But **when there's a lot of friends...that makes me more tired.** Trying to focus on conversations and then trying to think about it and process it makes me a little tired."*

–teen with bilateral cochlear implants

*"In the cafeteria, they try to listen but that's their starting time of "fading down" so they just kind of take it a break time. I've had my one student, she sometimes just **takes her implant off and even turns the volume down on her hearing aid and that's like her time to just sit and not have to listen.**"*

–Deaf education teacher



*"Yesterday we took a field trip - explored a museum. The gentleman was great, but he spoke so fast—she was still **missing stuff.** In a very hectic environment, and if things go really, really quick for her, I can tell her it's a lot for her. **She has to make an effort, and it wears her out.**"*

–Parent of a 10-year old with bilateral hearing loss

*"Yeah, **you wanna give up.** You just don't want to try anymore because you know you won't actually get what they're trying to say or sometimes you think it's just you. Maybe I need to try a little harder to listen but when you do try, you **put all of your focus on what they're trying to say and you still can't hear them.**"*

–teen with bilateral hearing aids

# Phase 2: Item Development

??

It is a lot of work for me to focus on others when they are talking.

It takes a lot of work to focus on listening.

I have to try hard to focus on what others are saying.

I get tired trying to keep up with group conversations.

I have to focus hard to understand group conversations.

I get tired trying to process and understand in a group conversation.

I want to give up when I have difficulty understanding what someone is saying.

I have to focus all of my energy on listening to understand what others are saying.

# Vanderbilt Fatigue Scale Sample Questions

TEACHER

**Never**

**Rarely**

**Sometimes**

**Often**

**Almost Always**

- My student stops participating in difficult listening situations.
- My student will give up trying to listen when it is difficult to hear.

PARENT

**Never**

**Rarely**

**Sometimes**

**Often**

**Almost Always**

- Trying to keep up in a conversation exhausts my child.
- My child gets frustrated when it is difficult to hear.

CHILD

**Never**

**Rarely**

**Sometimes**

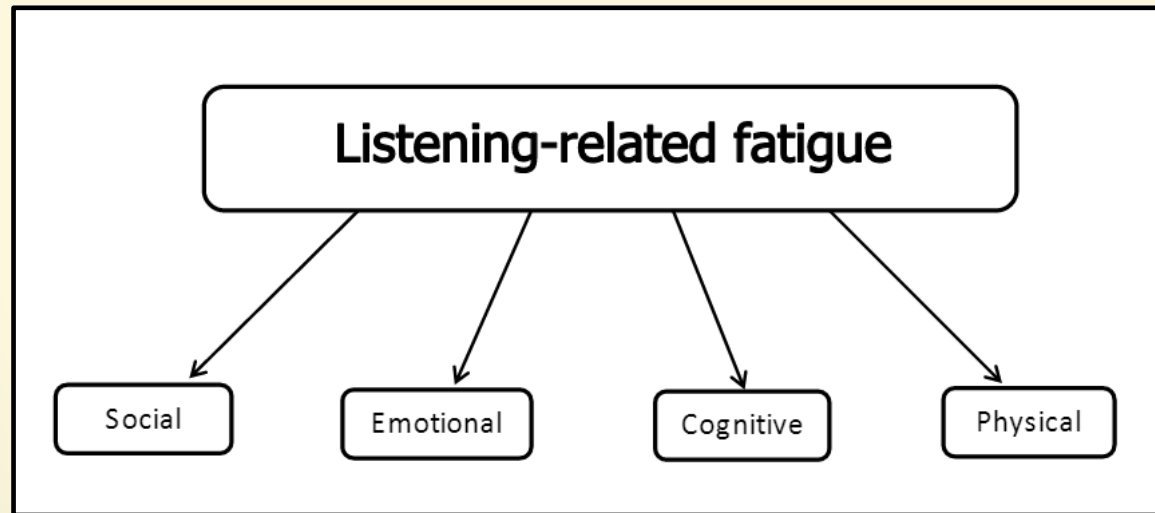
**Often**

**Almost Always**

- I use a lot of energy trying to understand what others are saying.
- I get annoyed when I have to listen in a noisy place.

# Small Group Discussion

- Do you note listening-related fatigue in your students with hearing loss?
  - If so, what symptoms are observed?



# Small Group Discussion

- If your student with hearing loss shows signs of fatigue, what does he/she do to cope?
- What are strategies/modifications/goals the classroom teacher, SLP, deaf educator, educational audiologist, etc. can use to help the student with hearing loss dealing with fatigue in the educational setting?



# Suggestions for IEPs

## ACCOMMODATIONS/MODIFICATIONS

Provide notes ahead of class time to reduce need to multi-task during lecture/discussion

Provide a space and/or scheduled break time for listening/quiet breaks

Consider schedule of day and timing of auditory tasks, including therapies or other pull-out sessions

Consistent personal amplification and FM system use

Preferential seating to potentially reduce listening effort

Visual information available in the classroom

Classroom acoustic modifications

**ADDITIONAL  
SUGGESTIONS?**



# Implications for Practice

## Be on the lookout for fatigue!

*Fatigue can manifest itself in a variety of ways:*

tiredness

sleepiness in the morning

inattentiveness and distractibility

mood changes (irritability, frustration, etc.)

changes in classroom contributions

difficulty following instructions





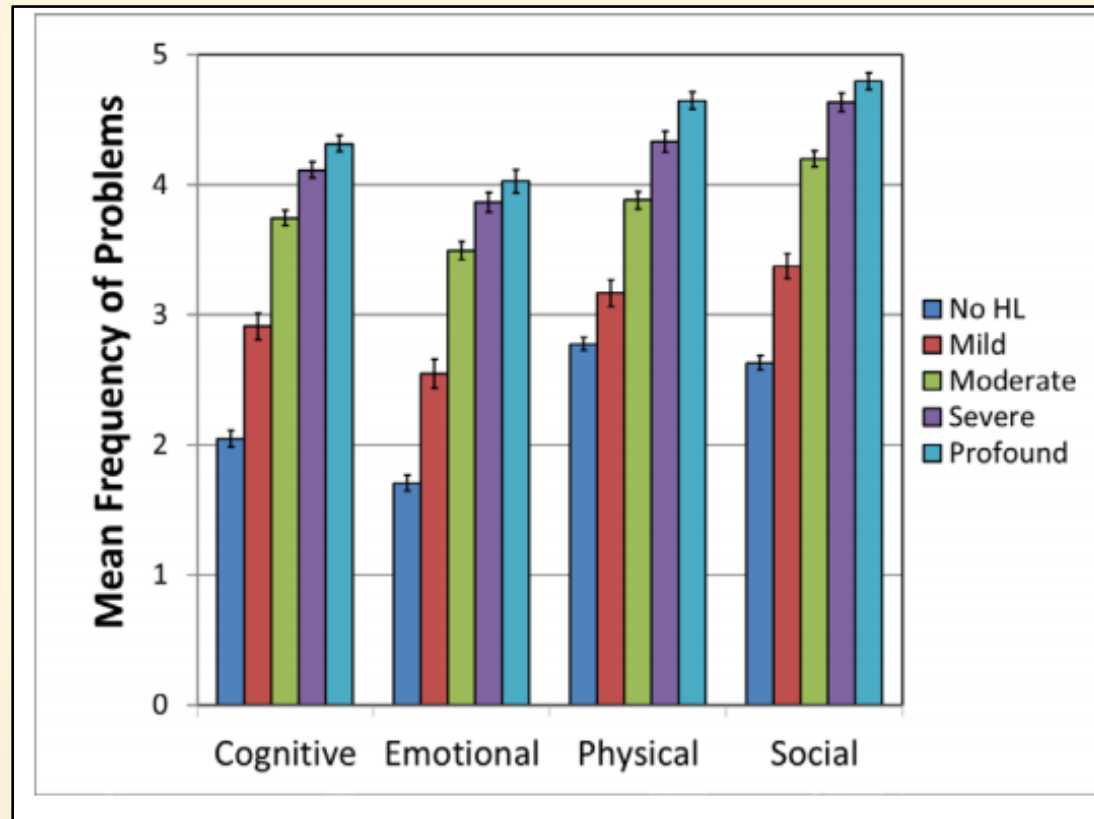
# Conclusions

- CHL demonstrate increased listening effort when listening in noise and reverberation
  - Even with hearing aids
- CHL report more cognitive fatigue than their normal-hearing peers and similar or more fatigue than children with other chronic illnesses
- CHL show atypical markers of perceived stress, a precursor to fatigue
- There is a need for specific subjective fatigue measures for this population in order to identify CHL struggling with fatigue (and to intervene)



# Phase 3: Initial Psychometric Testing

## *VFS-AHL: Preliminary Data*



Hornsby et al., 2017 (data presented at the ARC conference, Indianapolis, IN)

# Next Steps: Phase 3

**The Vanderbilt Fatigue Scale – Children with Hearing Loss is in Phase 3. This version has parent, teacher, and child components.**

If you're interested in helping to distribute this scale to children with hearing loss, parents, and teachers during the validation stage, please provide your contact information on the page provided.

If you have questions specifically related to these fatigue scales, please contact the study coordinator, Dr. Hilary Davis at [Hilary.Davis@vanderbilt.edu](mailto:Hilary.Davis@vanderbilt.edu)

# Questions? Comments?



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

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# Phase 2: Item Development

My child complains of frequent headaches.

My child struggles to understand audio from computers.

It is difficult for my child to focus with competing background noise.

My child struggles to keep up with fast-paced conversation.

My child puts a lot of effort into keeping up with conversation.

My child must make an effort to keep up with fast-paced conversation.

My child gets worn out from the effort of keeping up with conversation.

My child's hearing difficulties impact his ability to interact with others.

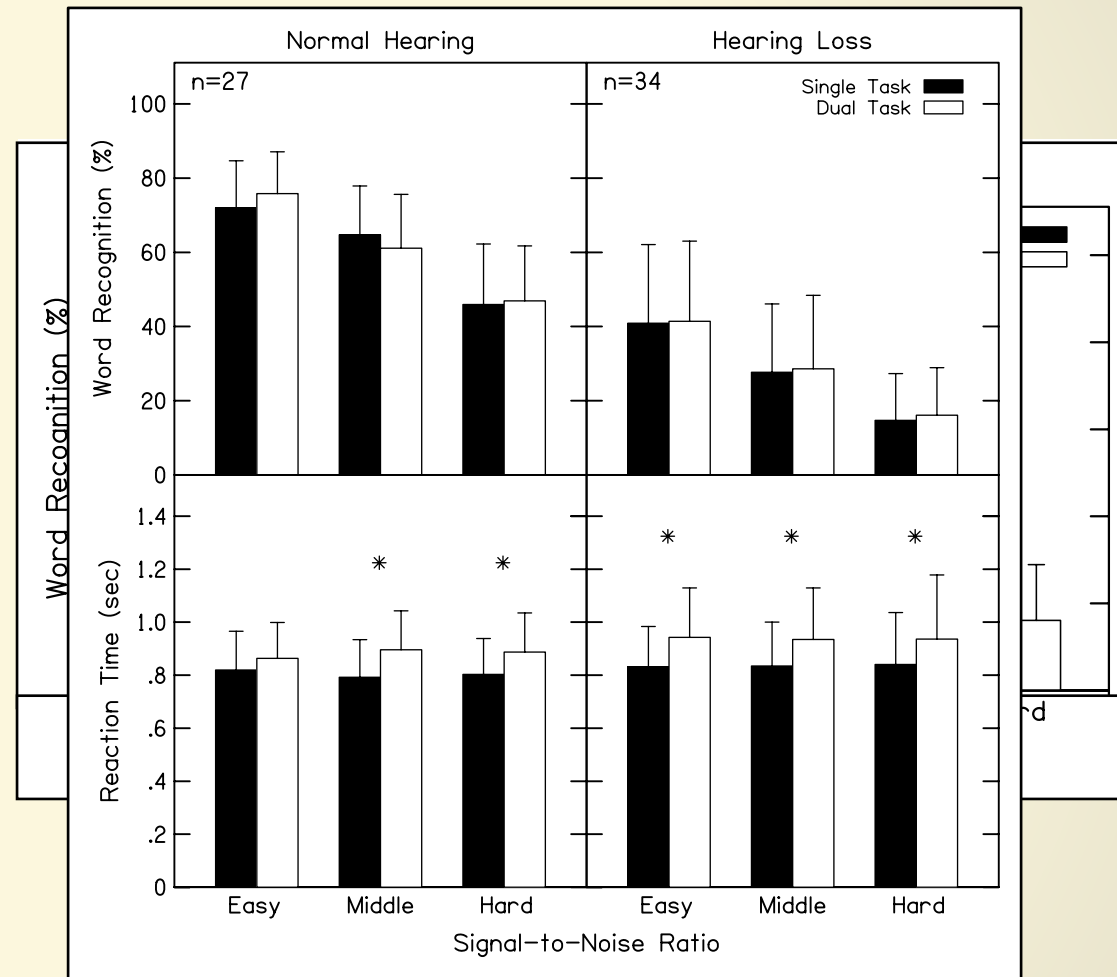
My child becomes tired in noisy situations.

My child gives up trying to listen in noisy places.

No difference in word recognition performance between single- and dual-tasks.

Longer response times measured with addition of second task.

Cognitive resources were allocated toward maintaining word recognition performance in the dual-task condition.

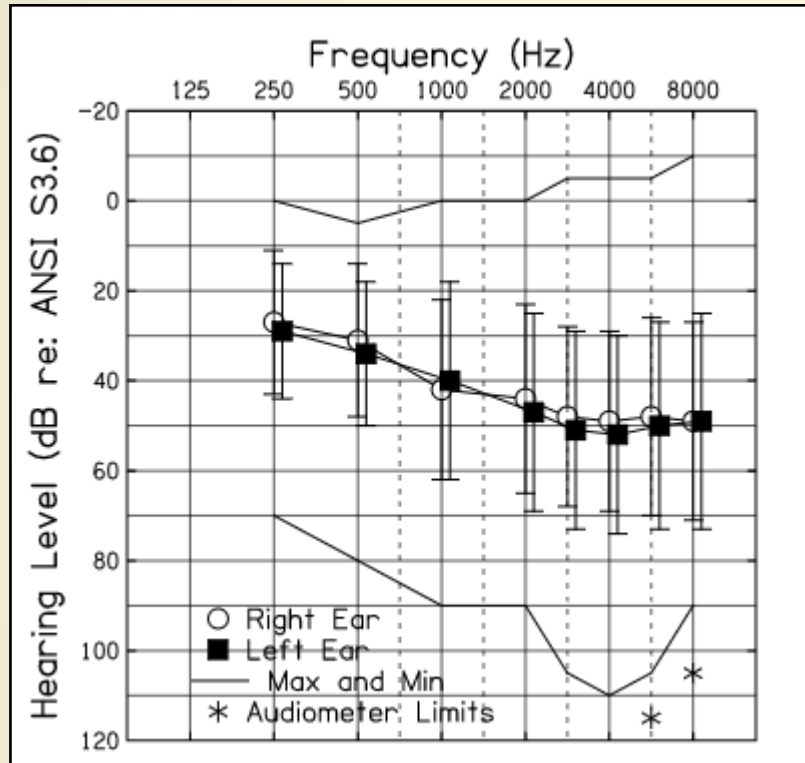


# Factors Influencing Fatigue in CHL

- What factors may modulate fatigue in CHL?
  - Hearing loss?
    - No
- Results varied with domain
  - General and Sleep/Rest: No associations with any measure
  - Cognitive and overall: significant association with CELF and PPVT (but not TONI)



# Study Participant Demographics

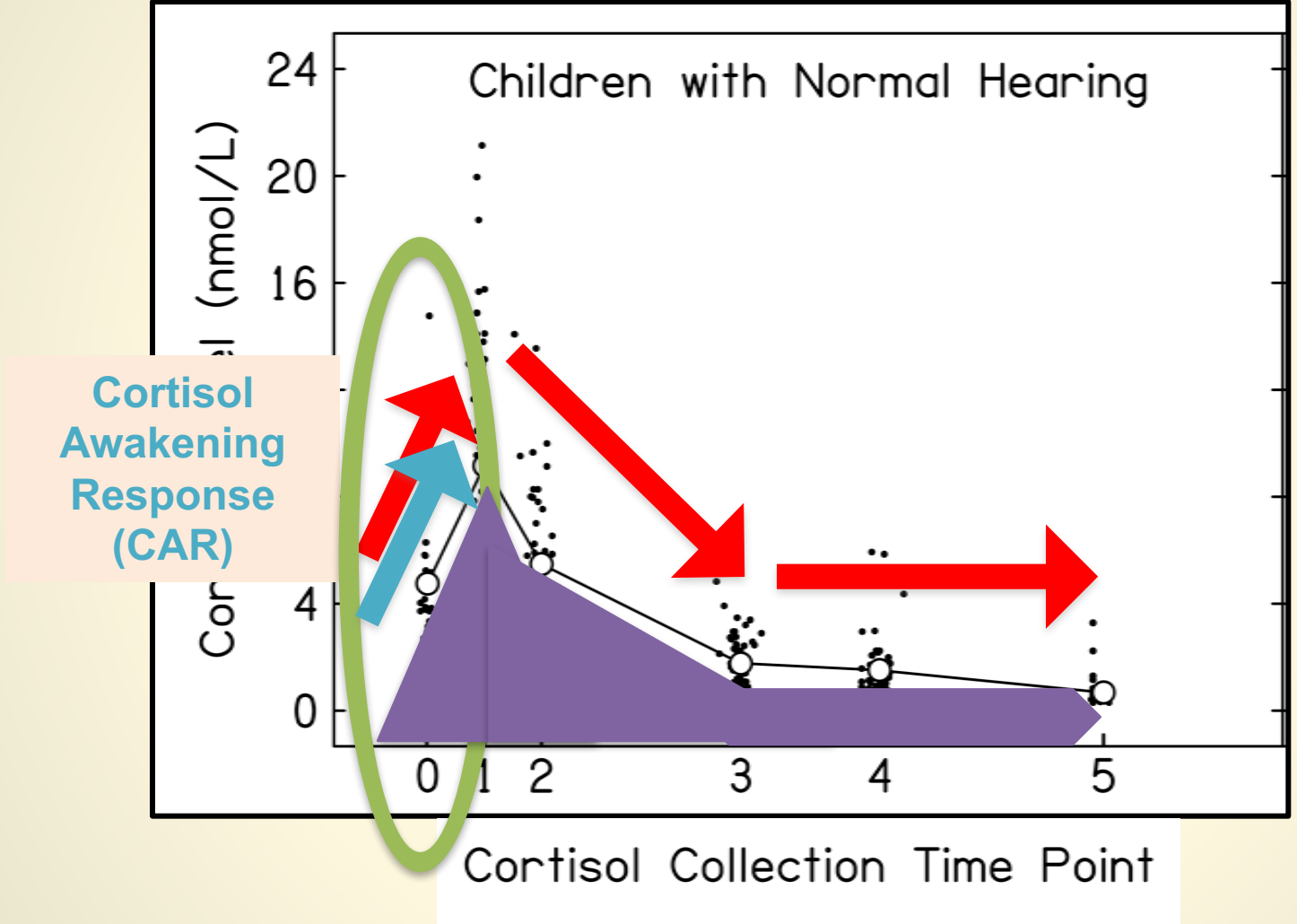


- Participants

- CNH and CHL (6-12 years old)
  - Parents
- Bilateral, mild to moderately-severe SNHL
- No CI users
- No diagnosis of developmental disorder or cognitive impairment

- Experimental (CHL) group (n=60) • Control (CNH) Group (n=43)
  - 31 males (52%), 29 females
  - Age = 10.0 (1.9) years
  - 26 males (60%), 17 females
  - Age = 9.1 (2.3) years

# Measured Cortisol Levels



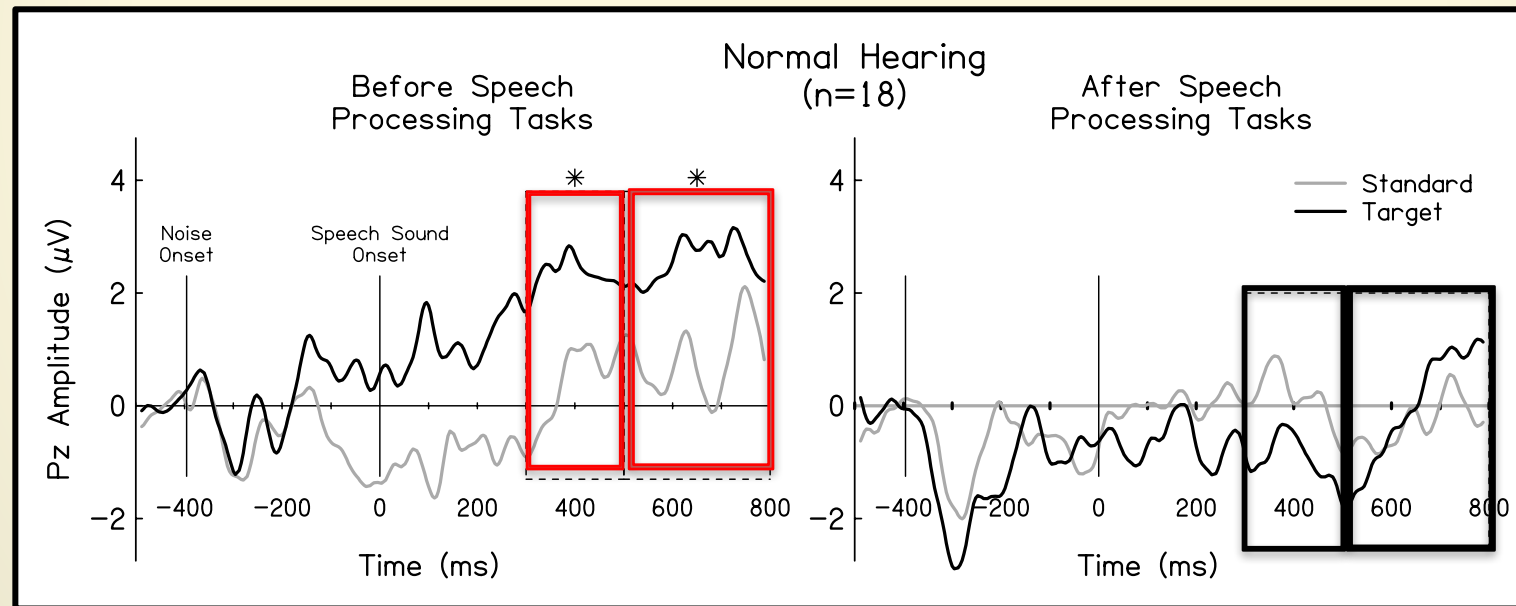
# Phase 2: Item Development

## Multi-Dimensional Construct Map-CHL

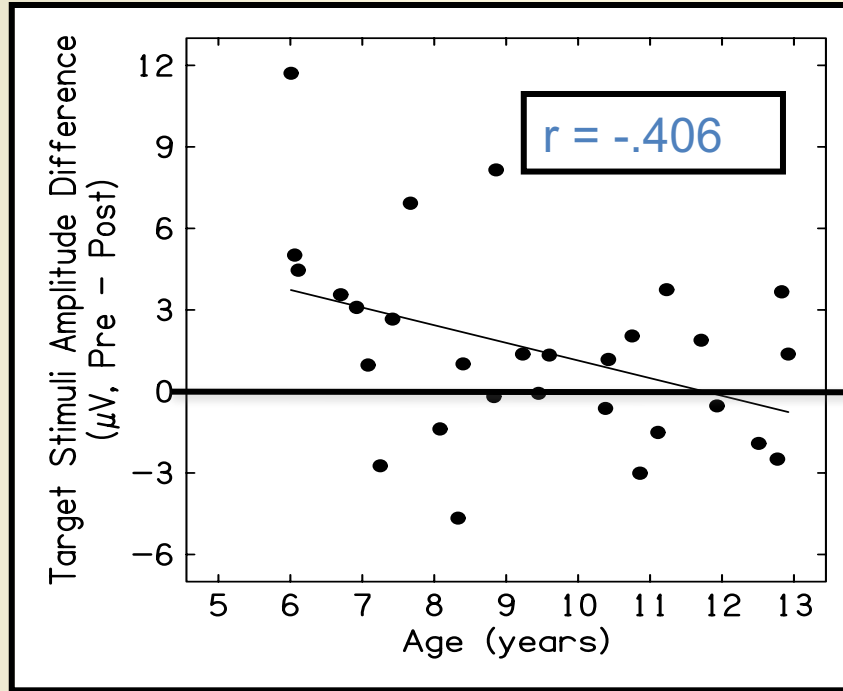
Level	D1: Social-Emotional	D2: Cognitive	D3: Physical
3-Severe Fatigue	<p><u>Behaviors:</u> Becomes extremely sad, upset, angered, stressed and/or emotionally exhausted by listening difficulties /fatigue. May throw tantrums and exhibit aggression. Social life is severely impacted by listening fatigue. Exhibits avoidance behaviors isolates oneself from social gatherings to cope with listening fatigue.</p> <p><u>Situations:</u> Across a wide range of easy-challenging listening situations</p>	<p><u>Behaviors:</u> Becomes unwilling /unable to maintain effort and attention when completing even routine mental activities. Becomes very unfocused and/or consciously decides to disengage (e.g., shuts down, gives up).</p> <p><u>Situations:</u> Across a wide range of easy-challenging listening situations</p>	<p><u>Behaviors:</u> Feels exhausted, drained and/or worn out from listening. Requires naps, additional sleep, and/or silent time to recover from listening fatigue. Regular breaks need to be scheduled into school day. Reports of significant sleep problems. Reports significant headache problems. Reports need to remove hearing device.</p> <p><u>Situations:</u> Across a wide range of easy-challenging listening situations.</p>
2-Moderate Fatigue	<p><u>Behaviors:</u> Becomes stressed, sad, frustrated, upset and/or emotionally tired by listening difficulties/fatigue. Social life is moderately impacted by listening fatigue. May avoid and/or withdraw from certain social gatherings.</p> <p><u>Situations:</u> Moderately-challenging listening situations or worse</p>	<p><u>Behaviors:</u> Must apply substantial mental effort to overcome difficulties remaining attentive when listening and following conversations. May tune/zone out. May need prompting.</p> <p><u>Situations:</u> Moderately-challenging listening situations or worse</p>	<p><u>Behaviors:</u> Feels tired after listening. May take listening breaks to recover. May get headaches from listening. May show abnormal sleep habits/patterns. May turn down hearing device.</p> <p><u>Situations:</u> Moderately-challenging listening situations or worse</p>
1-Mild Fatigue	<p><u>Behaviors:</u> Becomes irritated, embarrassed or anxious from listening difficulties/fatigue. Social life is mildly impacted by listening fatigue. May avoid and/or withdraw from certain social gatherings.</p> <p><u>Situations:</u> Very challenging listening situations only</p>	<p><u>Behaviors:</u> Some difficulty following fast-paced conversations and remaining attentive.</p> <p><u>Situations:</u> Very challenging listening situations only</p>	<p><u>Behaviors:</u> May exhibit mild tiredness after listening. Would enjoy a short rest or a listening break (not a requirement).</p> <p><u>Situations:</u> Very challenging listening situations only</p>

# Change in Processing Resources: *Children with No Hearing Loss*

Cognitive processing was reduced following sustained speech-processing tasks ( $p < .05$ ).



# Who's at Risk? CNHL



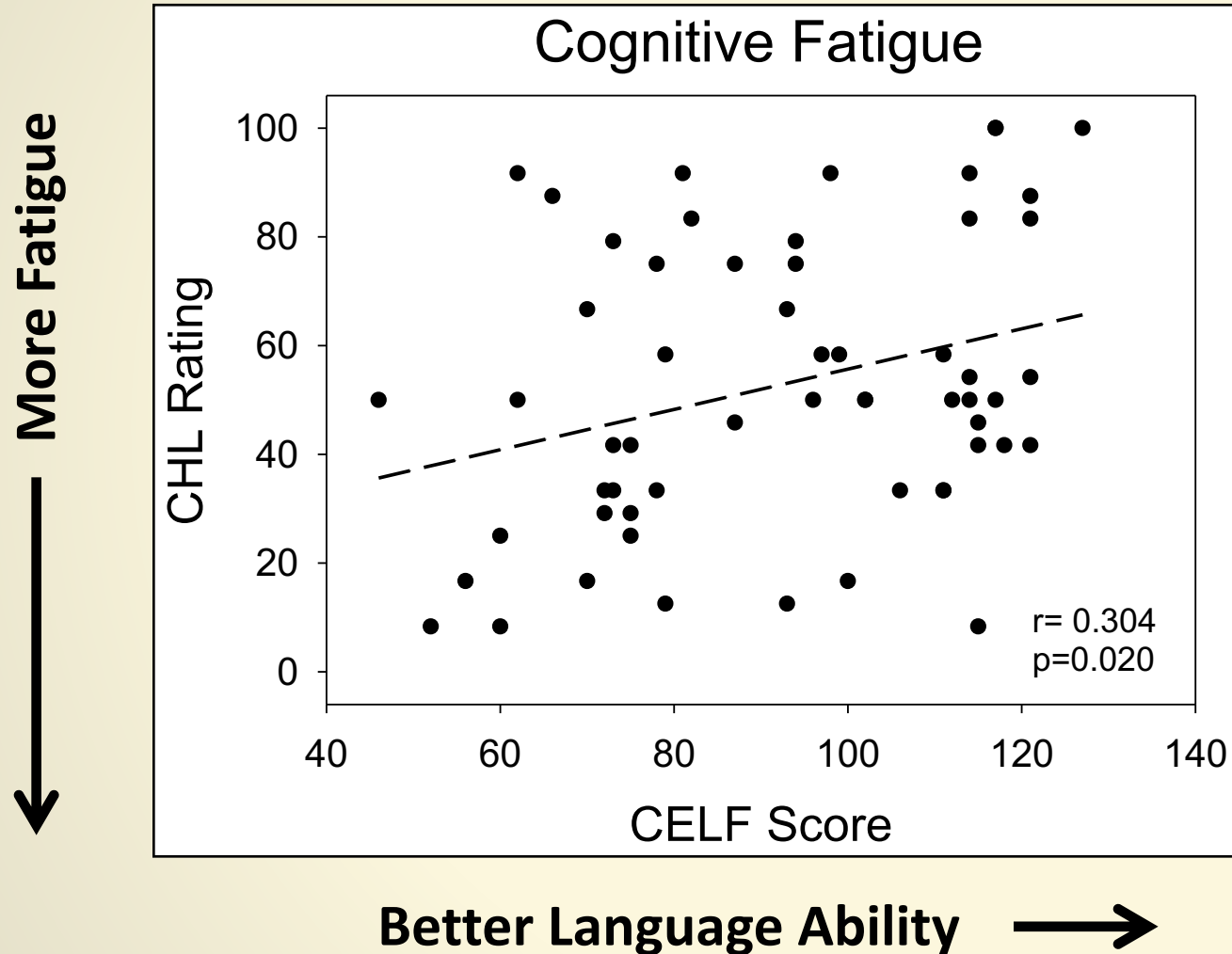
For children with no hearing loss, **younger children** were more likely to show reductions in cognitive processing due to speech-processing related fatigue ( $p < .05$ )

Neither language or nonverbal intelligence significantly related with cognitive processing changes following sustained speech processing.

# Take Home Points: CHL and Fatigue

- School-age children with mild-moderately severe HL
  - Report more fatigue, especially cognitive fatigue, compared to control groups
  - Their fatigue is comparable, or greater, than that reported by children with other chronic health conditions
- Higher fatigue ratings are
  - Are not modulated by degree of hearing loss
  - But are associated with poor language abilities (CELF scores), in both CHL and CNH
- Parent and child report, using a generic scale, provides distinct information

# Poorer Language Scores = More Fatigue?



- Similar, but weaker, correlations seen for
  - CELF and Overall fatigue ( $r=0.271$ ,  $p=0.04$ )
  - PPVT and Cognitive fatigue ( $r=0.270$ ,  $p=0.038$ )
- No other associations noted

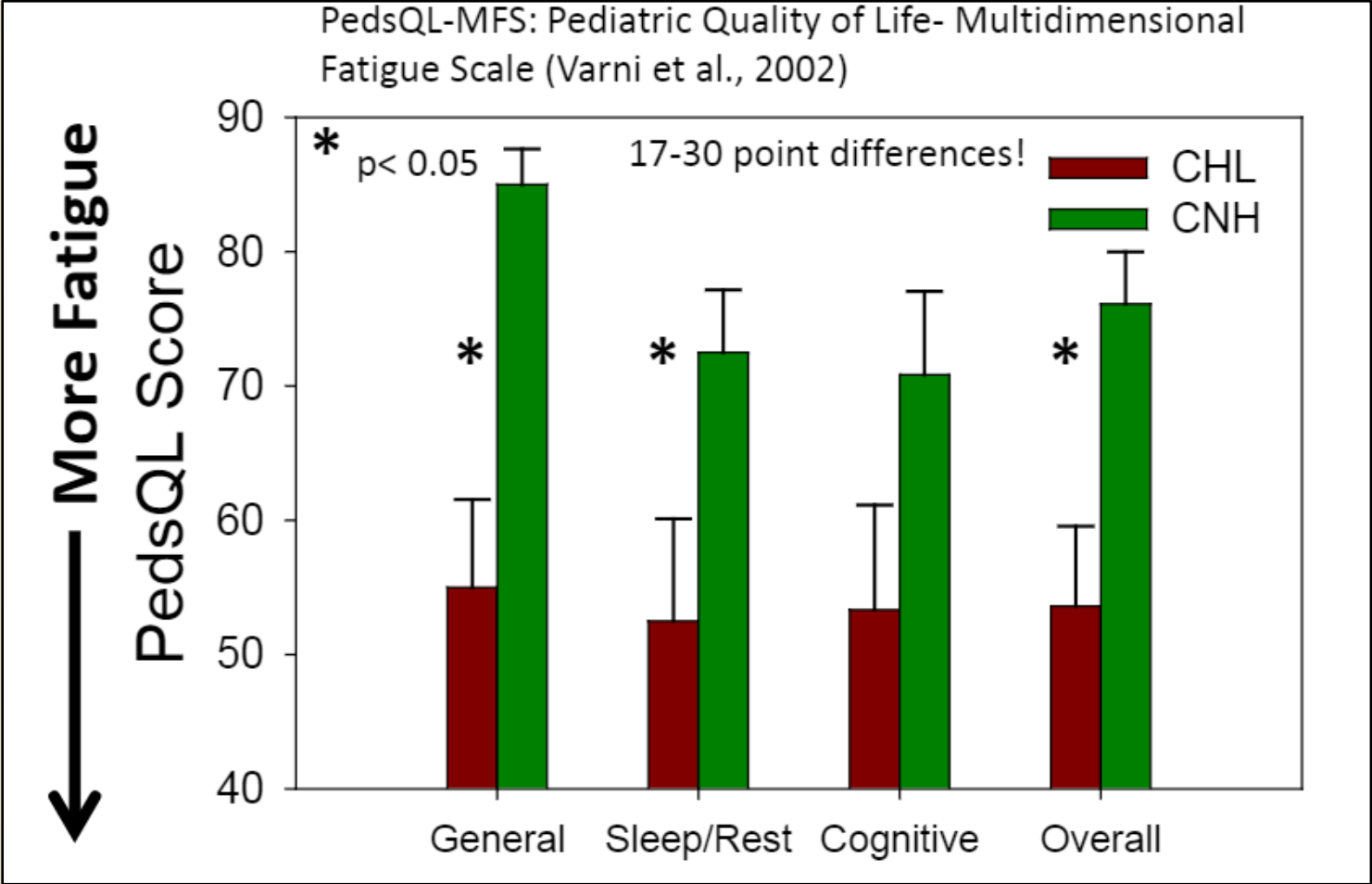
# Assessing Listening Effort: *Vocal Response Time*

- Moderately reverberant environment
  - average RT60 ~450 ms
- Multi-talker babble presented at 56 dB SPL from four loudspeakers around the listener
- Consonant- vowel- consonant words
- Three conditions, ranging from -4 to +12 dB SNR





# PedsQL Findings

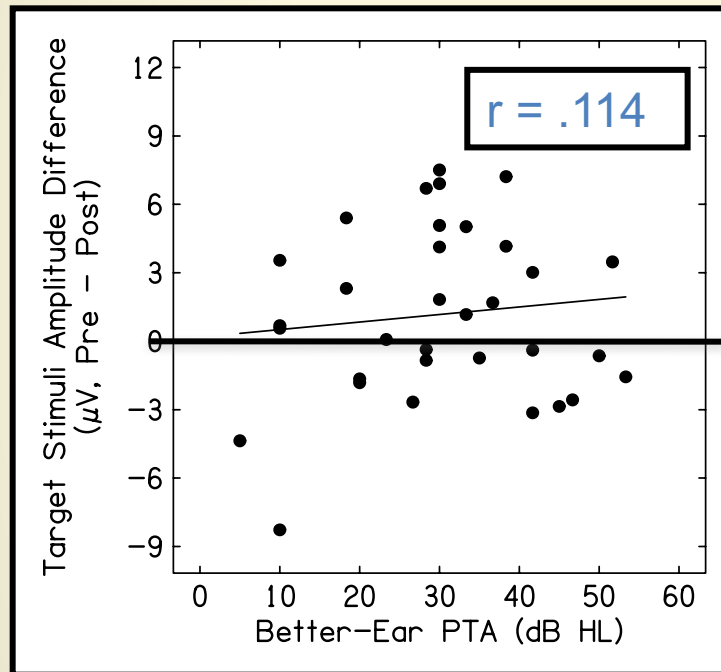


- CHL reported significantly more fatigue across domains

### Limitations:

- Small sample size (n=10)
- Wide range of hearing loss and amplification
  - 4 symmetric, mild to moderate SNHL with bilateral hearing aids
  - 2 asymmetric losses; unilateral hearing aids
  - 4 CI users with bilateral profound HL

# Who's at risk? CHL



*Reduced  
Cognitive  
Processing*

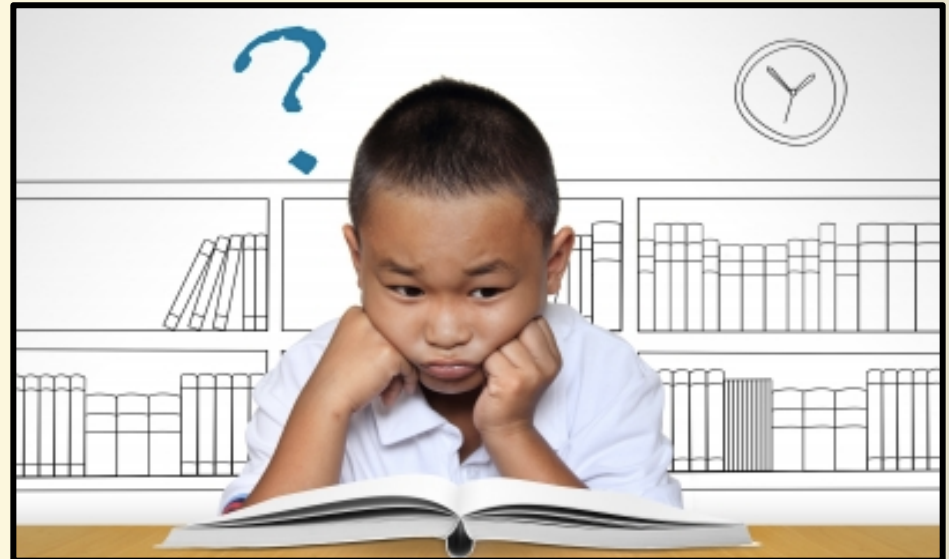


This lack of relationship with degree of hearing loss is consistent with subjective fatigue data and suggests that children with even mild hearing loss are at increased risk for fatigue.

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

# Factors Influencing Fatigue in CHL

- What factors may modulate fatigue in CHL?
  - Hearing loss?
  - Intelligence? (TONI)
  - Language levels? (CELF)
  - Receptive vocabulary levels? (PPVT)



# Listening and Learning Lab



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