Sustained attention is related to heartbeat counting task performance but not to self-reported aspects of interoception and mindfulness

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ABSTRACT

Although association between sustained attention and various aspects of interoception (i.e. the perception of the body state) seems plausible, research on this subject is scarce. In the present study, 74 undergraduate students (41 females; age: 22.3 ± 4.04 yrs) filled out the Body Awareness Questionnaire, the Mindful Attention Awareness Scale, and the Somatosensory Amplification Scale and completed the Heartbeat Counting Task (HCT), a sensory-perceptual measure of cardiac interoception and the PEBL Continuous Performance Test (CPT) assessing sustained attention. The HCT score showed a weak to moderate negative correlation with the number of commission errors shown in CPT, indicating a lack of response inhibition (frequentist analysis: r2 = −0.313, p = 0.008; Bayesian analysis: r2 = −0.216, BF10 = 5.865). Questionnaire measures did not show any connection with CPT-performance. These findings suggest that the subjective representation of attentiveness to bodily processes is unrelated to the objectively measured sustained attention. Response inhibition, however, is moderately related to HCT performance.

1. Introduction

Interoception is defined as the perception of the body state and bodily changes (Ceunen et al., 2016; Craig, 2002; Ehlers & Breuer, 1992). Although the term in the broadest sense also includes physiological regulation based on automatic processing (Cameron, 2002), the commonly assessed aspects of interoception focus on states and changes that are (at least under certain circumstances) available to conscious awareness. Regarding these aspects, attention plays a role in the perception process, both under laboratory and everyday conditions (Matthias et al., 2009; Murphy et al., 2019). Attention can be automatically caught by strong, homeostatically salient interoceptive cues (e.g. urge to urinate, nausea, or pain) in a ‘bottom-up’ or ‘exogenous’ way; alternatively, it can be directed on inner sensations deliberately in a ‘top-down’ or ‘endogenous’ manner (Hohwy, 2014; Khalsa et al., 2018; Posner, 1980). Although this classic phenomenological distinction is widely used and practically useful, it does not necessarily refer to conceptually different underlying processes (Feldman & Friston, 2010). For example, the predictive processing framework conceptualizes attention as the estimated reliability of signals, that substantially impacts all levels of hierarchical processing (Feldman & Friston, 2010; Hohwy, 2012; 2016).

Paradigms assessing various aspects of interoception typically require endogenous attention. Based mainly on the type of the
applied assessment, the literature generally differentiates between two major dimensions of interoception (Ceunen et al., 2013; Garfinkel et al., 2015; Garfinkel & Critchley, 2013). The sensory-perceptual component (called interoceptive accuracy or sensitivity) focuses on a certain interoceptive channel, such as the perception of the heartbeats (e.g. Schandry, 1981; Whitehead et al., 1977) or gastric fullness (van Dyck et al., 2016) and compares the perceived sensation with objectively measured bodily processes. The self-reported dimension (called interoceptive sensibility) is typically assessed with questionnaires, and it refers to trait-like awareness of and attentiveness to a variety of body sensations that belong to different sensory modalities.

Concerning the sensory-perceptual interoceptive accuracy, Khalsa and colleagues (2018, supplement p.4) emphasize the importance of attention by pointing out that the former „necessarily depends upon interoceptive attention given the reliance on attentional mechanisms for generating accuracy estimates”. Respecting cardiac interoception, both main types of heartbeat perception tasks (i.e. tracking and discrimination based: Schandry, 1981; Whitehead et al., 1977) require considerable attentional resources. In the Heartbeat Counting Task (HCT) (Schandry, 1981), a popular representative of the tracking paradigm, attention is focused on the interoceptive cues (individual heartbeats) and their tracking by counting; as for the discrimination tasks, a continuous switching of attentional focus between internal and external cues takes place. Although attention very likely substantially impacts performance in these tasks, the possible role of individual differences (e.g. attentional divisibility, sustainability, biases) is usually not examined and taken into consideration.

Similarly, questionnaires assessing interoceptive sensibility use concepts that presuppose the involvement of various attentive processes, such as noticing, being aware, or focusing intentionally (e.g. Body Awareness Questionnaire - BAQ, Shields et al., 1989; Body Perception Questionnaire - BPQ, Porges, 1993). This also applies to questionnaires that use a multidimensional approach to interoceptive sensibility (e.g. Multidimensional Assessment of Interoceptive Awareness, Mehling et al., 2012), or assess the negative aspects of bodily focus. An example of the latter is the Somatosensory Amplification Scale (Barsky et al., 1990), which measures the “tendency to experience somatic and visceral sensation as intense, noxious, and disturbing” (Barsky et al., 1988, p. 510). All these constructs involve self-reported bodily focus thus implicitly assume that the subject has a certain capacity to sustain attention, to focus on a particular body area or sensation which leads to the detection of internal events even during everyday activities. For example, one of the three claimed components of somatosensory amplification is hypervigilance to body states and changes (Barsky et al., 1988; 1990).

From a therapeutic point of view, there are two substantially different perspectives of bodily focus (Ginzburg et al., 2014; Mehling, 2016; Mehling et al., 2009; Tihanyi et al., 2016). One approach considers enhanced bodily focus harmful because it is a prerequisite for clinical hypochondriasis and somatization disorder among other pathological states (Abramowitz et al., 2007; Asmundson et al., 2010; Barsky, 1979; 1992). The second perspective highlights the adaptivity of being attentive or sensitive to bodily signals as it is associated for example with self-consciousness (Cameron, 2002), decision-making (Damasio, 1994; 1999; 2010), and emotion regulation (Füstös et al., 2013; Kever et al., 2015; van ’t Wout et al., 2013). Benefits of bodily focus are highlighted by several authors with respect to psychotherapy (Bakal, 1999; Farb et al., 2015; Fogel, 2013; Mehling, 2020; Mehling et al., 2011) and also utilized in mind-body practices (e.g. yoga; Rani & Rao, 1994). An important component of these techniques is sustained attention to all bodily experiences without analysis or judgment; this type of attitude is closely related to mindfulness (Baer et al., 2006). Some theories consider mindfulness skills (e.g. sustained attention, non-reactivity, experiencing without judgment) an inherent part of body awareness, i.e., the attentiveness to normal nonemotive processes (Mehling et al., 2009; Shields et al., 1989). Depending on the conceptualization, this can also be regarded as interoceptive sensibility. Based on results revealing that higher performance on visual sustained attention tasks is linked to higher levels of trait mindfulness (Ruocco & Wonders, 2013; Schmertz et al., 2009), it might be expected that interoceptive sensibility is also linked to sustained attentional abilities. However, empirical evidence does not seem to support this hypothesis so far (Tihanyi et al., 2017).

Beyond theoretical considerations, empirical evidence shows a link between attention and interoceptive processes. Pollatos et al. (2007) reported an association between cardioceptive accuracy, assessed by the HCT (Schandry, 1981), and the attentive processing of visual stimuli assessed with the P300 amplitude in an EEG oddball paradigm. Matthias and colleagues (2009) found that participants with higher HCT scores have better performance in visual divided and selective attention tasks. However, they did not find an association between the HCT score and sustained attention.

Sustained attention (aka vigilance) itself is a complex construct assessed with a number of different tests. According to Cohen (2014), the following four core elements of attention can be identified: a) sensory selective attention, b) focus and capacity, c) response selection and control or executive-attention, and d) sustained attention. These components often occur in the aforementioned temporal sequence, and sustained attention requires the appropriate operation of the first three systems. Matthias et al. (2009) used the vigilance substest of Test Battery for Attentional Performance (TAP), which requires the participant to be alert for a longer period of time and to detect relevant infrequent stimuli, and the alertness subtest of TAP, where the participant has to respond as fast as possible to easily distinguishable stimuli (van Zomeren & Brouwer, 1994). There are sustained attention tests, however, with a different focus. For example, the widely used Conners’ continuous performance task (CCPT) combines the assessment of sustained attention with response inhibition (Homack & Riccio, 2006). As this approach does not only assess the reaction to certain stimuli but also the inhibition of response to non-relevant cues, it might provide us with more information on the factors impacting interoception.

The primary aim of the present study was to directly test the supposed association between different aspects of interoception (i.e. performance in the HCT, interoceptive sensibility), the negative aspect of body focus (somatosensory amplification), mindfulness and

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2 In discrimination tasks, participants are asked to decide whether brief series of visual or auditory stimuli are in synchrony with their heartbeats or not.
the ability to sustain attention. Fig. 1 illustrates the relation between these constructs. We hypothesize that sustained attention is positively associated (1) with heartbeat counting performance, (2) interoceptive sensibility, (3) mindfulness, and (4) somatosensory amplification.

2. Materials and methods

2.1. Participants

The calculation of the required sample size was conducted using the G*Power v3.1.9.4. software (Faul et al., 2007). Assuming $\alpha = 0.05$ (one-tailed), $1-\beta = 0.8$, and a correlation of 0.3, a minimum sample size of $N = 67$ was determined. A total of 74 voluntary undergraduate students (41 females; age: $22.3 \pm 4.04$ yrs) took part in the study.

2.2. Procedure

The questionnaires were filled out online in Hungarian before the experiment. Participants completed the PEBL Continuous Performance Test and the HCT during the experimental part, which took place in the laboratory of the university. All participants previously signed an informed consent form. The study was approved by the Research Ethics Committee of the Faculty of Pedagogy and Psychology, Eötvös Loránd University, Budapest, Hungary.

2.3. Questionnaires

Interoceptive sensibility was assessed with the Body Awareness Questionnaire (BAQ; Köteles, 2014; Shields et al., 1989). The BAQ consists of 18 items rated on a 7-point Likert scale and measures the construct on a single factor. The questionnaire examines the sensitivity to bodily cycles and rhythms, the ability to detect small, normal changes, and the ability to anticipate bodily reactions. (Example item: “I can accurately predict what time of day lack of sleep will catch up with me.”) Higher scores indicate higher levels of interoceptive sensibility. Cronbach’s alpha of the BAQ in this study was 0.877.

The tendency to experience somatic sensations as intense, noxious, and disturbing was measured by the Somatosensory Amplification Scale (SSAS; Barsky et al., 1990; Köteles et al., 2009). The 10 items of the SSAS are rated on a 5-point Likert scale, higher scores refer to higher levels of amplification tendency. (Example item: “I hate to be too hot or too cold.”) The internal consistency of the scale in this study was 0.631.

The Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003; Simor et al., 2013) was used to measure trait mindfulness, the extent of one’s ability to pay attention to the present moment in an open and non-judgmental way. The MAAS consists of 15 items, each of them formulated inversely (i.e. how often subjects find themselves being inattentive, preoccupied, or acting automatically), rated on a 6-point Likert scale. (Example item: “I rush through activities without being really attentive to them.”) Higher scores indicate higher levels of mindfulness. In the present study, Cronbach’s alpha of the MAAS was 0.860.

2.4. HCT

The HCT was used to measure a sensory-perceptual aspect of interoception (Schandry, 1981). Subjects were in a seated position

![Conceptual background of the constructs assessed in the present study](image-url)

Fig. 1. Conceptual background of the constructs assessed in the present study. BAQ = Body Awareness Questionnaire; HCT = Heartbeat Counting Task; SSAS = Somatosensory Amplification Scale; MAAS = Mindful Attention Awareness Scale.
with both feet on the ground, hands placed on the thighs. Their task was to count their heartbeats within three intervals (25, 35, and 50 s; presented in random order) then verbally report the number. Each interval started with a verbal start signal and ended with a stop signal by the experimenter. The participants were reassured that zero is a valid answer if they did not feel any heartbeats but encouraged to count if they had even a slight sensation (for the exact instruction, see Supplementary material). The real trials were preceded by a 15-sec practicing phase. No information was provided to the subjects about the exact length of the trials or their performance. The actual number of heartbeats (ECG) was recorded by the NeXus monitoring system (NeXus Wireless Physiological Monitoring and Feedback: NeXus-10 Mark II, Version 1.02; BioTrace + Software for NeXus-10 Version: V201581; Mind Media BV, Herten, the Netherlands). The HCT score was calculated by comparing the number of reported heartbeats with the number of actual heartbeats and then averaging the score of the three intervals. The following formula was used for each interval: (1 − ([HRrecorded − HRcounted]/HRrecorded)).

2.5. Sustained attention

Sustained attention was assessed by the Psychology Experiment Building Language (PEBL; software version v0.14; Mueller & Piper, 2014) Continuous Performance Test (CPT), a 14 min implementation of the Conners Continuous Performance Task. During this test, participants have to maintain their attention and respond to letter stimuli appearing on the computer monitor. The instruction is to press the SPACE key as quickly as possible for any letter of the alphabet, except ‘X’, in which case one must withhold their response. In this task a total of 324 target letters (A, B, C, D, E, F, G, H, I, J, K, L, M, O, P, Q, R, S, U) and 36 foils (X) are presented, the inter-stimulus interval is 1, 2, or 4 s. Performance is characterized by three indices: the number of commission errors (when SPACE bar was pressed after an ‘X’, considered an indicator of lack of cognitive control), omission errors (when after a stimulus that was not an ‘X’ SPACE bar was not hit, indicative of distractibility), and the average reaction time with respect to the correct reactions only.

2.6. Statistical analysis

Data were analyzed using the Jasp v0.11 software (JASP Team, 2019). As the distribution of data deviated from a normal distribution for certain variables, associations were analyzed with non-parametric methods, using both the frequentist (Spearman’s rho coefficient) and the Bayesian approach (Kendall’s tau coefficient). In the frequentist analysis, p = 0.05 (two-tailed) was accepted as the threshold of significance; in the Bayesian approach, a BF10 between 3 and 10 was considered as positive or substantial evidence in favor of the alternative hypothesis and BF10 between 0.1 and 0.33 as positive or substantial evidence in favor of the null hypothesis (Jarosz & Wiley, 2014).

3. Results

Descriptive statistics of the assessed variables are presented in Table 1. Frequentist correlation analysis indicated a moderate negative association between the number of commission errors and the HCT score (rs = −0.313, p = 0.007), and the Bayesian analysis, indicating a weak negative association, supported this finding (τb = −0.216, BF10 = 5.865), see Table 2. Associations with the number of omission errors and reaction time were non-significant; actually, the Bayesian results showed the superiority of the null hypothesis (i.e. the lack of association) over the alternative hypothesis (BF10 < 0.33) for both cases. Similarly, the null hypothesis proved to be more probable for each association between indicators of sustained attention and questionnaire scores with the exception of SSAS score and omission errors (Table 2).

4. Discussion

In a laboratory study with the participation of 74 young individuals, participants’ self-reported interoceptive sensibility, mindfulness, and somatosensory amplification were independent of the indicators of the ability to sustain attention. HCT score was independent of reaction time and omission errors but showed a weak to moderate negative association with the number of commission errors in the sustained attention task.

Table 1
Descriptive statistics.

<table>
<thead>
<tr>
<th></th>
<th>M ± SD</th>
<th>Min – max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heartbeat Counting Task performance</td>
<td>0.587 ± 0.258</td>
<td>0.000 – 0.990</td>
</tr>
<tr>
<td>Body awareness</td>
<td>86.467 ± 14.448</td>
<td>45 – 119</td>
</tr>
<tr>
<td>Somatosensory amplification</td>
<td>29.973 ± 5.276</td>
<td>19 – 42</td>
</tr>
<tr>
<td>Mindfulness</td>
<td>58.270 ± 10.201</td>
<td>37 – 84</td>
</tr>
<tr>
<td>Number of commission errors</td>
<td>15.960 ± 6.671</td>
<td>6 – 32</td>
</tr>
<tr>
<td>Number of omission errors</td>
<td>1.867 ± 2.082</td>
<td>0 – 9</td>
</tr>
<tr>
<td>Reaction time (ms)</td>
<td>326.844 ± 39.693</td>
<td>238,860 – 476,980</td>
</tr>
</tbody>
</table>
Table 2
Pairwise association between variables, using frequentist (Spearman’s rho) and Bayesian (Kendall’s tau) analysis.

<table>
<thead>
<tr>
<th></th>
<th>N = 74</th>
<th>Vigilance</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Commission errors</td>
</tr>
<tr>
<td>Heartbeat Counting Task performance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spearman’s rho (p)</td>
<td>0.313 (0.007)</td>
<td>0.128 (0.277)</td>
</tr>
<tr>
<td>Kendall’s tau (BF10)</td>
<td>-0.216 (5.865)</td>
<td>-0.091 (0.289)</td>
</tr>
<tr>
<td>Body awareness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kendall’s tau (BF10)</td>
<td>0.063 (0.208)</td>
<td>0.042 (0.174)</td>
</tr>
<tr>
<td>Body awareness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kendall’s tau (BF10)</td>
<td>0.038 (0.170)</td>
<td>-0.133 (0.604)</td>
</tr>
<tr>
<td>Somatosensoy amplification</td>
<td>0.010 (0.935)</td>
<td>-0.054 (0.649)</td>
</tr>
<tr>
<td>Mindfulness</td>
<td>0.002 (0.151)</td>
<td>-0.026 (0.160)</td>
</tr>
</tbody>
</table>

Note: Coefficients with p < 0.05 (two-tailed) and BF10 > 3 are marked with bold.

4.1. HCT performance and sustained attention

Sustained attention is a complex construct, conceptualized, and operationalized in different ways. In the present study, we used the PEBL CPT, which applies a response-inhibition paradigm.

The negative association we found between the number of commission errors and the HCT score to some extent supports our first hypothesis assuming a positive relationship between sustained attention and HCT performance. As the number of commission errors in the PEBL CPT is interpreted as an indicator of (the lack of) cognitive control (i.e. more errors indicate a worse inhibition of automatic processing) (Piper et al., 2016; Riccio et al., 2002), our results suggest that higher HCT scores are associated with a more pronounced inhibition component of sustained attention. On the one hand, it makes sense that higher HCT scores are related to better attentional abilities in general; on the other hand, however, this specific result seems counter-intuitive at first sight. Based on the criticism of the HCT task highlighting that most participants underestimate their heart rate during the task (Desmedt, Houte, et al., 2020), one could assume that people with higher HCT scores are characterized by lower level of cognitive control than those with low HCT scores. For example, heartbeats that were not actually felt but estimated relying an internal rhythm are not suppressed. Previous findings (Matthias et al., 2009) show that participants with higher HCT scores have a higher performance in tests of divided (measured by a visual-auditory dual task paradigm) and selective attention (measured by the ‘d2 test of attention’). Selective attention also includes response inhibition to irrelevant stimuli (Riccio et al., 2002); in this sense, our results correspond with the ones reported by Matthias and colleagues (2009). Similarly, in the case of adult patients with ADHD, where delayed behavioral inhibition is a primary issue (Barkley, 1997), impairment of HCT performance was reported (Kutscheidt et al., 2019). Also, Kutscheidt and colleagues (2019) found that while 100% of the ADHD patients underestimated their heartbeats in the HCT, in the control group underestimation occurred only in 4.89% of cases. Moreover, the findings of Herman et al. (2019) suggest that better performance in the heartbeat discrimination task is predictive of lower nonplanning impulsivity (but not other subtypes of trait-impulsivity). Thus, the lack of response-inhibition does not seem to lead to a higher number of reported heartbeats. Overall, these findings are conceptually linked to the results of the present study.

It is important to note, that although non-interoceptive (i.e. biasing) factors might contribute to the HCT score, they do not completely determine it (Schulz et al., 2021). It can also be assumed that the comparatively strict instruction used in our study reduced the impact of biasing factors. It is possible that with the usage of a more liberate instruction (e.g. allowing estimation explicitly), participants with high HTC score would show higher commission errors scores (i.e. showing lower ability to inhibit automatic processing). Other factors, most importantly attention, could improve the processing of the sensory signal, i.e., the perception of actual heartbeats. In other words, all other things being equal, individuals with higher level of acute body focused attention are able to sense more heartbeats. Thus, assuming that biasing and attentional factors are not related to each other (i.e. the contribution of biasing factors to the HCT score is independent from that of attentional factors), our finding might simply indicates the connection of the latter with heartbeat perception assessed with HCT. It is an open question whether there is a causal relation between them, but the impact of attentional factors on heartbeat counting seems plausible. An alternative explanation of the positive association of HCT and response inhibition could be that effective self-regulation builds on self-monitoring, which can be related to the perception of internal signals (Kutscheidt et al., 2019). Hence, the ability indicated by the HCT score - to a certain extent - may support response inhibition. Finally, it is also important to remember that the found association is in the weak to moderate domain, which supports the idea that other (here not investigated) factors have a bigger influence on cardioceptive accuracy assessed with the HCT. As the factors that impact performance in the HCT are largely unknown, the above described explanations are admittedly speculative.

In our study, HCT score was not related to other assessed aspects of sustained attention, i.e., reaction time and omission errors in the PEBL CPT task. Similarly, a previous study reported the independence of HCT score and sustained attention (assessed with the alertness and the vigilance subtest of the Test Battery for Attentional Performance, TAP) (Matthias et al., 2009). The lack of association between HCT scores and the other sustained attention-related variables might be due to the modality specificity of the PEBL CPT measurement and attention in general. The sustained attention tasks applied in this study and by Matthias and colleagues (2009) investigate exteroceptive attention; specifically, the present study investigates visual attention which might be substantially different from the way we pay attention to and perceive our bodily signals. For example, visual signals in these tasks are unambiguous thus easy to detect, whereas body signals, including heartbeat under resting conditions, are vague and presumably more sensitive to top-down influences. This can even lead to body illusions or hallucinations, i.e., the perception of somatic events in the absence of actual physiological
changes (Corneille et al., 2020; Körmendi et al., 2020; McKenzie et al., 2010; Mirams et al., 2010; 2012; 2017; Tihanyi et al., 2017; 2018; Van den Bergh et al., 2018). In other words, attention does not only enhance the sensibility of top-down interoceptive signals, but it is also able to generate body sensations.

4.2. Sustained attention and self-reported bodily focus

There were no associations between self-reported interoceptive sensibility, somatosensory amplification, mindfulness, and the assessed aspects of sustained attention, just like in our previous study (Tihanyi et al., 2017). To explain this finding, one has to keep in mind that self-reports are heavily influenced by factors beyond sensory-perceptual processes and information processing, while a sustained attention task is closer to low-level cognitive information processing. Moreover, empirical evidence shows that perceived performance in a sustained attention task does not necessarily correspond to actual performance with respect to reaction time and the number omission errors (Babulka et al., 2017). We are not able to gain a realistic picture about our actual attentional performance (i.e. we are not aware of the events we ignored), thus the latter won’t be represented in self-reports.

4.3. The question of ecological validity

Our findings support the view that the perception of vague interoceptive signals is linked to our limited attentional capacity. The vast majority of bodily information is processed at lower levels of the central nervous system and do not reach conscious awareness (Adám, 1998; Cameron, 2001; 2002). This protects our finite capacity of attention, divided between the competing stimuli from inside and outside, from being overburdened (Liotti et al., 2001; Pennebaker, 1982; Pennebaker & Lightner, 1980). Our results show that when the ability to perceive (and count) heartbeats is assessed in the laboratory, those who are better at response inhibition with respect to the irrelevant stimuli may have a slight advantage. It is an open question, however, whether this advantage still exists in everyday situations (Köteles, 2021).

In the context of attention, the definition of interoception raises the question – which is interesting not only theoretically but also methodologically – if those interoceptive sensory impulses that do not reach awareness can or cannot be regarded as interoception. According to Cameron (2001), interoceptive processes can occur outside of conscious awareness and they can affect behavior. However, most of the recent research paradigms depend on verbal or behavioral reports, and (either by questionnaire or by sensory-perceptual tasks) investigate perceptions that reach conscious awareness. The sensory-perceptual measures of interoceptive accuracy and questionnaires of interoceptive sensibility have a rather narrow focus, as they do not cover cues that we cannot pay attention to as it is reflected by the direct verbal or behavioral reaction. Interestingly, even in studies that specifically aim to assess interoceptive attention (Avery et al., 2015; Stern et al., 2017; Tihanyi et al., 2018), attentional capacity is rarely investigated. Generally speaking, measures of interoceptive accuracy require endogenous, i.e., top-down attention. In everyday life, however, exogenous attention focusing on homeostatically relevant signals is at work. This is mainly because signals coming from the environment are usually more significant from an evolutionary perspective (Adám, 1998). This striking difference between the very nature of the measures of interoceptive accuracy and how interoceptive signals are generally processed in everyday life somewhat undermines the validity of the common measures of interoceptive accuracy, like HCT.

4.4. Limitations

This study has several limitations. The sample consisted of healthy young individuals, which limits the generalizability of the findings. The Somatosensory Amplification Scale (Barsky et al., 1990; Köteles et al., 2009) had a relatively low consistency value in our study; however, this is not without example in the literature (Köteles & Witthöft, 2017). The validity of the HCT was questioned recently (Desmedt, Corneille, et al., 2020; Desmedt et al., 2018; Ring et al., 2015; Ring & Brener, 2018; Zamaioni et al., 2018); although a strict instruction was applied to reduce the impact of top-down factors in the current study, non-interoceptive information might have contributed to participants’ performance. It is also an open question how sustained attention measured in other modalities than the visual domain (e.g. auditory, tactile) relate to heartbeat perception, or more specifically, to HTC. Last but not least, replication of the recent study is needed to confirm the reliability of the presented results.

4.5. Conclusions

The findings of the current study suggest that the self-reported aspect of interoception (i.e. interoceptive sensibility), somatosensory amplification and mindfulness are unrelated to sustained attention. The response-inhibition aspect of the latter, however is moderately related to the performance shown in the Heartbeat Counting Task.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to
Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2021.103209.

References


