

**EFFECTS OF PHYSICAL ACTIVITY ON THE ASSOCIATION BETWEEN
INTEROCEPTION AND ANXIETY IN FINNISH ADULTS**

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ABSTRACT

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Interoception is the ability to sense one's physical perturbations in the body. Interoception has gained relevance in psychological studies of emotion within the past decade, as the brain structures responsible for relaying interoceptive signals also share structures responsible for emotion-processing. Of note, a heightened sense of interoception has been linked with increased measures of anxiety, a common mental illness that may be of detriment to those of which it afflicts. Physical exercise has consistently shown to reduce anxiety and may serve as a therapeutic form of interoceptive exposure. Thus, identifying how physical exercise impacts the relationship between interoception and anxiety should be explored. This study investigated the differences that physical activity may have on the intensity levels of anxiety in participants with high levels of interoception. Participants (n=50; male=22, female= 28) completed an objective measure of interoception in the form of a heartbeat discrimination task, a self-report of hours of weekly physical activity, and a subjective measure of anxiety (Beck Anxiety Inventory). Independent t-test comparisons identified no significant statistical difference between anxiety levels of participants varying in physical activity level regardless of high levels of interoception accuracy. Relevance and implications of these finding to existing and future research are discussed.

Keywords: interoception, anxiety, physical activity, heartbeat detection task.

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1 INTRODUCTION

Our ability to regulate our behaviors in response to and in relation to our emotions is critical to our everyday life and function. Thus, our ability to *feel* “how we are doing” both emotionally and physically at any given time is important. According to the James-Lange theory of emotion (James-Lange, 1884), human emotion is derived from the sensations of change in our physiology after recognition of an evoked stimulus. For example, if you notice your heart beating faster and palms sweating before a large public speech you must give, you may then identify as feeling “anxious”. Similar to that of the James-Lange theory, The Somatic Marker Hypothesis proposed by Antonio Damasio (1994) suggests that our subjective feeling states, which drive decision making towards the maintenance of homeostasis, can only be articulated after changes in our bodily states occur and are registered by the brain. Recently, Damasio (2003) opines that optimal recognition of ones bodily states are pivotal in the expression of human emotions and decision-making and reflects that the neural basis of “the self” resides in the right insula of which interoceptive pathways, which carry homeostatic information of the body, also lead. As theories evolve and as evidence mounts, *interoception*, simply the sense of the physiological condition of the body (AD Craig, 2002), has been of increased interest to researchers across multiple disciplines and is theorized to play a crucial role in emotional awareness; and that the neural substrates responsible for subjective awareness of ones emotional feeling states are based on the neural representation of your body’s physiological state (Craig, 2016). An inclusive definition, interoception has been of critical relevance in recent studies of health and psychology (Cuenen, Vlaeyen, and Van Diest, 2016); including that of emotional processing and decision-making (Dunn, Galton et al., 2010; Paulus, 2007; 2011), affective disorders (Domschke, Stevens, Pfleiderer & Gerlach, 2010; Dunn, Galton et al., 2010, Paulus & Stein, 2006, 2010), and optimal athletic and exercise performance (Georgiou et al., 2015; Herbert & Pollatos, 2014; Paulus et al., 2010, 2012).

Interoception, detailed above, is simply the ability to sense one's internal-bodily state. Although there has been a steady surplus in interoception research, it should be noted that the methods in which interoception have been measured have been inconsistent (Medford & Critchley, 2014). However, a recent attempt has been made to delineate constructs of interoception (Garfinkel, Seth, Barrett, Suzuki, and Critchley, 2015). Garfinkel and colleagues aim to distinguish three constructs of interoception, including: interoceptive awareness, sensibility, and accuracy. Interoceptive awareness is the metacognitive appraisal of accuracy at sensing their bodily signals. That is to ask, "Do you know whether or not you are accurately or inaccurately detecting your bodily signals?". Interoceptive sensibility appraises how often one thinks they attend to their body and its signals. That is to ask "How often do you find yourself noticing your own heartbeat?". Both interoceptive awareness and interoceptive sensibility are measured by subjective questionnaires. Interoceptive accuracy, often used synonymously with sensitivity, is another construct of interoceptive awareness; however, interoceptive accuracy is distinctly defined by the objective empirical measure of a behavioral performance task, often by detecting and tracking internal bodily sensations. It is this, interoceptive accuracy, that has been judged as the foundation of which all other interoception measures are built (Garfinkel et al., 2015) and is measured, most notably, by heartbeat perception tasks (Brener & Kluitse, 1988; Critchley et al., 2004; Ludwick-Rosenthal & Neufeld, 1985; Schandry & Specht, 1981). Heartbeat perception tasks typically fall into two categories: 1) heartbeat *detection* tasks, where one is asked to perceive and silently count their own heartbeats during a set time frame ("heartbeat tracking": Schandry & Specht); and 2) heartbeat *discrimination* tasks, where one is asked to discriminate if their heartbeat is in sync with an external stimulus tone or not ("heartbeat discrimination": Whitehead et al., 1977).

Given interoceptive accuracy is often measured via cardiac perception tasks as previously described, it is important to consider how physical fitness and cardiovascular physical activity or exercise may influence one's cardiac perception. Indeed, some studies have shown that increased cardiac arousal via exercise results in increased cardiac perception and thus, interoceptive accuracy (Georgiou et al., 2015; Herbert, Ulbrich, and Schandry (2007)). The theory behind this assumption is because as one initiates cardiovascular arousal, brain structures and their resulting activation are connected with structures also responsible for interoceptive awareness; specifically, the

right thalamus, insula, and the medial/dorsal cingulate gyrus (Pollatos, Schandry, Auer, and Kaufmann, 2007). More simply, during physical exertion, it is not uncommon for one to experience the sensation of the heartbeat pounding, thus, improving one's ability to sense the heartbeat more definitely.

Although previously theorized that interoception and physical fitness were positively associated with one another based on studies that found normal Body Mass Index (BMI) to be advantageous in heartbeat detection tasks (Schandry, Bestler, & Montoya, 1993), these early studies used BMI as the general indicator of physical fitness, without testing physical performance. A more recent study by Herbert, Ulbrich, and Schandry (2007) aimed to broaden this understanding of physical fitness and interoception by investigating actual physical activity performance of thirty-four healthy, young-adults in relation to their interoceptive processes. Herbert and colleagues found that participants who were good heartbeat perceivers were better at regulating their physical effort during a cycling performance task in comparison to the poor heartbeat perceivers. Simply, these researchers concluded that those with more interoceptive accuracy were better at maintaining their physical output at an efficient, moderate, and steady rate versus those cyclists who had poor interoceptive accuracy. Although this study found that interoception was related to regulation of physical effort, it was not necessarily related to physical fitness (as measured by aerobic Physical Working Capacity, or a person's power outage, at 150 heartbeats per minute (PWC150)) and it should be noted that participants of this study were excluded if regular involvement in sports or endurance exercises was reported. Because the participants of this study were not typically physically active individuals, comparisons between physically-active and non physically-active participants cannot be made and thus provides an avenue in which to explore. An additional limitation of this study as presented by its authors, is that anxiety or other personality characteristics were not measured and could have been possible confounds; that it could potentially have been feelings of anxiety or fatigue, rather than interoception ability, which lead to the fine-tuned control over physical output.

In a similar study where children were its participants, Georgiou and colleagues (2015) investigated the association between interoception accuracy via a heartbeat detection task and physical activity via a physical performance task and daily physical activity monitoring. This study revealed a positive correlation between physical activity

performance and good heartbeat perception, while finding poor physical activity performance associated with poor heartbeat perception. In addition, twenty one children's daily physical activity was tracked with a multi sensor device, revealing that those who were good heartbeat perceivers also engaged in more light physical activity in comparison to the poor heartbeat perceivers. Taken these findings into consideration, the authors argue that interoception abilities constitutes a crucial role in physical activity engagement and performance. However, the aims of the Georgiou study specifically excluded participants in the adult population, thus replicating these findings in an adult population may prove fruitful in future research endeavors. In addition, and similar to the Herbert et al. (2007) study, Georgiou and colleagues did not propose or investigate subsequent effects of these interacting variables with respect to personality measures.

In addition to studies showing that physical activity is associated with an improvement in interoceptive accuracy, mounting evidence also exists which suggests those who are anxiety sensitive or have anxiety-related disorders also report superior cardiac perception and interoception accuracy (Ehlers & Breuer, 1992, 1996; Zoellner & Craske, 1999). For example, Ehlers & Breuer performed three studies investigating cardiac perception in various anxiety disorders across both subjective and objective measures. In their first study, patients diagnosed with panic disorders and other forms of anxiety disorders reported greater subjective cardiac awareness compared to controls. In their second and third study, the heartbeat tracking method was used as an objective measure of cardiac perception and revealed that those with panic disorders and generalized anxiety disorders had better interoceptive accuracy. This finding held consistent when compared to both a control group and to a patient group presenting with depression symptoms. It should be noted that the superior heartbeat trackers were those patients diagnosed with clinical panic disorder, but nevertheless, findings also revealed a relationship with other anxiety-like disorders and interoceptive accuracy.

It is well-established that physical activity and exercise is important to human health and well-being, with the American Heart Association recommending thirty minutes of moderate to high intensity physical activity, five days a week (Haskell et al., 2007). In general, regular exercise has been suggested to act as a protective agent against mental illness and to maintain mental health (Raglin, 1990), and has been considered to be an alternative method to treat various mental disorders (Strathopoulou, Powers, Berry,

Smits, and Otto, 2006). Anxiety disorders are quite prevalent, with an estimated lifetime occurrence of nearly 29% (Kessler et al., 2005), but it is well-established that exercise, both habitual and acute exercise, attenuates symptoms of anxiety (Anderson & Shivakumar, 2015; DeBoer, Powers, Utschig, Otto, and Smits, 2012). Because the modes as to how exercise produces anxiolytic effects has not yet firmly been established, recent efforts have focused on identifying any interacting variables (DeBoer et al.) responsible for any change. One theory suggests that physical exercise in itself may result in bodily perturbations which mimic that of anxiety related symptoms (i.e.: sweating, quickened heartbeat), and as such, physical exercise may constitute as a type of interoceptive exposure where exercise induced bodily sensations allow an individual to discover that the sensations are not catastrophic (Asmundson et al., 2013).

Although interoception accuracy has been correlated with an improved ability to sense ones own and others' emotional states (Dunn, Evans, Makarova, White, and Clark, 2012), it is important to note that there remains a spectrum of emotions, some of which may prove maladaptive to well-being under some circumstances. As mentioned, studies on both clinical and non-clinical populations have found that a heightened sense of interoception correlates with increased anxiety-like symptoms and anxiety related disorders (Domschke, Stevens, Pfleiderer & Gerlach, 2010; Dunn et al., 2010; Paulus & Stein, 2006, 2010). Interesting, however, are the studies that show that an increased interoceptive ability is associated with an increase in physical fitness (Borg & Linderholm, 1967; Montgomery, Jones, and Hollandsworth, 1984; Herbert & Pollatos, 2014) and better regulated physical performance in exertion tasks (Georgiou et al., 2015; Herbert et al., 2007). Given that it is well established that physical activity generally attenuates anxiety symptoms (Barhke & Morgan, 1978; Hale & Raglin, 2002; Hale, Koch & Raglin, 2002; Knapen et al., 2009; Asmundson et al., 2013) it is of interest to explore the nuanced roles that interoception, physical activity, and anxiety may have with each other in order to better understand potential moderators of anxiety.

Taken together, the studies presented above have suggested that interoceptive accuracy is related to both physical activity, as well as symptoms of anxiety. What remains to be investigated is the way in which physical activity may change the relationship between those presenting with high interoceptive accuracy and anxiety symptoms in a non-clinical, healthy, adult population.

2 PURPOSE OF THE STUDY

The purpose of this study was to investigate how interoception and physical activity, together, may influence measures of anxiety in a healthy, adult population. Based on current literature, it was hypothesized that individuals' level of physical activity would moderate the relationship between accuracy perceiving a heartbeat task and reported anxiety symptoms. In particular, accurate heartbeat perceivers involved in high levels of physical activity were expected to report fewer symptoms of anxiety (hypothesis 1). In contrast, accurate heartbeat perceivers who are not physically active were expected to indicate greater symptoms of anxiety (hypothesis 2).

3 METHODS

3.1 Participants

A convenience sample of fifty Finnish participants (22 male, 28 female) were initially included in this study; where a total of thirty-five participants qualified for data analysis based on their level of interoceptive sensitivity. Participant ages ranged from ages 18-35 ($M = 24.32$; $SD = 4.16$). Initial inclusion criteria for participating in this study were: (1) being between the ages of 18 and 35, (2) ability to understand the Finnish language, (3) being right-handed, and (4) having no metal in the body. Some participants ($n=12$) included in this study were recruited specifically for their engagement in competitive sport; these participants were included in the physically active group of participants.

3.2 Apparatus and Materials

Heartbeat Discrimination Task

The heartbeat discrimination task is a measure of interoception accuracy initially developed by Whitehead, Drescher, Heiman, and Blackwell (1977), with subsequent deviations known as a method of constant stimuli (MCS). MCS tasks asks participants to identify their own heartbeat in relation to an external stimulus tone, which occurs at time delays following the onset of myocardial contraction, or the R-wave of the electrocardiogram. According to Katkin and colleagues (1981), the discrimination task is a valid measure of an individual subject's heartbeat discrimination because it is unaffected by a subject's respiratory or muscular perturbations and is a commonly used in studies of interoception.

Anxiety

Beck Anxiety Inventory (BAI; Beck, Epstein, Brown and Steer, 1988) is a short list describing 21 anxiety symptoms such as feeling "terrified" or "afraid of dying". Respondents are asked to rate how much each of these symptoms bothered them in the past week, on a 3-point Likert scale ranging from 0 (not at all) to 3 (severely). The total range for the scale goes from 0 to a maximum of 63. Totaled scores falling within the range of 0 and 21 are considered "low anxiety", while scores between 22 and 35 are considered "moderate anxiety", and scores exceeding 36 are considered "extreme anxiety". The scale has been validated in a sample of 160 psychiatric outpatients with

various anxiety and depressive disorders, diagnosed with the Structured Clinical Interview for DSM-III (APA, 1987). High internal consistency alphas (Cronbach's $\alpha = .94$) have been previously reported (Beck et al., 1988).

Physical Activity Measures

Participants were instructed to report their average quality and intensity of weekly physical activity. Specifically, an open ended question asked “How many times per week do you engage in at least 30 minutes of light physical activity” and “How many times per week do you engage in at least 30 minutes of heavy physical activity”. This measure was recorded once during intake.

3.3 Procedure

This study was part of a larger collaboration project between Center for Interdisciplinary Brain Research, the Department of Psychology and the Faculty of Sports and Health Sciences at the University of Jyväskylä beginning in the Fall of 2015. The project aimed to investigate the neural substrates of interoception in association with subjective measures of physical activity and various personality measures. A convenience sample was recruited primarily via email blasts to all students at the University of Jyväskylä, as well as some recruitment posts at local gyms. Participants were greeted and briefed on the aims of the study upon arrival to the lab. Participants were screened once again via verbal confirmation that they did not have metallic clothing or material, which may have produced artifacts during neural data acquisition. If artifacts resulted in clothing, a participant was allowed to change in lab-provided clothing. Participants were again provided directions on how to complete the experimental tasks required for that of the MEG related tasks and the interoception task immediately prior to data acquisition and task completion. Directions, as well as question clarification was all conducted in Finnish. Due to the MEG study being outside of the realm of the immediate study, detailed disclosure on subject preparation with MEG, EOG, and EKG electrodes for neural data acquisition will not be explained. Participants' neural magnetism was recorded via an Triux System Elekta-Neuromag MEG apparatus within a magnetically shielded room (MSR) at the Center for Interdisciplinary Brain Research in Jyväskylä. The heartbeat discrimination task performed was designed similar to Whitehead et al., (1977) where an individual's

heartbeat created a tonal stimulus randomly generated to either be in sync with one's heartbeat or at a delay. Two blocks of twelve heartbeat discrimination tasks were completed, resulting in a total of twenty-four completed trials where a participant was asked if their heartbeat was in sync with a tone, or not. Twelve of the twenty-four trials were randomly assigned de-synchronous tones, which deviated by a delay of 40% of the time between two earlier heartbeats. After each trial, a projection screen within the MSR prompted participants to answer "yes" or "no" to whether or not the tone was "synchronous" with their heartbeat via electronic touchpad. An average, total task completion took thirty minutes, while entire experiment beyond the interoception task took one hour and thirty minutes. Upon completing the heartbeat discrimination task, participants were removed from the MSR and were assisted in removing MEG, EOG, and EKG electrodes. Upon removal, participants were allowed to change back into their clothing and were provided a quiet office space in which to complete subjective questionnaires. Upon leaving the lab, participants were given a movie ticket in exchange for their participation in the study. Neuromag's Data Acquisition software was used to record the participant heartbeat, stimulus channels, and participant responses on the interoception task while in the MEG machine.

3.4 Data analysis

MaxFilter 2.0 was used to filter response data while a Python script was used to extract a subject's response of synchronicity for the heartbeat discrimination task. A median-split score of correct responses ($Mdn=11$) was used as a cut-off point to distinguish between "Poor" interoception and "Good" interoception accuracy, where "Poor" <11 correct answers; "Good" >11 correct responses. Those participants who had "Good" accuracy were used for subsequent data analysis based on their level of physical activity. "High"/"Low" levels of physical activity were assigned, where three hours of intense physical activity per week qualified as being "high physical activity", and those with less than three hours qualified as being "low physical activity" based on the American Heart Association recommendation of 2 and a half hours of moderate to high intensity physical activity to be performed each week (Haskell et al., 2007).

Descriptive statistics and tests of normality were computed by SPSS across relevant variables and revealed a non-normal distribution. Missing values, as well as outliers,

were explored. A nonparametric t-test was used to compare the two groups of accurate heartbeat perceivers and their anxiety based on their level of physical activity.

4 RESULTS

Interoception Accuracy Assessed by Heartbeat Discrimination Task

Fifty participants successfully completed the heartbeat discrimination task (see Table 1). Thirty-five participants qualified as having high interoception accuracy, where their number of correct responses during their heartbeat detection task was equal to or greater than the median-split of 11 correct detections, suggesting good heartbeat detection and having a high level of interoception ability.

Table 1. Descriptive statistics of the study variables

Study variables	<i>N</i>	<i>Min</i>	<i>Max</i>	<i>M</i>	<i>SD</i>
Interoception (correct HBD responses)					
Good HBD	35	11	22	14.37	3.32
Poor HBD	15	1	10	7.8	2.27
Physical Activity (hrs/week)					
Low PA (3 or less hrs/wk)	19	0	3	1.37	1.05
High PA (3 or more hrs/wk)	31	3.5	19	7.02	2.99
Anxiety					
Low anxiety (score 0-21)	50	0	21	6.08	5.19
Mod anxiety (score 22-35)	0	0	0	0	0
High anxiety (score 35+)	0	0	0	0	0

Note. HBD = heart rate discrimination task; PA = physical activity; BAI = anxiety scores

High Interoception Accuracy and Physical Activity Level

Of the thirty-five participants who were good heartbeat detectors, thirteen of them reported three hours or less of physical activity per week ($M= 1.65$, $SD=1.07$, $Min=0$, $Max=3$) qualifying as being low in physical activity. Twenty-two good heartbeat perceivers reported more than three hours of physical activity per week ($M=6.72$, $SD=2.09$, $Min=3.5$, $Max=10$) which qualified them as being high in physical activity.

High Interoception Accuracy, Physical Activity, and Anxiety

All thirty-five participants' anxiety scores were compared based on their level of physical activity, high or low (see Table 2). Anxiety scores for both, high physical activity and low physical activity groups fell within the "low anxiety" range. A one tailed-T test was conducted to test whether the mean BAI score of the low physical activity group is significantly higher than that of the high physical activity group, as hypothesized. No significant differences between groups on anxiety measurements were observed $t(13)= 1.67$, $p=.10$; 95% CI (-0.69, 7.03).

Table 2. Anxiety scores and amount of physical activity

	Anxiety scores				
	<i>N</i>	<i>Min</i>	<i>Max</i>	<i>M</i>	<i>SD</i>
High Physical Activity	22	0	19	8.31	6.71
Low Physical Activity	13	0	21	5.14	4.52

5 DISCUSSION

The aim of this study was, for the first time, to explore how the combination of interoceptive accuracy and physical activity may influence subjective measures of anxiety in a healthy, adult population. The results of this study reveal no significant difference between reported levels of subjective anxiety in a healthy, adult population, dependent on levels of physical activity in participants with high levels of interoceptive accuracy. In other words, high levels of interoception paired with low exercise did not result in a greater reports of anxiety symptoms compared to those individuals with high levels of interoception but reported high levels of physical activity. This finding is contrary to previous research that suggests high interoception skill is related to high levels of anxiety (Ehlers & Breuer, 1992; 1996; Zoellner & Craske, 1999).

LIMITATIONS

There were many limitations to this study, including, but not limited to experimental design and methodology, of which must be addressed in order to criticize the study's validity.

First, the author of this study had many limitations including access, longitudinal effects, cultural and language biases. Regarding access, the author was not the only collaborator behind this study and relied on many individuals within the Center of Interdisciplinary Brain Research. The author was not able to access participants face-to-face and explain research materials and procedures. Had full control been provided, additional measures would have been taken to ensure validity, including additional subjective measures of anxiety, and careful recruitment of participants. However, due to the language barrier (participants and materials were used in Finnish; while this author solely is reliant on the English language), this author was unable to participate in much of the recruitment, and explanation of tasks and procedures to its participants. It is possible that human error had occurred, and that some data had been skewed due to misunderstandings of the heartbeat detection task, or confusion regarding the subjective questions asked during initial intake.

Second, methodological limitations included deficiencies in sample size, lack of prior research studies on the topic, and the measures used to collect the data, including the

use of self-reported data. Although there were an initial fifty participants that completed the heartbeat detection task, only thirty-five participants were identified as having high interoception based on a median-split dichotomization. Had there been time and access to more participants, it could be that a stronger relationship could have been identified. However, because of the use of the MEG machine during the heartbeat detection task, it was not always possible to schedule participants to complete the task. Additionally, some participants were rejected from this research due to requirements of performing the task within the MEG machine (ie: being left handed or having braces in the mouth). Although there was a foundation laid in which was used to understand the research problem being asked, this study was strictly exploratory and the best measures for data collection could only be theorized based around varied previous research on interoception. Indeed, whether or not the heartbeat discrimination task is a valid method of interoception accuracy has been brought into question, as it has been argued that the method is bias because it cannot account for individual differences. For instance, Knoll and Hodapp (1992) had found that those participants with elevated blood-pressure performed statistically better in interoception accuracy tasks. The researcher of this study did not have access to blood-pressure equipment, nor was it a variable considered prior to finalization of the project's protocol and procedures. Additional bias has been called into question when the task includes a customized delay tone, such that it is dependent on an individual's heart rate, where the slower the heart rate, the potential for correct discrimination becomes easier. In addition, differences between male and female participants have also been reported. It has been found that male participants are typically better heartbeat discriminators compared to women (Katkin, Blascovich, & Goldband, 1981). Nonetheless, gender, as well as other individual differences not accounted for in this research project, should be considered in future studies of interoception. Lastly, this methodology for assessing accurate heartbeat is only one method for detecting visceral responses; thus, it is questionable that one measured response modality is likely to provide a comprehensive, or quantifiable, measure of interoception. Expanding on methods to objectively measure interoception, as well as including subjective measures, may allow a more accurate assessment of interoception to be surmised. Including subjective measures of interoception could reveal a broader understanding, and highlight the importance of cognitive appraisal during physically stimulating tasks. For instance, Yoris and colleagues (2015) examined twenty one anxiety disorder patients with panic disorder and thirteen healthy controls on

both objective and subjective measures of interoception. Patients did not differ in objective measures of interoception; however, significant differences were found between patients and controls subjective interpretation of their interoception processes. This research supports the idea that hyper-vigilance to body symptoms is not necessarily a bottom-up process, but rather a metacognitive process related to negative beliefs about bodily sensations.

Limitations related to the measures used for data collection include that of the subjective questionnaires, as well. In hindsight, much of the data was pulled from a non-clinical population, and thus, the odds of these participants experiencing extreme measures of anxiety, or at least more symptoms resulting in a larger variance between groups, is now assumed to be minimal. Lastly, due to the use of self-report measures and not having collected much of this data myself, it is possible that the data is limited by the fact that it cannot be independently verified and that this data could contain biases, including selective memory and exaggeration when completing the physical activity questionnaire and the anxiety inventory by its participants. An additional limitation to our study was the arbitrary use of three hours per week of heavy physical activity as our threshold between “high” and “low” physical activity. Based around the WHO’s (World Health Organization) recommendations, adults should exercise at least two and a half hours per week for health benefits; it could be that both interoception accuracy and anxiety symptoms are subject to more extreme lifestyles, where larger differences between sedentary individuals, and extremely physically active individuals would be more apparent.

Contrary to many studies relating anxiety related symptoms to high levels of interoception, our findings suggest that high levels of interoception do not necessarily correlate to a greater response in anxiety scores. Possibilities for these findings may be particularly due to two reasons, first our population was a convenience sample of young, healthy adults. Our initial recruiting method was not designed to delineate participants based on any clinical illness. Additionally, given the cross-sectional nature of the research, no causal relationship could be determined. Given this assumption, future research could control for this, running an experiment to see if people with high interoception whom live a sedentary lifestyle would be affected by engaging in physical activity over time.

IMPLICATIONS AND FUTURE RESEARCH

Despite extensive limitations to the current study, this author believes that the study of how physical activity may modify the relationship between interoception and anxiety is still of worthy cause. Identifying treatment options for anxiety and anxiety like symptoms is important. Anxiety disorders are a common mental illness affecting multiple different subgroups across the world (Remes, Brayne, Van der Linde, and Lafortune, 2016), for instance, the prevalence of anxiety in the United States is estimated to be 18% (Kessler et al., 1999), while the European Union (EU) also cites anxiety as the most prevalent psychiatric condition in the EU (Bandelow and Michaelis, 2015). If future research can identify that physical activity does modify the relationship, more evidence proposing that exercise is in-itself a low-cost, and a virtually universal and accessible source of treatment for mental illness could be surmounted. For example, interoception exposure as a hyperventilation task has already been shown to ameliorate some anxiety symptoms in high anxiety individuals (Holtz, Hamm, and Pane-farre, 2018) it would make sense to study exercise as a method of interoception exposure, as well because exercise naturally results in physiological responses similar to those used in interoception tasks. Future research could focus on performing the interoception heartbeat detection task with both a normal, healthy population; and with those already screened for high anxiety symptoms. What's more, one could perform a longitudinal study, identifying the changes in anxiety symptoms across individuals with high interoception and high anxiety symptoms.

Additionally, understanding interoception is still in its infancy. Understanding the mechanisms and effects of interoception on human emotions and subjective well-being offers insights into potential root causes of emotional disturbances. What's more, studies on understanding how exercise and interoception are linked are virtually non-existent. Exercise induces cardiac arousal, and this arousal activates the same brain structures responsible for interoception (insula), an area also responsible for affect. For instance, the participants in our study had low anxiety symptoms, regardless of having high interoceptive accuracy; so could it be that interoceptive accuracy does not predict anxiety symptoms, but instead, interoception's proposed link to anxiety symptoms is confounded by unearthed variables?

In conclusion, our study revealed that high levels of interoception paired with low exercise did not result in a greater reports of anxiety symptoms compared to those individuals with high levels of interoception but reported high levels of physical activity, as proposed. However, due to the limitations of this study, much can be approved upon in order to investigate these relationships with greater validity in the future.

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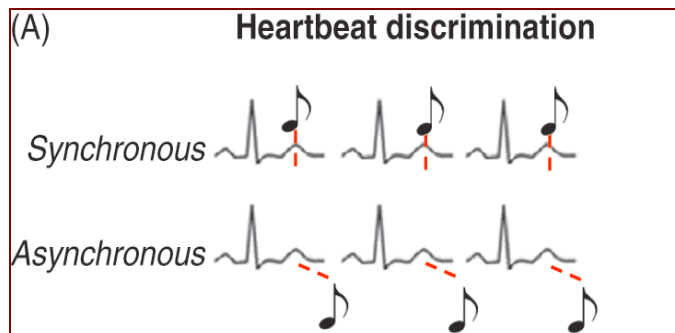
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APPENDIXES

Heartbeat Discrimination Task



(B)

Was your heartbeat in sync with the tone?