Cardiac Measures of Autonomic Activity are Associated with ERP Measures of Selective Attention in Children & Adults
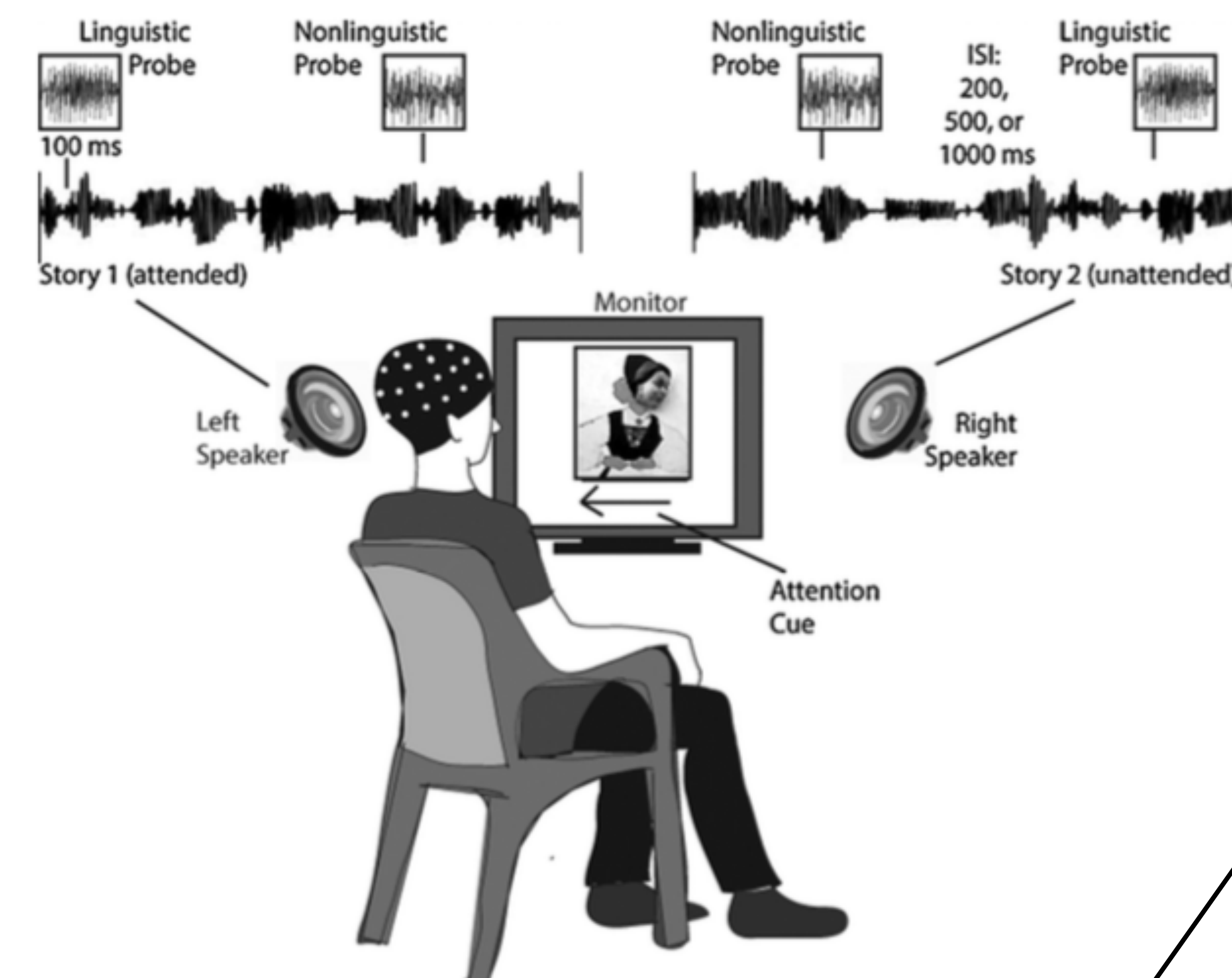
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Aim #1: Characterize PNS & SNS contributions to selective attention

- **Neurovisceral models suggest a link between neural & autonomic activity**
  - ✦ Greater levels of parasympathetic nervous system (PNS) activity associated with better self-regulation across lifespan[1]
  - ✦ High PNS tone associated with better cognitive performance due to more efficient PFC-subcortical function[2]
- **Neurovisceral studies largely ignore the role of the SNS, postulating a unique association between the PNS and neurocognitive processes**
- **Yet, few studies have examined how PNS & SNS interact with core neurocognitive mechanisms, such as selective attention**
  - ✦ A number of findings implicate higher-order brain function in sympathetic nervous system (SNS) activity[3,4]

Aim #2: Examine whether PNS/SNS activity mediates effects of adversity on attention

- **Children at higher risk for exposure to early adversity show deficits in ERP measures of selective attention[5,6]**
- **Early adversity associated with altered PNS and SNS function[7]**
- **Does exposure to adversity impact attention via altered PNS/SNS?**

Participants

Psychophysiological science stands to benefit from studies of more diverse populations, varieties of stress exposure[8].

Parent-child dyads were recruited through Head Start, as part of a larger study on parenting and child development.

Children, N=100	Adults, N=93
Mean age = 4.31 years (range 3.8-5.4) 50 male, 50 female	Mean age = 32.56 (range 22-67) Predominantly female (n=87)

Cardiovascular Physiology

High-Frequency Heart Rate Variability
- Index of Parasympathetic Nervous System
- Power in the .24-1.04 Hz band for children
- Power in the .15-.40 Hz band for adults

Pre-Ejection Period (PEP)
- Index of Sympathetic Nervous System
- Derivative of the cardiac impedance signal used to calculate time in milliseconds between left ventricular depolarization ("Q") and ventricular ejection ("B")

All physio data processed in 30-second epochs using Mindware HRV & IMP

Baseline Values: 5-minute neutral video while seated quietly; approximately 40 minutes after arrival at lab

Task Values: Calculated for each block of ERP task, and averaged across blocks
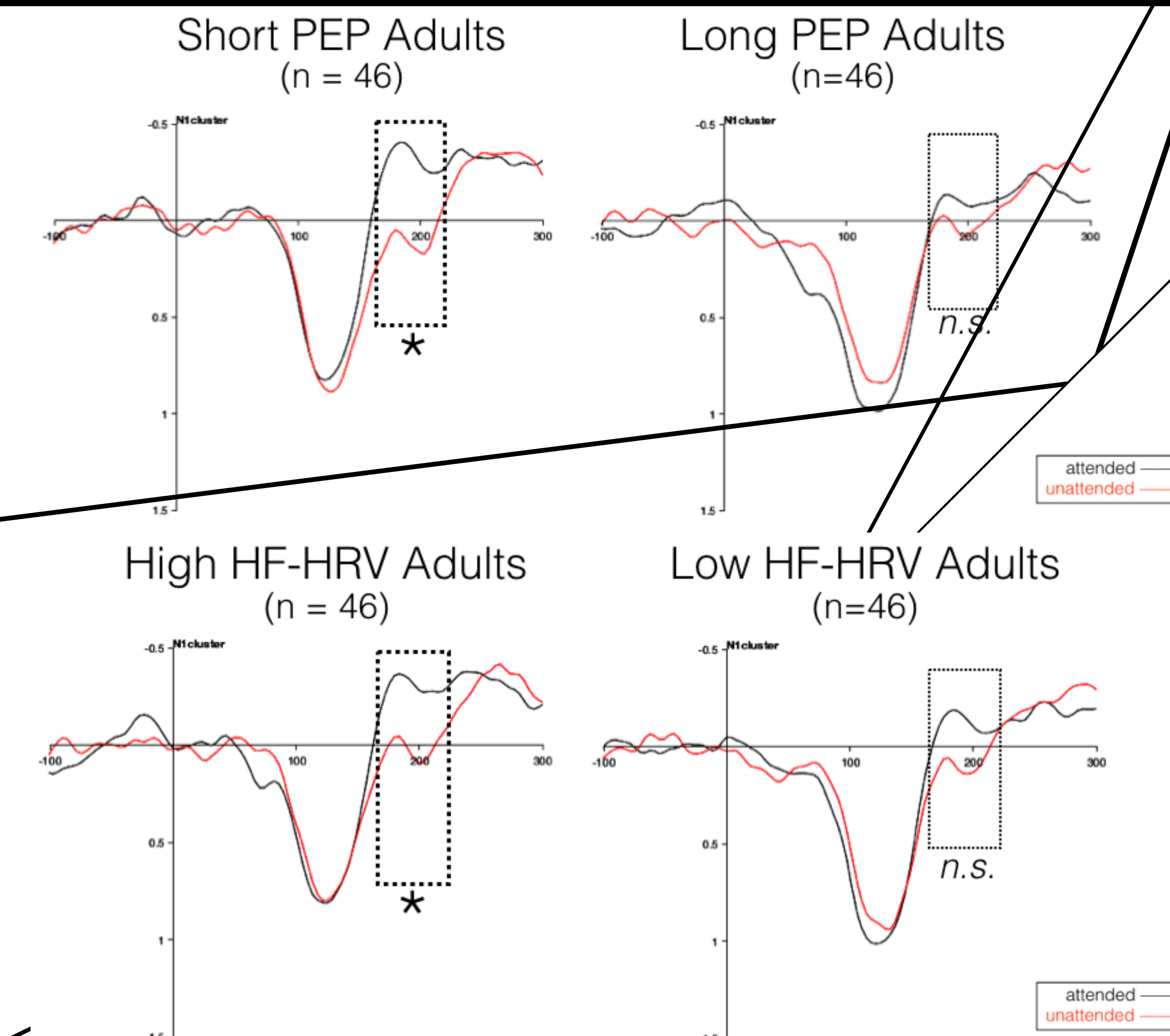
Selective Attention ERP Task

- Two stories are presented simultaneously in separate speakers, one read by a male narrator and the other by a female narrator
- Participants are instructed to listen to one of the narrators for a 3-4 minute story, accompanied by still images corresponding to the narrative flow of the story
- Narrator gender and side of attention counterbalanced across the four stories heard by each participant
- ERPs recorded to 100 ms sound probes superimposed on the to-be-attended and to-be-ignored narratives
- We have repeatedly shown this task to be a robust measure of selective attention from 3 year olds to adults[5,6,9,10,11,12]
- Larger modulation of ERPs by selection attention has been associated with greater WM capacity in adults and enhanced executive function in 3-5 year old children[9,12]
- Analyses focus on the difference between attended and unattended ERPs at early stages of processing (P1-N1)

EEG Methods

- **Kids:** 32-channel Active2 electrodes (BioSemi) sampled at 512 Hz
- **Adults:** 64-channel Active2 electrodes (BioSemi) sampled at 512 Hz
- Bandpass filtered from 0.1 to 40 Hz; Average mastoid reference
- Processed via custom EEGLAB/ERPLAB scripts
- Statistical analyses performed on mean amplitudes in time windows of interest
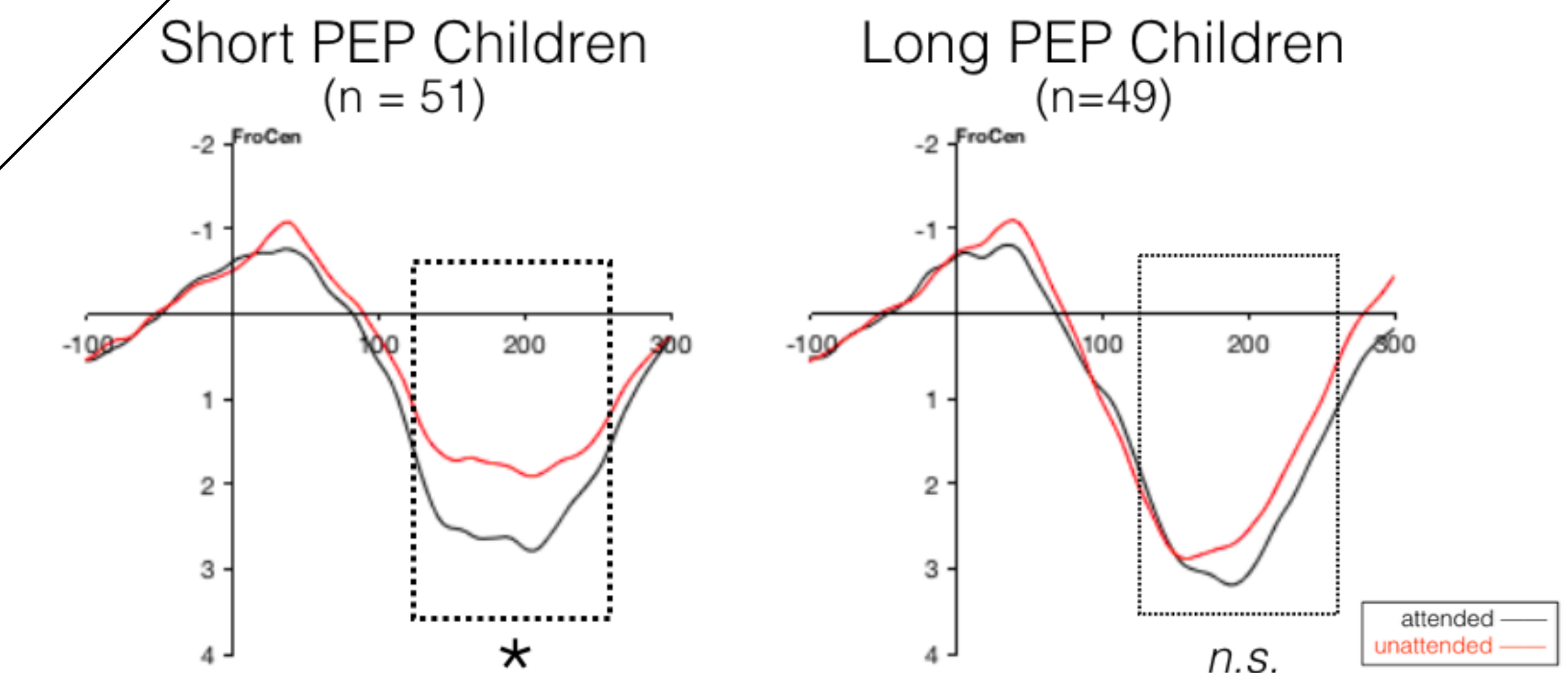
Adults (N=93)

ERPs shown are aggregated across clusters of electrodes demonstrating significant effects of selective attention: left anterior (5), medial anterior (4), medial central (6), left posterior (7), medial posterior (7).
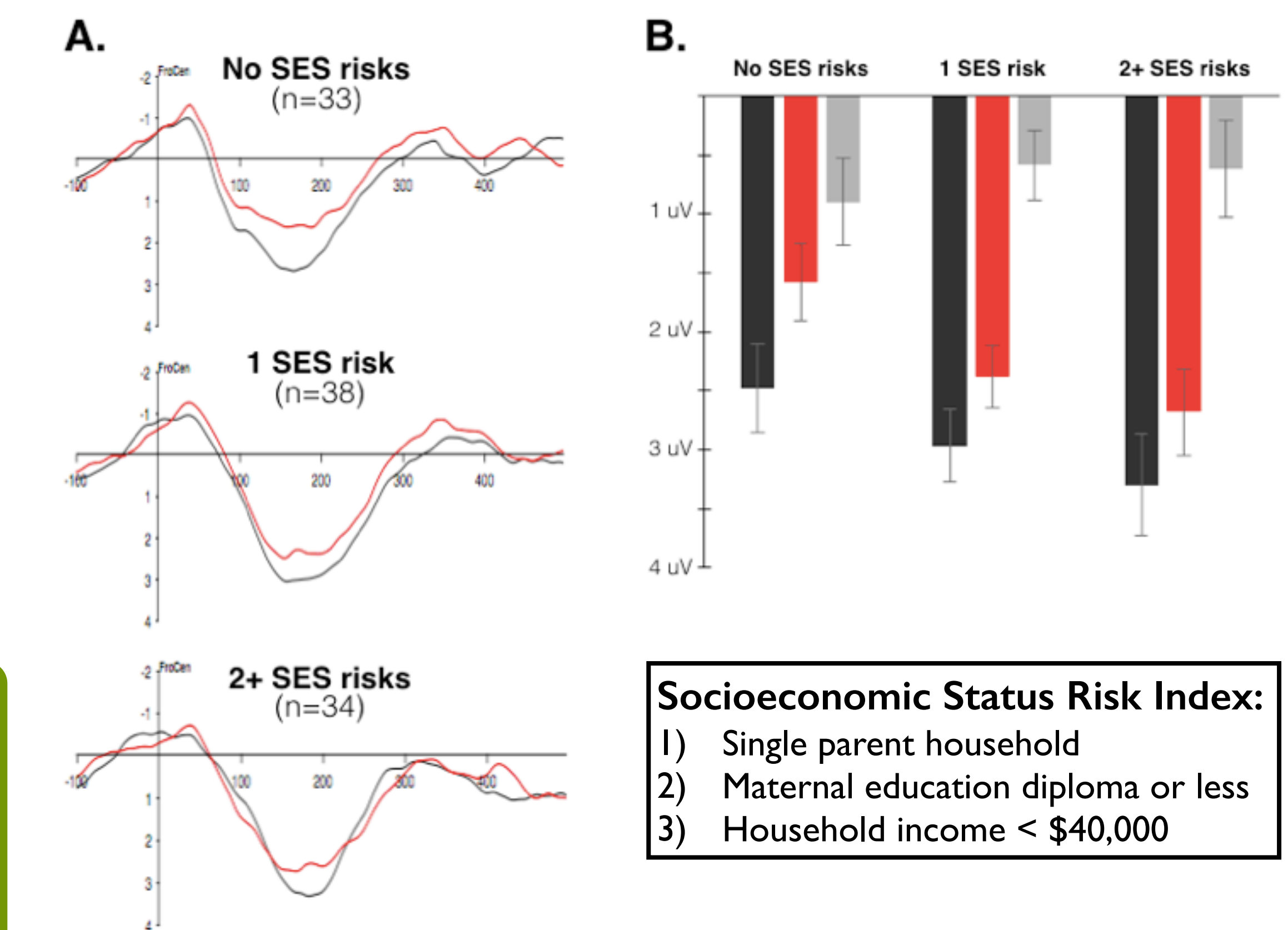

Short PEP Adults (n = 46) | Long PEP Adults (n=46) | High HF-HRV Adults (n = 46) | Low HF-HRV Adults (n=46)

Children (N=100)

ERPs shown are aggregated across eight frontocentral electrodes in the 32-channel montage: F3, F4, C3, C4, CP1, CP2, Fz, Cz.
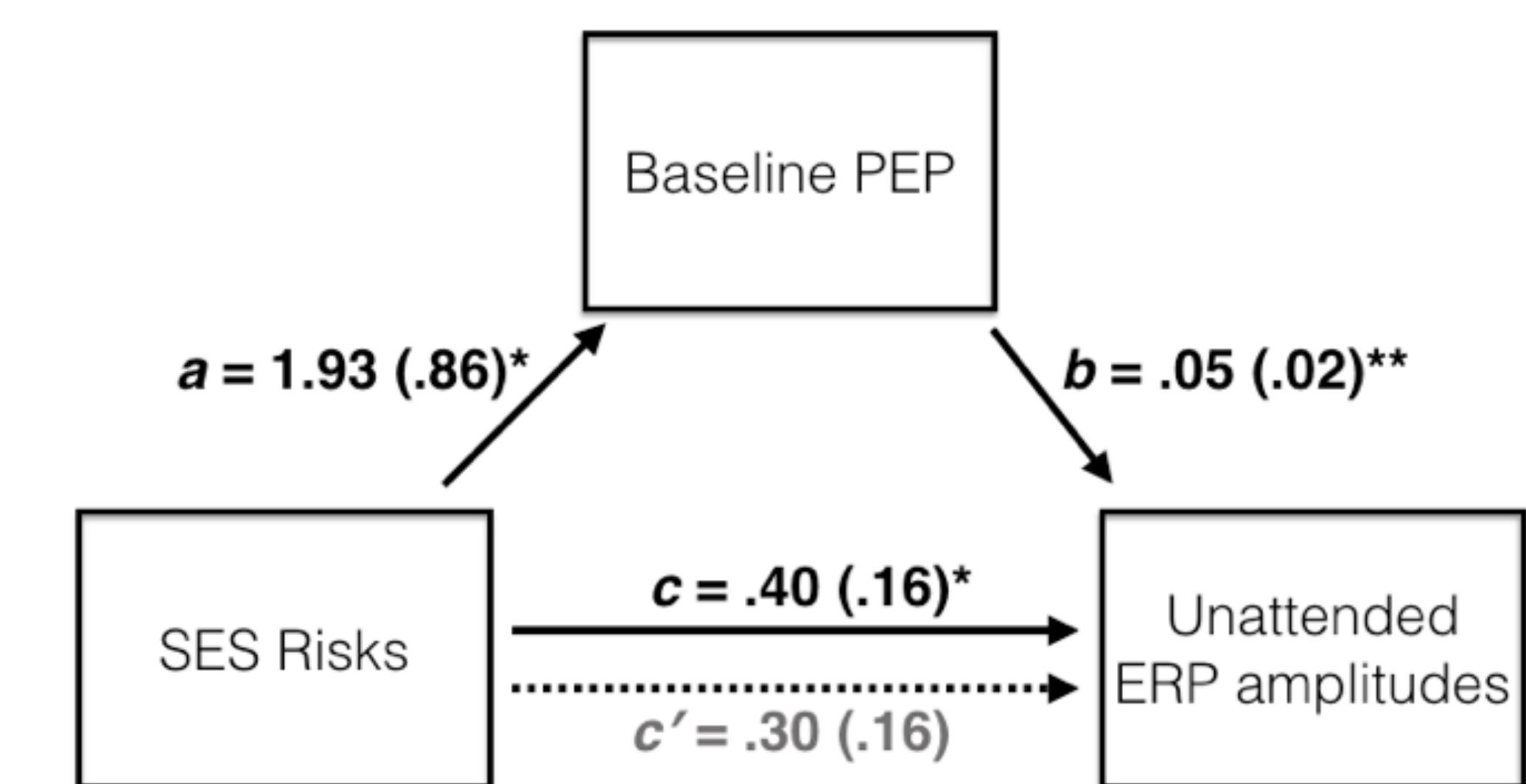

Short PEP Children (n = 51) | Long PEP Children (n=49)

Child ERPs impacted by risk exposure: increasing risk, larger distractor ERP

A. No SES risks (n=33) | 1 SES risk (n=38) | 2+ SES risks (n=34)

B. No SES risks | 1 SES risk | 2+ SES risks

Socioeconomic Status Risk Index:
1) Single parent household
2) Maternal education diploma or less
3) Household income < $40,000

Effect of risk exposure on distractor ERP mediated by PEP in children

$a = 1.93\ (.86)*$

$b = .05\ (.02)**$

$c = .40\ (.16)*$

$c' = .30\ (.16)$

Summary

- **Pre-ejection period, a central measure of SNS activity, is associated with neural mechanisms of selective attention in both children and adults**
  - **PEP has been proposed to index reward-related SNS activity associated with mesolimbic dopaminergic mechanisms[13] as opposed to threat-related SNS activity indexed by galvanic skin response[14]**
- **In adults, PNS and SNS measures contributed unique variance to neural mechanisms of selective attention**
  - **Suggests updates to the neurovisceral model's focus on PNS-brain interactions**
- **Pre-ejection period mediated effects of SES risk exposure on deficits in child selective attention**
  - **Autonomic activity may mediate the effects of the early environment on the neurocognitive development of attention**

References

1, Beauchaine & Thayer (2015). *Int J of Psychophys.* 2,Thayer et al. (2012). *Neuro Bio Beh Reviews.* 3, Beissner et al. (2013). *Neuroscience.* 4. Hugdahl (1996) *Curr Op Neurobio.* 5, Stevens et al. (2009). *Dev Sci.* 6, Neville et al. (2013). *PNAS.* 7, Propper & Holochwost (2013). *Dev Review.* 8, Gatzke-Kopp (2016). *Psychophysiology.* 9, Giuliano et al. (2014). *J of Cognitive Neurosci.* 10, Karns Isbell Giuliano et al. (2015). *DCN.* 11, Sanders et al. (2006). *Neuropsychologia.* 12, Isbell et al. (2015). *Dev Science.* 13, Brenner & Beauchaine (2011). *Psychophysiology.* 14, Dawson et al (2007). *Handbook.*