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# Interoception in the Determination of Reaction Times and Pulse Amplitude Sensitivity

*Oheneba Boateng*

Interoception is the awareness of changes of sensation within the body. Over the years, interoception has been analyzed in the context of the perception of visceral activity and its effects on emotional regulation. There is little to no knowledge of how the interoceptive ability of an individual affects physical parameters such as Reaction Time (RT). Measures such as the MAIA-2 have been used to rank an individual's interoceptive ability. The Multidimensional Assessment of Interoceptive Awareness (MAIA) is an 8-scale state-trait questionnaire with 37 items to measure multiple dimensions of interoception by self-report. Participants ($n = 29$, $\bar{x} = 21.4$ years) in the study first completed the MAIA-2 and a series of tests to extrapolate measures of RT [ms], Reaction Time Variability (RTV) [ms], and the minimum differentiable pulse amplitude (lower limen) [um] of two stimuli. RT and RTV scores were compared to subscales scores of Noticing, Self-regulation, and Body-Listening. Non-Distracting, Non-Worrying, and Attention Regulation were compared to lower limen scores. External cues for these measures were presented with the Brain Gauge from Cortical Metrics. No correlations were found between the RT, RTV, lower limen, and their respective MAIA-2 categories. Clusters of data are evident for certain categories (i.e. RTV), however, they may be influenced by the age composition of the sample. Though there are no conclusive results, further post-testing along with more variable samples could reveal connections between self-perception and interactions with the environment.

## Introduction

Interoception is the awareness of one's changes in bodily sensations [1-3]. It is a subjective evaluation of personal experience and the body's internal state, assessed by self-measure reports. Internal states involve feelings such as fullness of the bladder, nausea or hunger. This concept has been used as a means of assessing how an individual's understanding of their internal body state may be able to influence other aspects of their being. For example, scientists have looked into interoception as a measure that influences emotional regulation and visceral control [1].

Throughout the years, interoception has been analyzed in a number of ways over the years. These methods came as a result of theories relating the self-perception of visceral activity or interoception and emotional regulation. Overtime, scientists needed a quantitative measure that allowed subjects to be better distinguished based on their performance on interoceptive tasks. The Heartbeat detection task was a popular measure of interoceptive sensitivity. The task typically involved recording the heartbeat of a subject while the subject indicates the exact time of that heartbeat. Wiens et.al used this method in assessing how performance in the Heartbeat detection task is correlated to the experience of emotions. In the study, skin electrodes were used to record the heartbeats of subjects as they were tasked to listen to a tone and indicate whether the tone arrived after their heartbeats. The tones were played in fixed intervals of 200 or 500 ms after the R-waves [2]. The Heartbeat detection task has been implemented in these types of studies in a variety of ways prior to studies such as this. However, the methods of measuring skin conductance and having the subject indicate the timing of the heartbeat were inconsistent and yielded insignificant results [cite Wien].

A more recent method of quantifying interoceptive sensibility is the Multidimensional Assessment of Interoceptive Awareness (MAIA). The assessment is an 8-scale trait questionnaire with 32 items to measure the multiple dimensions of interoception by self-report. These are the following categories of the MAIA-2:

1. *Noticing*: Awareness of uncomfortable, comfortable, and neutral body sensations
2. *Not-Distracting*: Tendency not to ignore or distract oneself from sensations of pain or discomfort
3. *Not-Worrying*: Tendency not to worry or experience emotional distress with sensations of pain or discomfort
4. *Attention Regulation*: Ability to sustain and control attention to body sensations
5. *Emotional Awareness*: Awareness of the connection between body sensations and emotional states
6. *Self-Regulation*: Awareness of the connection between body sensations and emotional states
7. *Body Listening*: Active listening to the body for insight
8. *Trusting*: Experience of one’s body as safe and trustworthy

Each of the subscales are ranked from 1-5 and averaged throughout the questions within the category. The developers of the survey stress an important aspect of interoception that must be highlighted. Interoception is the process in which the nervous system interprets internal bodily sensations. Interoceptive sensitivity or accuracy is how well an individual can sense these changes based on their performance on tasks such as the Heartbeat detection tasks. The focus of the MAIA-2 is to quantify interoceptive awareness. Interoceptive awareness is “the conscious level of interoception with its multiple dimensions potentially accessible to self-report”. This distinction is very important as biases within self-reports are always evident [3].

Despite how self-reports may impact comparisons within a normal population, the results are significant within populations with neurological disorders. In a study comparing adults with Chronic Tic Disorder (CTD) and normal adults, the MAIA-2 Noticing and Not-Worrying scores differed significantly. Adjustments to scores were made based on the severity of tics and obsessive-compulsive symptoms. The results then showed that the subscales of Noticing, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trusting subscales were all significantly associated with premonitory urge, a symptom of CTD. Premonitory urge is the unpleasant sensation before a tic [4].

The authors of the study focused on this symptom despite how self-reporting can bias data sets. The premonitory urge was chosen due to its connection to a part of the brain closely linked to interception, the insular cortex. Narapareddy et. al highlights results from previous studies that found the thickness of the insular cortex to be closely linked to premonitory urge [4].

The insular cortex plays a role in sensory processing, decision-making, motor control, emotional and physiological regulation. Like most bodily processes, interoceptive feedback loops are integrated in the insula. Afferent signals from the body are received and combined with signals from the sensorimotor and frontal cortical regions [4,5]. Since the two are closely linked, studies wanted to explore how different substrates expressed by the brain are linked to feelings of anxiety. The Heartbeat detection task along with a series of questions were used to gauge levels and categories of interoceptive sensibility. The participants were then given different neural substrates that would indicate the processing of different bodily sensations. Results of these tests were used to investigate possible correlations between the neural substrates and different perceptions of feelings. They found that the engagement of the left anterior insula was negatively correlated with extraversion and positively correlated with openness to experience. The right cortex was positively correlated with neuroticism and negatively correlated with extraversion, agreeableness and openness to experience [6].

The knowledge base regarding the relationship between interoception and visceral control is growing rapidly. However, there is little known about how interoceptive ability relates to reflexes and tactile perception. The aim of this study is to explore the relationship between interoceptive awareness and external cues. Interoceptive awareness was quantified with the MAIA-2. External cues are simulated by the BrainGauge from Cortical Metrics. These cues were used to test each participant's average reaction time (RT), reaction time variability (RTV) and lower limen (minimum differentiable pulse amplitude) from two presented stimuli. This approach to the field of interoception may reveal advantages or disadvantages individuals may have based on their interoceptive ability. A narrower focus of how interoception affects our daily lives is a necessity to develop methods people can use to improve their interactions with the environment.

# Methods

Twenty-nine individuals (n = 29, 22 females, 7 males, mean age = 21.4) were classmates recruited for the study. The Brain Gauge devices and associated software were supplied to each individual.

## MAIA-2

Participants in the study were asked to complete the MAIA-2 and report their scores for each subsection. The scores were recorded for later data analysis.

## Reaction Time and Amplitude Discrimination

Data for the two parameters of focus were obtained from previous studies performed by other groups within the course. Both data sets presented the age and gender of the participants. RT data was given in milliseconds and amplitude in microns. The participants ran through a series of tests to react to a sudden stimulus for the RT and RTV experiments. For determining the lower limen, the participants were presented two different stimuli and told to choose which stimulus had a greater amplitude.

## Data Analysis

A correlational study between different subscales of the MAIA-2 and the two parameters were performed. Two subscales were excluded due to their irrelevance to either of the parameters of focus. The Trusting and Emotional Awareness categories did not fit into the scope of the measures.

The definitions for the Non-Distracting, Non-Worrying, and Attention Regulation subscales most closely conicided with amplitude discrimination. It was determined that the Noticing, Self-regulation, and Body-Listening were the closest subscales to that related to RT and RTV.

A correlational analysis was performed to find if there is a correlation between the Noticing, Self-regulation, and Body-Listening scores and RT and RTV. Amplitude discrimination was also analyzed in conjunction with its assigned subscales.

# Results

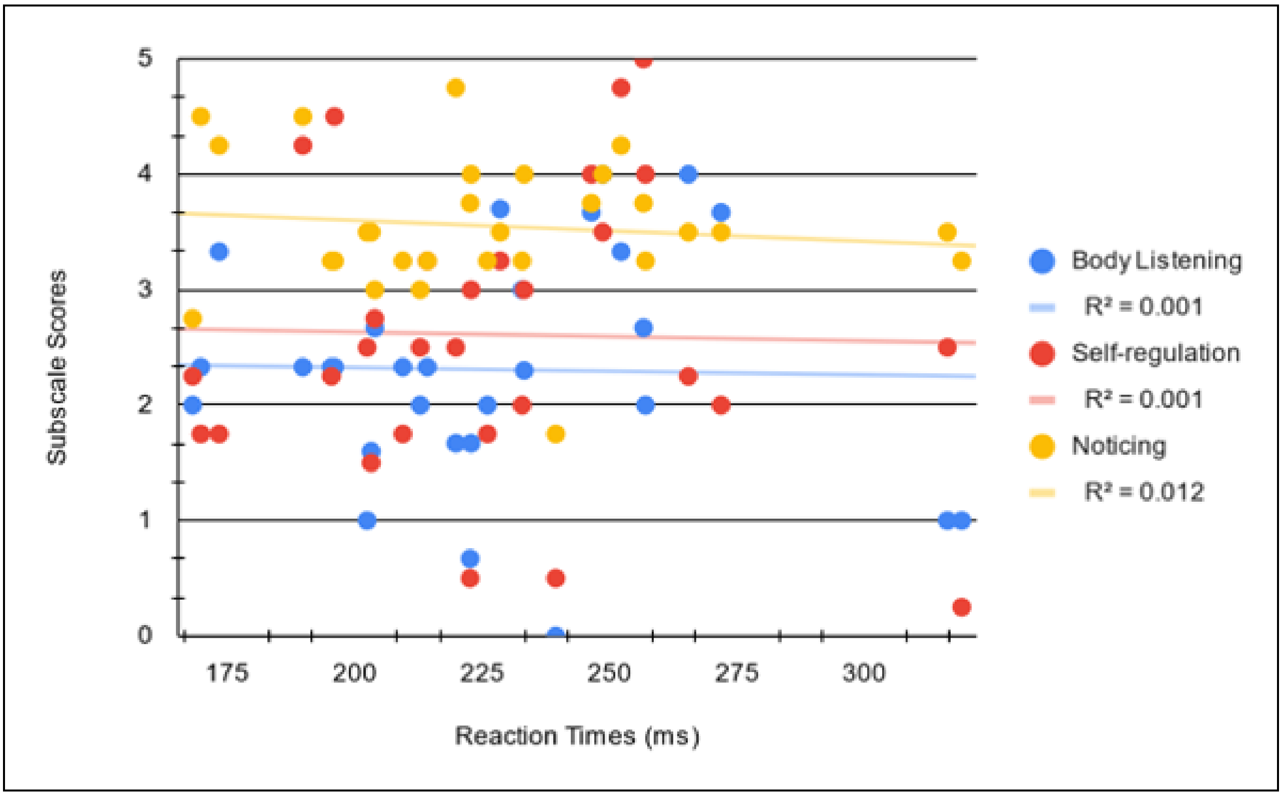


**Figure 1.** *Graph of Reaction Times [ms] vs. the Noticing, Self-regulation, and Body-Listening subscale scores with displayed $R^2$ values.*

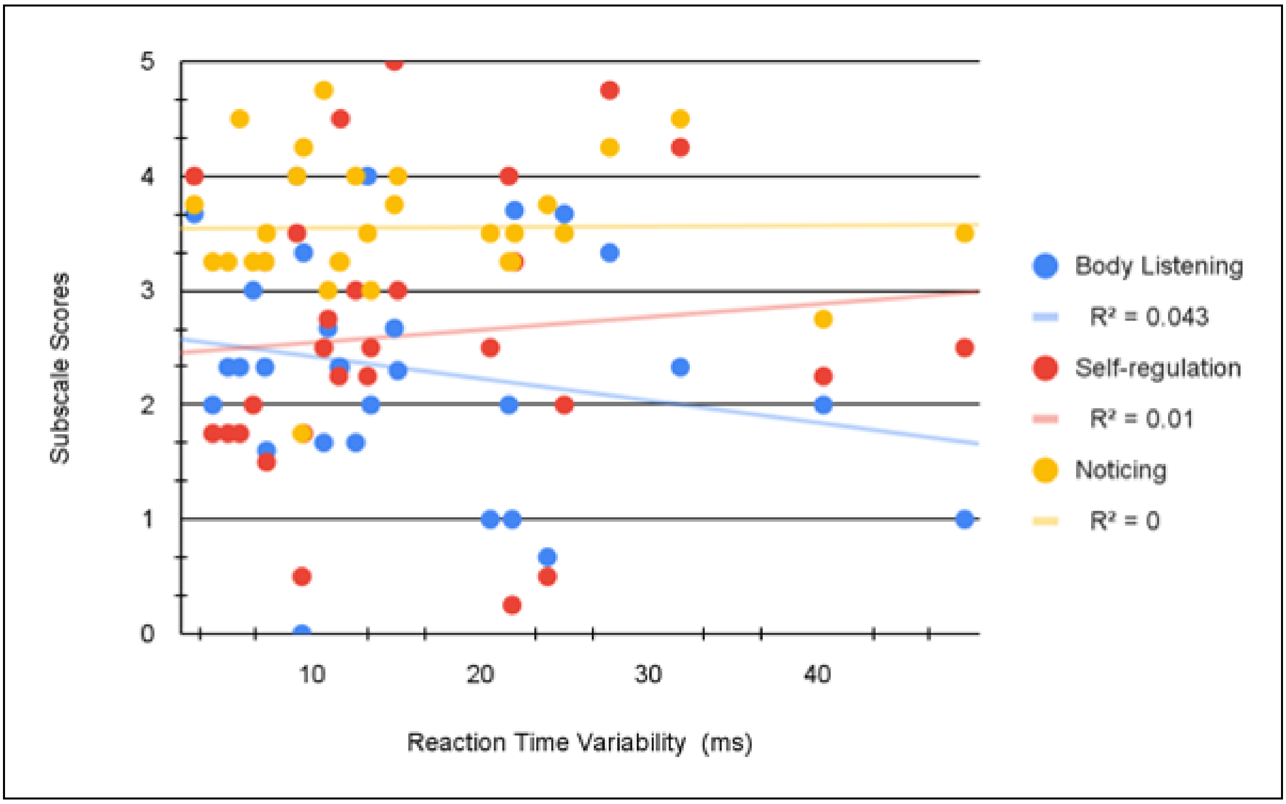


**Figure 2.** *Graph of Reaction Time Variability [ms] vs. the Noticing, Self-regulation, and Body-Listening subscale scores with displayed $R^2$ values. Noticing, Self-regulation, Body-Listening, and Reaction Time and Reaction Time Variability Non-Distracting, Non-Worrying, and Attention Regulation and Amplitude Discrimination*

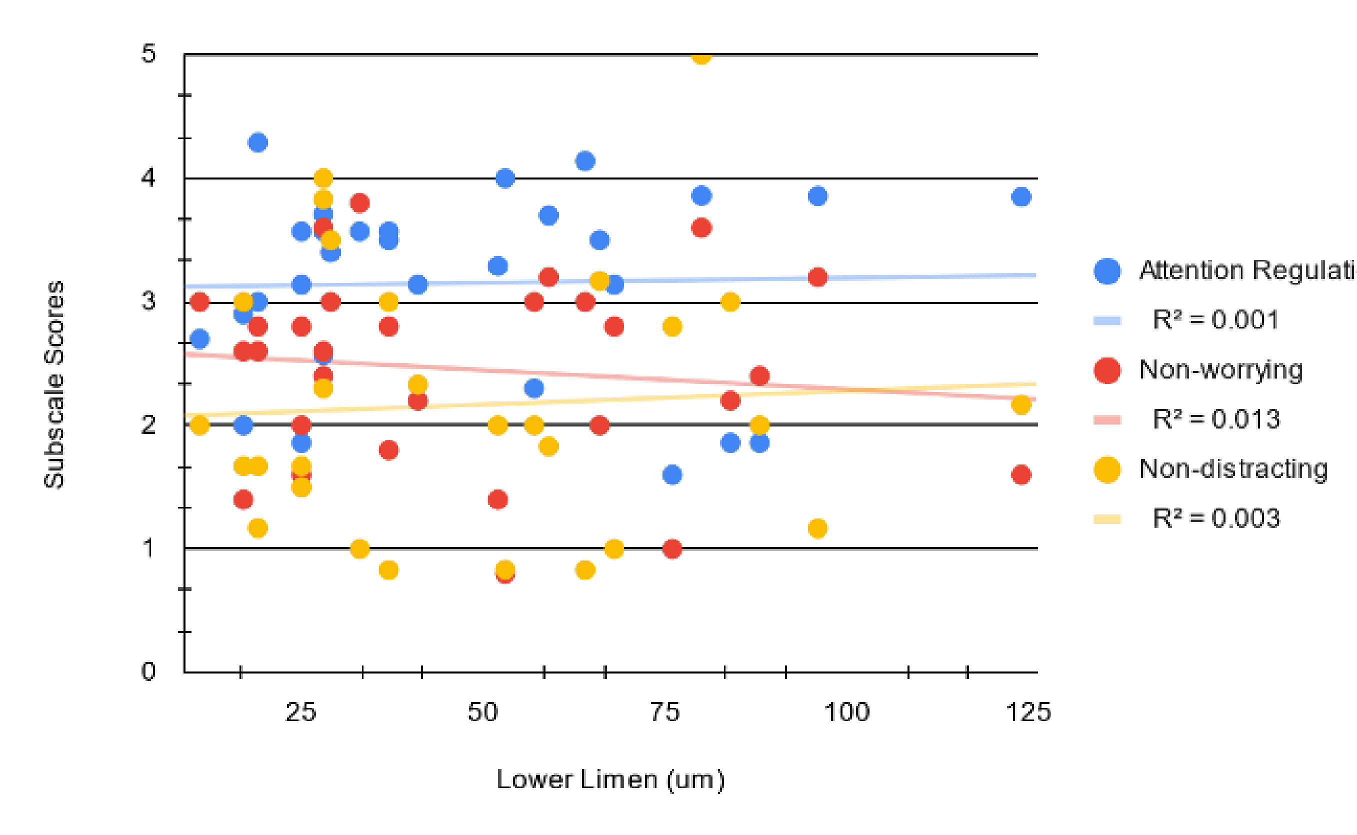


**Figure 3.** *Graph of Lower Limen for amplitude discrimination (um) vs. the Non-Distracting, Non-Worrying, and Attention Regulation subscale scores with displayed R2 values.*

# Conclusion

## Reaction Times

There were no correlations between the MAIA-2 subscale scores and RT. All measured parameters had R^2 values less than 0.05. Noticing scores were typically higher than 3 and Body Listening scores lower than 3. Scores for Self-Regulation displayed high variability with no clustering. Though there is no discernible reason for the clustering, the behavior may be impacted by the similarities in age of the participants. People in their early 20s may view their ability to notice bodily sensations as stronger than their ability to actively listen to their body for insight and feedback.

## Reaction Time Varability

There were no correlations between the MAIA-2 subscale scores and RTV. Though the $R^2$ values for each parameter were very low, the correlation between the Body Listening scores and RTV were slightly stronger than the correlation between the scores and RT. Despite clustering about lower reaction time variabilities (< 30 ms), the clustering of scores for Noticing and Body Listening remained consistent with those seen with RT.

## Amplitude Discrimination

There were no correlations found between the lower limen and the Non-Distracting, Non-Worrying, and Attention Regulation subscales. Clusters of data above 3 were evident for Attention Regulation as seen in Figure 2. Non-distracting and Non-worrying scores typically fell below a score of 3. Most lower limen measurements were below 90 um. The measurements may have been influenced by the limited age range of the participant pool as well as the familiarity they have with using the Brain Gauge.

## Limitations

With the biases self-reporting presents to assessing interoceptive awareness, the sample size at hand could not be considered a representative population. The age ranges of 21 to 22 years placed limits on what could be explored regarding differences in MAIA-2 across age groups. There was an outlier of 28 years old and their data could not be used to represent the scores of people around that age.

In addition to the limited range of scores, there was little variability in gender. The collected data could not be used for gender comparisons to obtain reliable results.

The MAIA-2 was implemented into this study as the only means to assess interoception, specifically interoceptive awareness. If other methods such Heartbeat detection tasks (assess interoceptive sensitivity) are coupled with the MAIA-2, the accuracy of ranking a participant's interoceptive ability will increase. Garfinkel et. al coupled these two methods to remove outliers as discussed before [6].

## Future Research and Impact

Though no definite conclusions can be drawn from the existing data and results, this pathway to exploring interoception could reveal connections between self-perception and interactions with the environment.

With further studies comparing tests from the Brain Gauge and interoceptive ability scores, the device and its software hold the potential to be a method of assessing and possibly quantifying interoceptive ability. The emotional awareness and trusting can be implemented in future studies.

Further analysis must be performed for each subscale. ANOVA and post-hoc testing could be performed on equal sample sizes within each subscale to explore differences in within-group and between-group subscale scores for RT, RTV, and lower limen.

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