Heart Rate Variability During Cognitive, Language, and Metalinguistic Tasks in Typically Developing Children

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Introduction

- Heart Rate Variability (beat-to-beat variation - HRV) has been used in psychophysiological research as an indicator of cognitive effort and its relationship to performance (Christensen & Wright, 2014; Thayer & Lane, 2009).

- The ability to reduce HRV in response to attentive demands is often positively associated with cognitive function, including better processing speed, working memory, learning, and receptive language skill (Patriquin et al., 2013).

- Some evidence that higher HRV is associated with better receptive language ability in children with ASD (Watson et al., 2010).

- The aims of the current study were to better understand the relationships between HRV and performance on cognitive and language tasks in typically developing children.

- Better understanding of these relationships could inform clinical decisions and shed light on how children with developmental disabilities approach language and cognitive tasks.

Research Questions

1. Does mean HRV predict performance on language, cognitive, and/or metalinguistic tasks?

2. Is there a relationship between task performance and HRV in typically developing children?

Participant Characteristics

- Participants included 25, 4-8-year-old typically developing children with no reported developmental disabilities.

Participants			
	Mean	SD	min-max
Age	6.8	1.2	4.6-8.8
Nonverbal IQ[a]	99.79	19.27	58-134
CELF[b] Recalling Sentences	10.4	2.69	5-15
Sex (M:F)	10:15		
Income			
< $50k	1		
$50-$100k	18		
>$100k	5		

[a]Based on Kaufman Brief Intelligence Test-2 (KBIT-2) Matrices subtest; standard score, mean = 100 SD = 15; [b]Clinical Evaluation of Language Fundamentals (CELF-IV) Recalling Sentences scaled score, mean= 10, SD = 1.5

HRV Measurement Device

- Researchers used the Empatica E-4 wristband to collect HRV data.

- This device uses photoplethysmography (PPG) to measure continuous heart rate.

Method

- At the 2016 Minnesota State Fair, children completed the following assessments:
  - Matrices subtest of the Kaufman Brief Intelligence Test, 2nd Edition (KBIT-2, Kaufman & Kaufman, 2004)
  - Recalling Sentences subtest of the Clinical Evaluation of Language Fundamentals (CELF, Semel, E. M., Wiig, E. H., & Secord, W., 2006)
  - Metalinguistic awareness probe

- Metalinguistic probe (right) comprised tasks used by other researchers to evaluate vocabulary and morphology metalinguistic skills.

- Parents completed the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, G.A., Isquith, P.K., Guy, S., Kenworthy, L., (2000).

- Of the 200 children who participated, we were able to collect HRV data on 25, 4- to 8- year-old children with the Empatica E-4.

Task 1: Word Manipulation
- My friend and I are making up a new language. Could this be a gok? Yes it could. What is this?
- Can you eat a gok?
- Do goks have wheels?

Task 2: Word Swap
- Suppose that everyone in the world agreed that from now on we will call the sun the moon and the moon will be called the sun. All we are going to do is change the names.
- What would this be? (moon)
- What will the sky look like when you see this? (blue)

Task 3: Wug Task
- I am going to show you some pictures and say some sentences. Sometimes a word will be missing. I want you to tell me the missing word.
- This is a wug.
- Now there is another one. There are two of them. There are two _____.

Task 4: Grammatical Judgment
- Wobo is a creature from outerspace. Sometimes she says things the wrong way. Sometimes she says things that are silly. You need to tell her when she says a sentence the wrong way.
- Apples grow on noses.
- I have two pencil.

Results
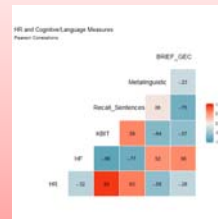
Pearson Correlations did not reveal significant relationships in the data between HRV and language or cognitive tasks.

- KBIT and HRV: $p = .71$
- CELF Recalling Sentences and HRV: $p = .43$
- BRIEF Global Executive Composite (GEC) and HRV: $p = .10$
- Metalinguistic Probe and HRV: $p = .51$
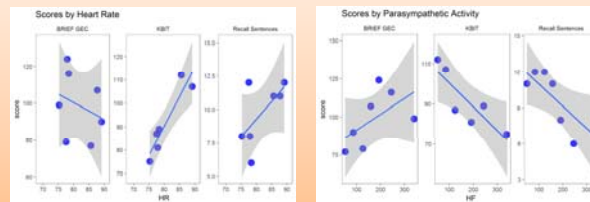
Trends emerged in our data with our standardized measures as follows:

- Higher KBIT and CELF Recalling Sentences scores were associated with faster heart rate and lower variability.
- For the BRIEF GEC score, the opposite trend was observed, with lower heart rate and higher HRV.

Example HR Plot and Spectogram
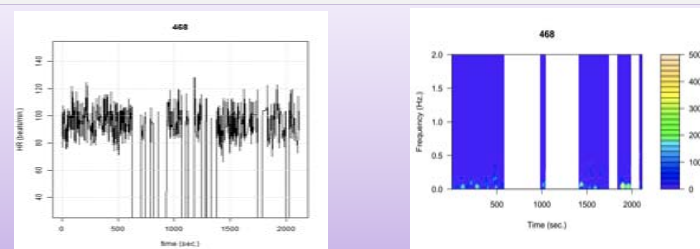
Limitations

- Results should be viewed with caution because on average, greater than 7% of raw data collected by the Empatica was removed to clean the data.

- The algorithm for cleaning the amount of time between heartbeats, or interbeat intervals (IBI), drops abhorrent beats due to motion artifacts and compresses the file. This results in significant time gaps (up to 17 seconds).

- For this reason, comparisons across tasks could not be made because the time stamps for each task did not line up with the data.

- Empatica E-4 wristband does not yield reliable HRV time-stamped data and is not an appropriate device for analyzing HRV in children during language or cognitive tasks.

Conclusions

- Based on the limited sample and data available, we did see trends toward positive relationships which motivates further study in this area.

- For the purposes of this study, a more reliable HRV collection device should be used to make valid psychophysiologic inferences.

- The Emaptica E-4 also collects electrodermal activity (EDA) via electrodes on the wrist. We are currently in the process of analyzing these files to see if it yields reliable psychophysiologic data.

Acknowledgments
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Key References
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