Interoceptive ability as a predictive screening measure for autism? A study examining whether tasks aimed at measuring interoceptive awareness and interoceptive sensibility can be used as a predictive screening tool for individuals with high autistic trait levels.

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Interoceptive ability as a predictive screening measure for autism?

A study examining whether tasks aimed at measuring interoceptive awareness and interoceptive sensibility can be used as a predictive screening tool for individuals with high autistic trait levels.

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Abstract

Alterations in interoception (i.e., the way in which individuals perceive their bodily signals) have been linked to autism spectrum disorder (ASD). As previous literature points out a negative relationship between ASD and interoception, we anticipated an implication that interoceptive ability could potentially serve as a predictive screening tool for ASD. For this, three major dimensions of interoception were studied, as identified in previous research, namely interoceptive accuracy, interoceptive sensibility and interoceptive awareness. More specifically, this study investigated the relationship between interoceptive awareness and autistic traits levels, and the relationship between interoceptive sensibility and autistic traits levels. Drawing from past research, we expected negative relationships. A total of 63 participants performed a heartbeat discrimination task (HDT) and two questionnaires, one on interoceptive sensibility and one on autistic trait levels. Regression analyses indicated that neither interoceptive sensibility nor interoceptive awareness showed to be a significant predictor of autistic trait levels. Further, exploratory analyses on the relationship between autistic traits and interoceptive accuracy and alexithymia revealed that only alexithymia is predictive of autistic trait levels. This suggests that, while interoceptive ability might not be a good predictor of autistic trait levels and potentially even ASD, alexithymia levels might be. Therefore, future research should further investigate alexithymia in relation to ASD.

Keywords: interoceptive ability, interoceptive awareness, interoceptive sensibility, interoceptive accuracy, autistic trait levels

Layperson's summary

Changes in interoception (i.e., whether people recognise signals inside their body) have been linked to autism spectrum disorder (ASD). As previous literature points out that higher levels of ASD are associated with lower interoception, we hoped to find that interoceptive ability could serve as a screening tool for ASD. For this, three major dimensions of interoception were studied, as identified in earlier research, namely interoceptive accuracy (i.e., performance on a task), interoceptive sensibility (i.e., how well you think you can perceive signals in your body) and interoceptive awareness (i.e., how confident you are on your performance on the accuracy task). More specifically, this study investigated the relationship between interoceptive awareness and autistic traits levels, and the relationship between interoceptive sensibility and autistic traits levels. Drawing from previous research, we expected negative relationships. A total of 63 participants performed a heartbeat discrimination task and two questionnaires, one on interoceptive sensibility and one on autistic trait levels. Our results indicated that neither interoceptive sensibility nor interoceptive awareness could predict autistic traits. Furthermore, two extra analyses on the relationship between autistic traits and interoceptive accuracy and alexithymia (i.e., whether you can put your body signals into words) revealed that only alexithymia could predict autistic traits. This suggests that, while interoceptive ability might not be a good at predicting ASD, alexithymia levels might be. Therefore, we recommend that future research investigates the relationship between alexithymia and ASD. In short, our study looked at whether interoception measures could be used as a prediction tool for ASD, however we concluded/identified that alexithymia measures could predict ASD.

Introduction

The way in which individuals perceive their bodily signals, i.e., interoception, has been a widely researched topic in the last couple of decades. The degree to which an individual perceives signals from the body has been defined as interoceptive ability and has been shown to differ greatly between individuals (Critchley & Garfinkel, 2017). For example, interoception is known to be lower in individuals with autism spectrum disorder (ASD) (Mul et al., 2018). Moreover, interoception has been associated with affective processes (Critchley & Garfinkel, 2017; Terasawa et al., 2014; Wiens et al., 2000) which are known to be impaired in individuals with ASD (DSM-5, American Psychiatric Association, 2013). Thus, interoceptive processing might be relevant in explaining difficulties experienced by autistic individuals. In those lines, a recently developed theory postulates that individuals with ASD experience a reduced competency to integrate interoceptive information (Hatfield et al., 2019). The authors speculate that this reduced competency may result in a limited attention to the body and could even result in reduced motivational and behavioural drives. For example, anger, an incorrectly perceived state, could result in a failure to generate an appropriate motivational and behavioural drive state to alleviate the anger. Moreover, difficulties with sensing internal bodily states may impact on a range of aspects of life in individuals with ASD, such as physical and mental health (Fiene & Brownlow, 2015). For instance, if hunger is incorrectly perceived, then an appropriate reaction to relieve the hunger could remain absent, which could result in problems. The benefits of researching the relationship between interoception and ASD are thus broad. However, while grasping modulations in interoceptive experiences in individuals with ASD might aid the understanding of altered emotional and behavioural processes, research has been scarce on this relationship.

Dimensions of interception

Interoceptive ability consists of three dimensions according to Garfinkel et al. (2015): interoceptive accuracy, interoceptive sensibility and interoceptive awareness. Interoceptive accuracy is an objective measure, measured through e.g., the performance on a heartbeat discrimination task (HDT) or on a heartbeat tracking task. The HDT has been first used in the early eighties (Katkin et al., 1981). In this version of the HDT, an electrocardiogram (ECG) was recorded in participants while performing the task. A trial consisted of a series of tones, which could be in line with the participants' heartbeat, or a delayed version of the participants' heartbeat. The participant thereupon had to decide whether the tones were synchronous with their heartbeat. In the heartbeat tracking task, participants are asked to count their own heartbeat and to indicate how many heartbeats have occurred during specific short time intervals (Mul et al., 2018). In contrast, interoceptive sensibility is a subjective measure through questionnaires and self-reports. The various existing questionnaires all focus on different aspects of interoceptive sensibility. The Body Perception Questionnaire (BPQ, Porges, 1993) assesses how aware participants are of their perceptions of physiological signals within their body. Two related but essentially different questionnaires are the Interoceptive Accuracy Scale (IAS, Murphy et al., 2019) and the Interoceptive Attention Scale (IATS, Gabriele et al., 2021). The IAS measures how accurately one can perceive specific bodily sensations without external cues, such as the heartbeat or hunger. On the other hand, the IATS measures how much attention one pays to specific bodily sensations, regardless of how well one thinks they can perceive them. The 32-item Multidimensional Assessment of Interoceptive Awareness questionnaire (MAIA, Mehling et al., 2012) is another questionnaire to measure interoceptive sensibility. This questionnaire is different from the BPQ in that it targets mostly elements of regulation and appraisal of bodily sensations, whereas the BPQ focuses on a larger scope of elements (i.e., awareness, stress response, autonomic nervous system reactivity, stress style, and health history inventory). Two other questionnaires that assess interoceptive sensibility are the Body Awareness Questionnaire (BAQ, Shields et al., 1989) and Thirst Awareness Scale (TAS, Fiene & Brownlow, 2015). The BAQ and TAS differ from the BPQ awareness subscale since they exclusively assess elements of thirst, hunger, temperature, satiety, and the prediction of the onset of illness, while the BPQ awareness subscale assesses awareness traits. A lesser known interoceptive sensibility questionnaire is the Interoception Sensory Questionnaire (ISQ, Fiene et al., 2018). The ISQ involves questions on confusion about interoceptive bodily states. Taken together, there are many different questionnaires that assess certain aspects of interoceptive sensibility, but the BPQ awareness subscale fits best with the focus on interoceptive sensibility that we want to measure. Another instance of interoceptive sensibility, as a self-report, is a task performance related (trial by trial) self-report, as used for example in a study by Katkin et al. (1981). They have asked participants to rate the confidence in their decision of whether the tones were synchronous with their heartbeat. Although it is a self-report measure, it is different from questionnaires which measure overall traits. Lastly, interoceptive awareness is the correspondence between the accuracy and sensibility. More specifically, the performance on the HDT and the associated confidence ratings are commonly used to calculate interoceptive awareness. In short, the confidence rating attributes to calculating one's actual accuracy in discriminating one's own heartbeat. So far, there are only a few studies that have investigated interoceptive awareness, and therefore there is a large gap in research on this topic.

Next to various cognitive processes, interoception has consistently been linked to emotion recognition and regulation (Domschke et al., 2010; Füstös et al., 2013; Stevens et al., 2011; Terasawa et al., 2014; Wiens et al., 2000). In some studies, an increased recognition of emotions has been found in individuals with a high interoceptive accuracy (Domschke et al., 2010; Terasawa et al., 2014), while in another study, high interoceptive accuracy has been associated with experiencing more intense emotions (Wiens et al., 2000). Further, individuals with high interoceptive accuracy have been better at regulating their emotions, as shown in a lower number of errors in public speaking as compared with individuals with low accuracy (Stevens et al., 2011). Interestingly, individuals with high interoceptive accuracy in the latter study have also reported higher levels of (social) anxiety. Moreover, they have found that anxious individuals are at a higher risk of misinterpreting physical symptoms as symptoms of physical anxiety and are therefore very aware of their bodily signals (Stevens et al., 2011). Another study has found that an increased interoceptive accuracy plays a role in downregulating affect (Füstös et al., 2013). As ASD is known to be comorbid with (social) anxiety (Hollocks et al., 2019; Nadeau et al., 2011; Zaboski & Storch, 2018), this could indicate that high interoceptive accuracy might also be observed in individuals with ASD. However, as a reduced emotion recognition and regulation is characteristic for interoception, it is also a known characteristic of individuals with ASD (DSM-5, American Psychiatric Association, 2013). Contrasting the indication that these characteristics are also similar to (social) anxiety, it might be very specific for ASD, all the more a reason to study interoception in individuals with ASD.

Autism spectrum disorder and interoception

Autism spectrum disorder (ASD) is a neurological and developmental disorder. Individuals with ASD are characterised by deficits in social communication and interaction, and restricted and repetitive patterns of behaviour (DSM-5, American Psychiatric Association, 2013). A typical tendency is a deficit in social-emotional reciprocity. It was argued that this may partly arise from a limited understanding of the point of view and thoughts of others, otherwise known as Theory of Mind (ToM, Kimhi, 2014). An understanding of the emotions of others is also impaired in individuals with ASD (Harms et al., 2010), hindering social interaction. As outlined earlier, such difficulties might be related to alterations in interoceptive processing. Past studies have already described decreased interoceptive ability in individuals with ASD. For example, one study has focused on interoceptive accuracy within two groups: a first experiment was conducted with autistic and neurotypical participants, and a second experiment was conducted with neurotypical participants but looked at individuals with high levels of autistic traits (Noel et al., 2018). The participants performed a variation on the HDT in which the tones were replaced with visual stimuli. Their results have suggested that both autistic participants and neurotypical participants high on autistic traits demonstrate a reduced interoceptive accuracy. Contrary to this observation, one study has found no difference in interoceptive accuracy between autistic adults and neurotypical participants (Nicholson et al., 2019). The authors have conducted two experiments: one with autistic and neurotypical adults, and one with autistic and neurotypical children. In the first experiment, the adult participants performed a heartbeat tracking task and a blow comparison task. The blow comparison task is a respiratory interoceptive accuracy task in which participants exhale twice in a peak flow meter attempting to produce the exact same intensity for both blows. In both tasks, no significant differences have been found between the autistic and neurotypical participants.

However, in the second experiment, with children, a heartbeat tracking task was administered and a reduced interoceptive accuracy has been found among the autistic participants. In another study by Mul et al. (2018), participants with and without clinically assessed ASD performed both a heartbeat tracking task as well as an HDT and conducted a questionnaire to measure interoceptive sensibility. During the tasks, their heartbeat was recorded by an ECG. The questionnaire that was administered was the MAIA. They have found that participants with clinically assessed ASD scored lower on interoceptive accuracy and interoceptive sensibility than neurotypical participants (Mul et al., 2018). Another study has assessed interoceptive accuracy as well as interoceptive sensibility among autistic participants compared to neurotypical participants (Garfinkel et al., 2016). Interoceptive accuracy was measured through a heartbeat tracking task and an HDT, and interoceptive sensibility was evaluated through the BPQ. Interestingly, a reduced performance has been reported on the heartbeat tracking task but not on the HDT in autistic participants. Here, the authors have found an increased interoceptive sensibility among the autistic participants, contradicting other studies that have found a decreased interoceptive sensibility among autistic participants (Fiene & Brownlow, 2015). In their study, they have investigated interoceptive sensibility and have found that participants with ASD scored low on interoceptive sensibility in comparison to neurotypical participants. Nonetheless, to assess interoceptive sensibility, they have used different questionnaires than the BPQ, namely the BAQ and the TAS. They have used the BAQ because they wanted to use a questionnaire that measures interoception it its entirety. Additionally, they have developed the TAS because no questionnaire existed yet to assess interoceptive thirst awareness. In another study, interoceptive sensibility has been measured in autistic adults using the ISQ (Fiene et al., 2018). Most of their participants reported low interoceptive sensibility. Moreover, they have found an inversed relation between neurotypical individuals high on autistic traits and interoceptive sensibility. In summary, interoceptive accuracy and interoceptive sensibility are found to be generally lower in individuals with ASD compared to neurotypical individuals across different objective and self-report measures, with some inconsistent findings.

However, there is quite some support for lower interoceptive abilities in ASD, but it is still not entirely consistent. Moreover, there are many different measures for interoceptive ability, yet a direct comparison between the different dimensions of interoception is rarely made, especially not within the field of ASD. As it is difficult to recruit participants with a clinical diagnosis for ASD, many studies have instead assessed autistic traits in participants. ASD is at the extreme end of the dimension of autistic trait levels, as confirmed in previous studies (Mul et al., 2018; Nicholson et al., 2019). In the beforementioned study by Mul et al. (2018), a questionnaire to measure autistic traits, the Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001), has been administered to all the participants, and they have found that participants who had been diagnosed with ASD also scored above the cut-off point of 32 on the AQ. This means that autistic participants reported high levels of autistic traits. Further, they have found that autistic traits were inversely correlated with interoceptive sensibility. In another study, autistic participants completed the AQ and a diagnostic questionnaire for ASD (the Autism Diagnostic Observation Schedule, ADOS; Lord et al. 2000) and it has been found that all participants met the cut-off score of 26 for the AQ and 7 for the ADOS, indicating clinically significant levels of autistic traits (Nicholson et al., 2019). These findings lead us to already expect a negative relationship between interoceptive abilities and autistic trait levels, which can be used as a foundation for future implications, such as a predictive screening measure for ASD.

The current study

The main focus of this project was to investigate whether interoceptive ability is related to autistic traits and, if yes, to which dimension(s) of interoceptive ability. We therefore looked at interoceptive awareness (an objective measure of interoception, assessed via the HDT and the associated confidence ratings), interoceptive sensibility (a subjective measure of interoception, assessed via the BPQ awareness subscale), and autistic trait levels (assessed via the AQ).

A significant relation between autistic traits and interoceptive awareness would indicate that an objective assessment of interoceptive ability could be predictive of autistic traits (H1). On the other hand, a significant relation between autistic traits and interoceptive sensibility would indicate that a subjective assessment, or a belief, of interoceptive ability could be predictive of autistic traits (H2).

Based on previous findings we expected that interoceptive awareness as well as interoceptive sensibility would be negatively related to autistic traits, reflecting reduced interoceptive ability with higher autistic trait levels.

Our results could be used to evaluate whether the HDT or a questionnaire on interoceptive sensibility (i.e., the BPQ awareness subscale) could emerge as a useful clinical screening tool for ASD. It would serve as an indication of high autistic traits levels based on the suggested link between deficits in interoceptive processing and ASD. Considering that high autistic trait levels and ASD are associated (Mul et al., 2018), this could be an innovative regard. Furthermore, our findings could possibly provide a foundation to understand other social deficiencies found in autistic individuals.

Methods

Design

This thesis was a sub-project of a larger research project conducted by the PhD Candidate J. Folz who, in addition to interoceptive ability, also examined emotion recognition and facial mimicry. Furthermore, a questionnaire was used to identify another clinical personality trait: social anxiety. For assessing emotion recognition, a separate task was used. As this additional task might have influenced the interpretation of the results, the entire experiment is detailed in the *Procedure* section. The study followed a cross-sectional design and there was no experimental manipulation or group comparison (no between-subject design). Participants completed two tasks and answered all questionnaires. For this thesis, only the results of the HDT and two questionnaires (BPQ awareness subscale and AQ, see *Materials and measuring instruments*) were considered to answer the research question. The dependent variable was autistic traits, which was measured by the total score on the AQ (interval). For predicting the score on the AQ, two independent variables were used. Interoceptive awareness (interval) was the first independent variable, which was measured by the score on the heartbeat discrimination task (HDT) and the associated confidence ratings. Through a receiver operating characteristic (ROC) curve analysis (Metz, 1978), scores reflecting the correspondence of the accuracy and the confidence were quantified (*see Data pre-processing and statistical analyses*). The second independent variable was interoceptive sensibility, which was measured by the total score on the BPQ awareness subscale (interval).

Participant demographics

A total of 63 participants (M_{age} = 20.3, SD_{age} = 2.3, 53 females [84.1%]) took part in the study. Most participants were of Dutch nationality (*N* = 26). All participants spoke fluent English. The inclusion criteria for participants were that they were healthy adults, between the age of 18-35 years old, and that they haven't had a current or prior neurological or psychiatric disorder. Further, they ought to not have had participated in a related online study. A power analysis was executed to estimate the smallest sample size needed with a power of 80% and an f^2 effect size of .15 (lower border of medium), which found a total of *N* = 55 participants. Another power analysis was executed to calculate the power with the current number of participants (*N* = 63), and a power of 86% was found. There was no missing data, except for some irregularities on the heartbeat data in the HDT. More specifically, nine participants had data with poor signal quality in some trials of the HDT. These trials were not excluded from all analyses, but separate analyses with and without those trials were conducted.

Participants were recruited through the participant management tool, Sona Systems (https://www.sona-systems.com/), used by Leiden University. Participants could sign up voluntarily in exchange for three participation credits, which were needed for first year social and behavioural sciences students to pass their first year. Prior to starting the experiment, a written informed consent was obtained from all participants. At the end of the experiment, participants received a written debriefing. This study was approved by the Leiden University ethical review board (CEP number: 2022-03-11-M.E. Kret-V2-3838, date of approval: 11-03-2022).

Procedure

Upon entering the laboratory, participants first read the information letter and signed an informed consent form. Then, they were briefly informed about the experiment they would perform. The experiment consisted of two tasks, a 10-minute emotion recognition task and a 15-minute heartbeat discrimination task and concluded with six questionnaires taking approximately 25 minutes (more information on the questionnaires under *Questionnaires*). Before each task, electrodes to measure physiological signals were attached to the participants (see *Materials and measuring instruments*). During the tasks and the questionnaires, the researcher left the room.

Emotion recognition task. The emotion recognition task is not of main interest for the current study and, therefore, is only briefly described. Participants were asked to view short clips of emotional expressions of different male and female individuals. Afterwards, they were asked to label the emotion (five categories: angry, happy, fearful, sad, neutral), assess its intensity, and rate their confidence of the estimation. The intensity and confidence were measured through a visual analogue scale (VAS). The task consisted of 60 trials. Facial muscle activity was measured through five electrodes attached to the face.

Heartbeat discrimination task. In the HDT, participants were given written instructions of the task on the stimulus PC. They were told not to feel their pulse but rather to try to feel their heartbeat internally. Participants were asked to press the "d" key if the tones were in sync with their own heartbeat or to press the "k" key if the tones were out of sync with their heartbeat. At the beginning of the task, a baseline ECG activity was recorded while participants viewed a calming oceanic video of two minutes. After this video, participants were asked to perform five practice rounds. In each practice round, they were asked to discriminate whether five tones were played in sync with an image of a black dot. After the practice rounds, if participants had no further questions, the main task began.

For the main task, participants were asked to judge whether their heartbeat was synchronised to a series of external “feedback” tones. A delay of 200 msec is perceived as “in sync” due to a delay in perceiving one’s own heartbeat evoked brain potentials, and a delay of 500 msec is perceived as “not in sync” (Wiens & Palmer, 2001). This feedback was recorded through an ECG, measuring their heartbeat with two electrodes attached to their chest and one to their collarbone. To create the heartbeat feedback, we identified the R-peak in the ECG recording and played auditory tones with the respective delay after each of the five consecutive R-peaks. After judging whether their heartbeat was synchronised with the external feedback tones, participants were asked to rate the confidence of their choice via a VAS. On the VAS, participants could adjust the dot on a ten-centimetre-long scale with a mouse and indicate their confidence. The VAS counted two extremes, with a text displaying “total guess (no heartbeat awareness)” at one end and “complete confidence (full heartbeat awareness)” at the other end. The task consisted of 60 trials: 30 trials in each condition.

At the end of the task, participants were asked to fill in several questionnaires (see *Questionnaires*). Afterwards, they received a debriefing form including relevant information and the goals of the study. If there were no further questions, the participants were thanked and accompanied out of the building. The whole experiment lasted an average of 80 minutes.

Materials and measuring instruments

Apparatus. For the tasks, stimuli were displayed on a Philips 243S monitor at 60Hz, placed 60 centimetres in front of the participants. A BIOPAC MP150 (Goleta, California, BIOPAC Systems) recording device was used to record all physiological signals. Since the emotion recognition task is not of importance for this project, only a brief description of the apparatus will be given. An EMG2-R module was used to measure facial electromyography (fEMG) in the corrugator supercilii region (the frowning muscle) and zygomaticus major region (the smiling muscle) with five electrodes in total. A BIOPAC Nomadix transmitter headband (Goleta, California, BIOPAC Systems) was used to transmit the signals to the EMG2-R module. The task was presented using E-Prime 3.0 software (Psychology Software Tools, Pittsburgh, PA).

For the interoception task, an ECG100C module was used to measure the electrocardiogram (ECG) with three Ag/Cl disposable isotonic BIOPAC electrodes attached to the body: one electrode on the lowest left rib, and two electrodes on the right; one below the lowest ribcage and one under the right collarbone of the participant. Prior to the electrode attachment, NuPrep gel was applied to clean the skin for the electrodes. This was done to clear the skin of any possible disturbances to the signal. A headphone to transmit audio to the participant and a speaker to adjust the volume were provided. For the feedback of the physiological signals, the detected peaks in ECG recordings (BIOPAC) were forwarded to the Arduino. There, the respective delay was inserted, and the signal was provided as audio output both to the participant and fed back into the BIOPAC to have a control recording of the feedback. Physiological measures were recorded with the acquisition software AcqKnowledge 5.0 (Goleta, California, BIOPAC Systems).

Questionnaires. The questionnaires which were used in the study were the AQ, LSAS-SR, IAS, IATS, BPQ awareness subscale and TAS-20. The questionnaires were meant to measure several personality and clinical traits, and their relationship to their body. In all questionnaires, a high score indicated a high level of the respective measured characteristic. The responses to the questionnaires were acquired using Qualtrics software, an online questionnaire platform (Qualtrics, Provo, UT).

The questionnaires of interest to this thesis were the AQ and the BPQ awareness subscale and will therefore be described in more detail than the others.

The Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001) is a questionnaire which quantifies the extent to which an individual with normal intelligence has traits associated with ASD. The AQ contains 50 items in which a range of 0 to 50 points can be scored in total. It assesses five different areas: social skill (items 1, 11, 13, 15, 22, 36, 44, 45, 47, 48), attention switching (items 2, 4, 10, 16, 25, 32, 34, 37, 43, 46), attention to detail (items 5, 6, 9, 12, 19, 23, 28, 29, 30, 49), communication (items 7, 17, 18, 26, 27, 31, 33, 35, 38, 39), and imagination (items 3, 8, 14, 20, 21, 24, 40, 41, 42, 50). It contains statements like “I find it difficult to work out people’s intentions” and participants indicate in what degree they agree to this on a four-point scale. The possible responses are 1 “Definitely agree”, 2 “Slightly agree”, 3 “Slightly disagree”, and 4 “Definitely disagree”. One point is scored when the response resembles the answer that is most associated with a high scoring individual with ASD. After reverse-coding some items, the responses of 1 and 2 are recoded to 0 points and the responses 3 and 4 are recoded to 1 point. Next, items are summed, with higher scores indicating greater levels of autistic traits. A reliability analysis was performed to assess the reliability of the AQ. The Cronbach’s alpha with a confidence interval of 95% was calculated before recoding the answers into zeros and ones and was medium for the AQ ($\alpha = .70$).

The Body Perception Questionnaire awareness subscale (BPQ, Porges, 1993) measures self-reported body awareness and autonomic reactivity. The original BPQ contains 122 questions divided over five areas: awareness, stress response, autonomic nervous system reactivity, stress style, and health history inventory. For this study, the awareness section of the BPQ containing 45 items on bodily sensations was administered, with scores ranging from 45 to 225. It contains statements like “During most situations I am aware of… noises associated with my digestion” and participants indicate how often they experience this on a five-point scale. Each item of the awareness subscale has to be answered on a five-point scale: a “Never”, b “Occasionally”, c “Sometimes”, d “Usually”, and e “Always”, in which “a” designates a score of 1 and “e” a score of 5. A reliability analysis was performed to assess the reliability of the BPQ awareness subscale. The

Cronbach’s alpha with a confidence interval of 95% was for high for the BPQ awareness subscale (α = .92).

The self-report version of the Liebowitz Social Anxiety Scale (LSAS-SR, Liebowitz, 1987) evaluates the self-reported extent of social anxiety traits of an individual. It contains 24 items.

The Interoceptive Accuracy Scale (IAS, Murphy et al., 2019) consists of 21 items, measuring the accuracy to which one perceives their own bodily signals without external cues.

To assess the degree of attentiveness of one’s perceived bodily signals, the Interoceptive Attention Scale (IATS, Gabriele et al., 2021) can be used, also including 21 items.

The twenty-item Toronto Alexithymia Scale (TAS-20, Bagby et al., 1994) is a self-report measure of alexithymia traits. An individual with alexithymia is characterised by having varying degrees of difficulties in identifying and verbalising one’s emotions and internal bodily sensations (Shah et al., 2016; Zamariola et al., 2018). The TAS-20 includes 20 items with statements regarding feelings.

Data pre-processing and statistical analyses

For the analysis on interoceptive awareness, the raw ECG data was pre-processed in the PhysioData Toolbox software (Kret & Sjak-Shie, 2019). All ECG recordings were visually inspected for irregularities to check whether the recordings can be used for analyses. For each recording in which irregularities were observed, the trial was noted down in an excel file, so that they could potentially be accounted for. The analyses were performed including and excluding those trials. In total, 24 trials were excluded, which is .6% of all trials (60x63).

The statistical programming software R (R Core Team, 2014) was used for further pre-processing and for analysing the data from the HDT, AQ and BPQ awareness subscale. A complete version of the R Markdown script to pre-process and analyse the data can be found at the online Open Science Framework (OSF, Boom, 2022).

For the interoception data, some pre-processing steps were needed to evaluate the accuracy. For each participant, the accuracy was calculated by dividing the number of correct responses by the total number of responses.

To quantify the correspondence between the accuracy, as measured through the scores on the HDT, and the associated confidence ratings on each trial, i.e., interoceptive awareness, a ROC curve analysis was performed. A ROC curve analysis reflects accuracy as a measure of decision performance, called decision threshold effect (Metz, 1978). It determines the strength with which one binary response (correct vs. incorrect discrimination) mirrors a continuous response (ranging from high to low confidence) at all possible detection thresholds. First, a hit rate (correct discrimination and high reported confidence) and false alarm rate (incorrect discrimination and high reported confidence) are determined. The ROC curve then plots the hit rate and the false alarm rate over all the possible detection thresholds. The area under the curve (AUC) of the ROC provides a measure of the extent to which confidence reflects accuracy. A score above .5 indicates above-chance performance, and a score below .5 indicates below-chance performance.

For the AQ and BPQ awareness subscale questionnaires, the total scores were calculated according to the respective questionnaire scoring guidelines.

To test our first hypothesis on whether lower interoceptive awareness was associated with higher autistic trait levels in our sample, we ran a linear regression analysis. As according to our second hypothesis to test whether lower interoceptive sensibility was associated with higher autistic trait levels, we also ran a linear regression analysis. Four assumptions had to be checked: linearity, homogeneity of variances, normality of residuals and independence of errors. Linearity was checked through a scatterplot, where the residuals were plotted against the predicted values. The assumption of linearity was met for both analyses. For the assumptions of homogeneity of variances, a scatterplot was created where the root of the absolute standard residuals was plotted against the predicted values. The plot showed that the assumption of homogeneity of variances had too little evidence to be rejected. Normality of residuals was checked through a P-P plot, with a line that followed the dots, and it showed that there were no standard residuals with that deviated more than 1. Therefore, the assumption of normality of residuals was met. Independence of errors was assured by the design of the study. In conclusion, no violations of assumptions were found (see Appendix A). The assumptions were neither violated for the analyses with the interoception indices when irregular trials were excluded. Influential observations were checked by plotting the standard residuals against the leverage values, and the plot showed no influential observations, thus no outliers were detected.

Results

Descriptive statistics

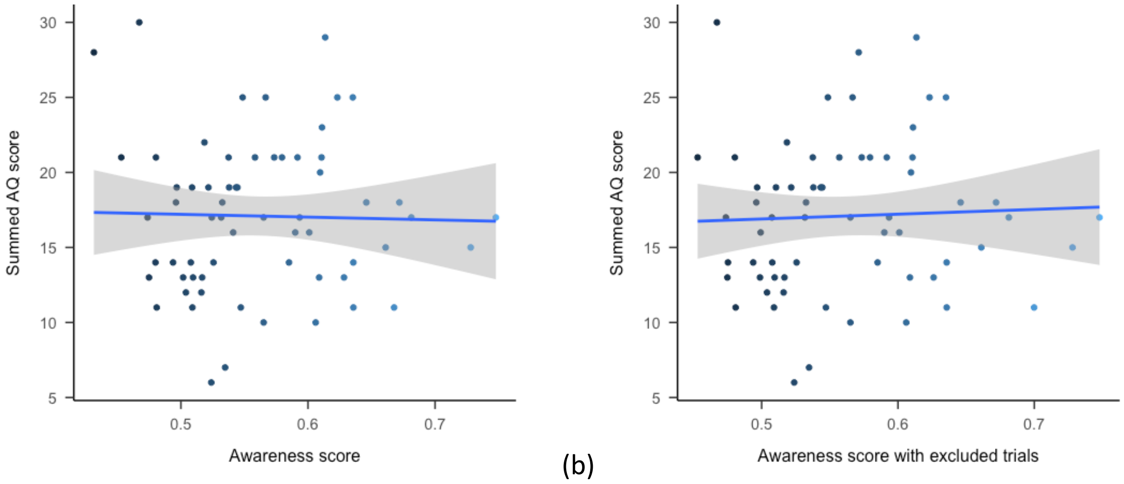
Autistic traits scores in our sample ranged from 6 to 30 (M_{AQ} = 17.2, SD_{AQ} = 5.2). Since most of the participants scored quite low on autistic traits, this was represented by the slight skew (.29) to the right of the distribution and a low kurtosis (2.81). Participants obtained interoceptive awareness scores ranging from .43 to .75 (M_{Aw} = .56, SD_{Aw} = .07), which was the same for the analyses including all trials and the analyses excluding the irregular trials. The awareness data followed a normal distribution. It was slightly skewed to the right (.57) and appeared to have a normal kurtosis (2.94). Interoceptive sensibility scores in our sample ranged from 79 to 197 (M_{BPQ} = 137.7, SD_{BPQ} = 24.6). The data was distributed close to normally. A slight skewness to the right was visible (-.08) and a low kurtosis (2.78) was present. For a visualisation of the data, see Appendix A.

Relationship between interoceptive awareness and autistic traits

To examine the relationship between interoceptive awareness, as measured by a ROC curve analysis, and autistic traits, as measured by the AQ, two simple regression analyses were performed: one including all the trials and one excluding the trials with irregularities. For the first analysis, the F-test was not significant (β = -.02, 95% CI [-.28, .23], F(1,61) = .04, p = .85). Thus, interoceptive awareness scores did not show to be a significant predictor of autistic trait level (see also Figure 1).

Figure 1

Linear models of the relationship between interoceptive awareness and autistic trait scores



(a)

(b)

Note. Both plots include the results of 63 participants, with the summed AQ score reflecting autistic trait level scores. a) shows the trend between the summary scores on the AQ and the interoceptive awareness scores, b) shows the same, but with the excluded irregular trials of interoceptive awareness.

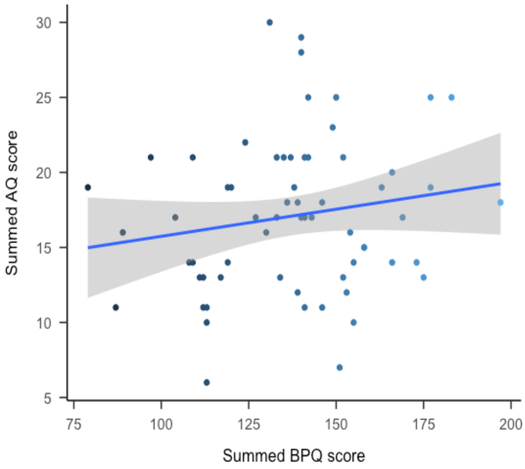
For the analyses excluding the trials with irregularities, the F-test was also not significant (β = .04, 95% CI [-.21, .30], *F*(1,61) = .11 *p* = .75). This implies that interoceptive awareness scores did not show to be a significant predictor of autistic trait levels, even when correcting for the irregular trials in the HDT task (see also Figure 1b).

Relationship between interoceptive sensibility and autistic traits

For the examination of the relationship between interoceptive sensibility, as measured by the BPQ awareness subscale, and autistic traits, as measured by the AQ, we conducted a simple regression analysis. The F-test was not significant (β = .17, 95% CI[-.08, .42], *F*(1,61) = 1.87, *p* = .18), which indicates that the interoceptive sensibility scores did not show to be a significant predictor of autistic trait levels (see Figure 2).

Figure 2

Linear model of the relationship between interoceptive sensibility and autistic trait scores



Note. The plot includes the summarised results of 63 participants on the BPQ awareness subscale, reflecting interoceptive sensibility, and the AQ, which reflects autistic trait level scores.

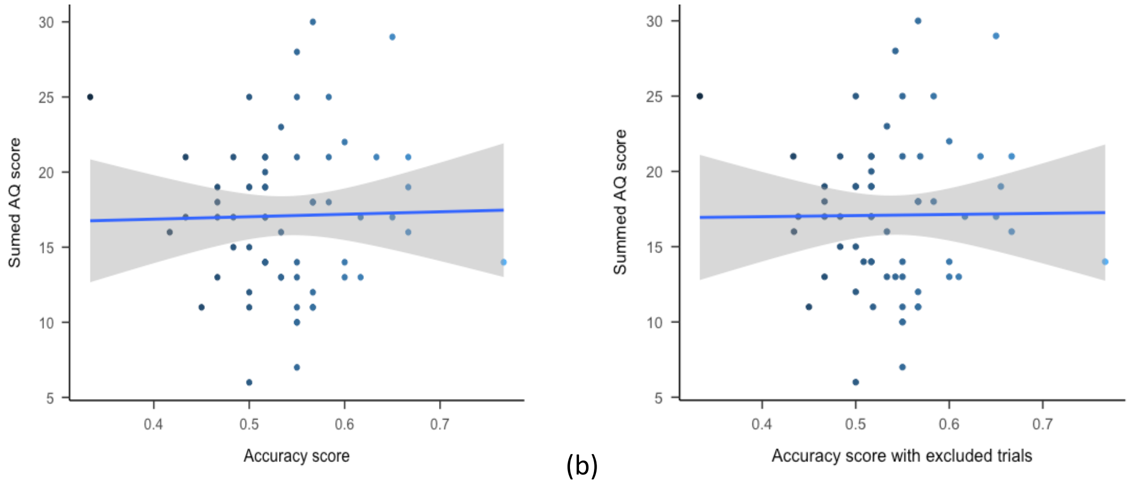
Exploratory analyses

As our results did not turn out as expected, i.e., interoceptive awareness and interoceptive sensibility did not show to be significant predictors of autistic trait levels, we ran two additional analyses which might be interesting to further investigate in future research.

Interoceptive accuracy. Drawing on former studies reporting significant relationships between autistic trait levels and interoceptive accuracy (Garfinkel et al., 2016; Noel et al., 2018), an exploratory analysis was performed to see whether autistic trait levels were negatively related to interoceptive accuracy. We had already calculated the interoceptive accuracy for calculating the interoceptive awareness (M_{Acc} = .54, SD_{Acc} = .07, range: .33-.77). The scores were the same for the analysis including all trials and the analysis excluding the irregular trials. The accuracy data was approximately normally distributed, with a skewness to the right (.32) and a high kurtosis (4.44). To examine the relationship between interoceptive accuracy and autistic trait levels, two simple regression analyses were conducted: one including all the trials and one excluding the trials with irregularities in the HDT. For the analyses including all the trials, the F-test was not significant (β = -.02, 95% CI[-.23, .28], $F(1,61)$ = .03, p = . 86), which implies that interoceptive accuracy scores did not show to be a significant predictor of autistic trait levels (see also Figure 3a).

Figure 3

Linear models of the relationship between interoceptive accuracy and autistic traits



(a) (b)

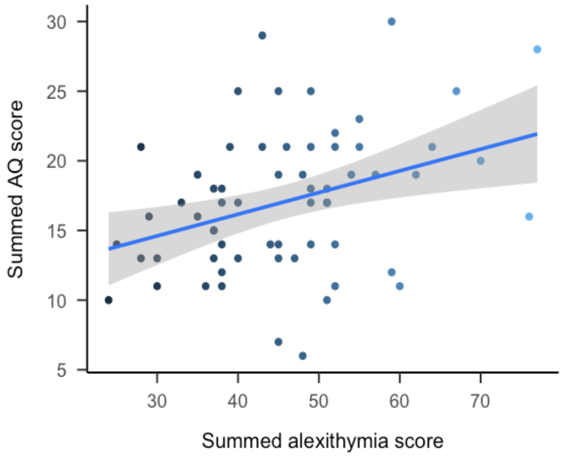
Note. Both plots include the results of 63 participants, with the summed AQ score reflecting autistic trait level scores. a) shows the trend between the summary scores on the AQ and the interoceptive accuracy scores, b) shows the same, but with the excluded irregular trials of interoceptive accuracy.

For the analyses excluding the trials with irregularities, the F-test was also not significant ($\beta <$ .001, 95% CI[-.25, .27], $F(1,61) = .006$, $p = .94$), which indicates that interoceptive accuracy scores did not show to be a significant predictor of autistic trait levels, even when accounting for the irregular trials of the accuracy scores (see also Figure 3b).

Alexithymia. Based on previous literature reporting a significant positive relationship between autistic traits and alexithymia (Mul et al., 2018; Shah et al., 2016), an exploratory analysis was carried out to see whether scores on the AQ were positively related to alexithymia in our sample. Since previous literature has suggested that alexithymia and ASD have been closely related, a more grounded conclusion than with the previous variables could be established from our results. Thereby, alexithymia scores in our sample ranged from 24 to 77 ($M_{Alexi} = 46.0$, $SD_{Alexi} = 11.6$). The alexithymia data followed a normal distribution, with a skewness to the right (.47) and a normal kurtosis (3.18). Cronbach's alpha with a confidence interval of 95% was for high for the TAS-20 ($\alpha =$ .83). A linear regression analysis resulted in a significant F-test ($\beta = .35$, 95% CI[.11, .59], $F(1,61) =$ 8.71, $p = .004$), which implies that alexithymia levels showed to be a significant predictor of autistic trait levels. Moreover, higher alexithymia scores were associated with higher autistic trait levels (see Figure 4).

Figure 4

Linear model of the relationship between alexithymia levels and autistic trait levels



Note. The plot includes the summarised results of 63 participants on the TAS-20, measuring alexithymia levels, and the AQ, which reflects autistic trait level scores.

Discussion

The present study aimed to test whether there would be significant relationships between autistic traits and interoceptive ability, namely interoceptive awareness, as measured through the performance on the HDT and the associated confidence ratings, and interoceptive sensibility, as measured through the score obtained on the BPQ awareness subscale. Although all our findings were not statistically significant, we did observe a slight trend that was in line with our expectations: individuals with a higher score on autistic traits tended to score lower on interoceptive sensibility.

As our first hypothesis, we expected a negative relationship between higher levels of autistic traits and interoceptive awareness, but no trend was observed. This result could suggest that a negative relationship might indeed exist, but that a significant effect might only be detected under other circumstances, or with different methods. As interoceptive awareness consists of the correspondence between interoceptive accuracy and associated confidence levels, the choice of the method for measuring the former could have an influence on the results. For measuring interoceptive accuracy, which is fundamental to calculating the interoceptive awareness, the HDT was used for this study. While this is a frequently used method for assessing interoceptive accuracy, some studies have used different methods. Another common method is the heartbeat tracking task (Forkmann et al., 2016; Garfinkel et al., 2016; Noel et al., 2018; Terasawa et al., 2014; Yang et al., 2022; Zamariola et al., 2018). The main difference between the HDT and the heartbeat tracking task is that in the latter, participants count their heartbeats during a given time, without manually checking their own heartbeat. Furthermore, Forkmann et al. (2016) have found that the HDT was better at assessing interoceptive awareness than the heartbeat tracking task. They speculated that this may be due to the multisensory integration nature of the HDT. They argued that for the heartbeat tracking task, the confidence judgements may be biased by one’s own beliefs about their heartrate as well as the difficulty of judging the length of the time intervals. Whereas for the HDT, one must be aware of multisensory integration (i.e., awareness of their own heartbeat in combination with listening to the feedback tones). Moreover, they link potential differences in results to methodological characteristics, such as the number of trials on the tasks, the scale on which confidence is measured (VAS vs. Likert), and whether the questionnaires were assessed non-digitally vs. digitally. Some studies have calculated the awareness from both the heartbeat tracking task and the HDT (Forkmann et al., 2016; Garfinkel et al., 2015). For the heartbeat tracking task, they have used Pearson's r correlations to calculate awareness. In another study, Garfinkel et al. (2016) performed both the heartbeat tracking task and the HDT in an autistic and neurotypical sample. They have found that participants in the autistic sample performed significantly lower on the heartbeat tracking task compared to the neurotypical sample. For the HDT, the interoceptive accuracy was also more diminished in the autistic sample compared to the neurotypical sample. Considering that interoceptive accuracy was lower in the autistic sample in both tasks, this would suggest that with the HDT an effect should be found. Nevertheless, seeing that they used a different population, the difference with our results could be explained, even though they follow the same negative trend. One study performed a meta-analysis to dissect the differences between the heartbeat tracking task and the HDT (Hickman et al., 2020). The authors have found a small correlation between the interoceptive accuracy of both measures, but they have found no correlation between the interoceptive awareness of both measures. They have suggested that it is hard to generalise interoceptive awareness between tasks and that careful consideration should be taken when interpreting the results of interoceptive awareness when it is assessed through one single task (Hickman et al., 2020). Moreover, they have argued that a minimum of 100 trials are needed to accurately measure interoceptive awareness. One study has investigated the heartbeat tracking task in both an autistic and neurotypical population and has found that autistic individuals as well as neurotypical individuals scoring high on autistic traits performed worse on the heartbeat tracking task than neurotypical individuals scoring low on autistic traits (Noel et al., 2018). Their results suggest that a difference in interoceptive accuracy can be found between individuals high and low on autistic trait levels when using the heartbeat tracking task. In other studies, no differences in the performance on the heart tracking task have been found between an autistic and neurotypical sample (Forkmann et al., 2016, Nicholson et al., 2019). Since other studies have used a heartbeat tracking task instead of a HDT, this might be an explanation as to why different results on interoceptive accuracy as well as interoceptive awareness were found. In short, results could have been interpreted differently because different methods were used. To conclude, after careful consideration of all the points, interoceptive awareness does not seem to differ with higher autistic trait levels.

As our second hypothesis, we expected a negative relationship between autistic trait levels and interoceptive sensibility. Our results were non-significant, but unexpectedly, there was an indication that the relationship between autistic trait levels and interoceptive sensibility might instead be positively related. For measuring interoceptive sensibility, the BPQ awareness subscale was used in this study. Garfinkel et al. (2016) has also used the awareness subscale from the BPQ to measure interoceptive sensibility, and they have found that autistic participants scored generally higher on the BPQ than neurotypical participants. This is different from our results and could be explained by the given that they compared autistic participants with neurotypical participants, while in our study all participants were neurotypical participants. Moreover, most studies have used different questionnaires, such as the MAIA, to measure interoceptive sensibility (Mul et al., 2018; Yang et al., 2022; Zamariola et al., 2018). As mentioned in the introduction, the MAIA is different from the BPQ in that it mostly targets elements of regulation and appraisal of bodily sensations, whereas the BPQ puts focus on a larger scope of elements (i.e., awareness, stress response, autonomic nervous system reactivity, stress style, and health history inventory). More specifically, the MAIA differentiates between multiple forms of interoceptive sensibility, mainly between “adaptive” and “maladaptive” forms in eight subscales (Mehling et al. 2012). A high score on the MAIA has been argued to be adaptive (i.e., having the ability to reduce distress by attending to one’s bodily sensations) whereas a high score on the BPQ awareness subscale can be viewed as maladaptive, mostly because it focuses on symptoms associated with anxiety (Yang et al., 2022). Namely, the BPQ awareness subscale assesses an individual’s general tendency to notice and be aware of their bodily sensations, which can lead to worrying or ruminating about one’s own bodily sensations (Mehling et al., 2012). Mul et al. (2018) have found a significant negative relationship between interoceptive sensibility (as measured via the MAIA) in autistic participants compared to neurotypical participants, which is in line with our initial hypothesis. Moreover, they have explicitly stated a strong negative correlation between performance on the MAIA and autistic trait levels, as measured through the AQ. Their clinical vs. non-clinical participant pool in combination with a different measure of interoceptive sensibility might explain the differences in our results compared to theirs. Nonetheless, Yang et al. (2022) have also used the MAIA to measure interoceptive sensibility in their sample and have found no significant relationship between their high and low autistic subgroups on interoceptive sensibility, comparable to our results. Aside from the BPQ and MAIA questionnaires, Zamariola et al. (2019) have used another questionnaire for measuring interoceptive sensibility: the BAQ. The BAQ contains items focused on measuring self-reported awareness to bodily signals. In their study, they have focused on the relationship between interoceptive sensibility and alexithymia, and they have found negative relationships between interoceptive sensibility, as measured through both MAIA and BAQ, and alexithymia scores (Zamariola et al., 2019). When using the BAQ, negative relationships between interoceptive sensibility and alexithymia have been found. Since alexithymia is generally positively related to autistic traits, as well in our study, the results acquired with the BAQ might also be indicative of results with autistic traits. The fact that the MAIA and BAQ measure different aspects of interoceptive sensibility (adaptive vs. maladaptive) might be related to the contradicting results found in our study and in previous literature. While we found no relation between interoceptive sensibility and autistic traits, and thus no indication for a relation between interoceptive sensibility and ASD, prior research has shown that interoceptive sensibility is correlated to autistic traits (Mul et al., 2018; Zamariola et al, 2019). Another conflicting result that we found is the indication of a positive trend between the level of autistic traits and interoceptive sensibility, while we expected a negative trend. Even though the relationship is non-significant, it is still questionable how some interoceptive concepts are negatively correlated to autistic traits and some positively. This indication of a positive trend might be at random, since the beta value in the analysis is very small.

To summarise, after considering all the points, our results indicate that interoceptive sensibility does not differ with higher autistic trait levels.

Moreover, two exploratory analyses were conducted which were initially not the primary interest. A first exploratory analysis examined the relationship between the level of autistic traits and interoceptive accuracy. Many studies have looked at interoceptive accuracy and its relationship to ASD before (Forkmann et al., 2016; Garfinkel et al., 2015; Garfinkel et al., 2016; Noel et al., 2018; Terasawa et al., 2014; Yang et al., 2022; Zamariola et al., 2018), and therefore we decided to investigate its relationship with autistic traits levels. In conclusion, in our sample, interoceptive accuracy did not seem to be related to autistic trait levels, which was surprising given previous literature. As mentioned before, a possible reason for the discrepancy between our results and previous literature could be the different measures for interoceptive accuracy.

A second exploratory analysis examined the relationship between autistic traits levels and alexithymia, to see whether it would be an interesting regard to investigate in future studies. As previously pointed out, alexithymia has been generally positively related to autistic traits (Shah et al., 2016). In their study, neurotypical participants completed the TAS-20, the AQ and a heartbeat tracking task. Although their results have indicated that alexithymia levels are associated with autistic trait levels as well as impaired interoceptive accuracy, they have found no direct relation between autistic trait levels and interoceptive accuracy. This implies that there must be a difference between alexithymia levels and autistic trait levels, but since this was not examined in our study, we encourage other researchers to investigate this. Nevertheless, their results are in line with our results, as our analysis revealed a significant positive relationship between autistic trait levels and alexithymia levels, suggesting that higher alexithymia trait levels were related to higher autistic trait levels. Furthermore, autistic individuals generally have higher alexithymia levels than neurotypical individuals (Mul et al., 2018). Followingly, the TAS-20 might be a better predictive screening measure for ASD, instead of interoceptive ability. This assumption could be further investigated.

Limitations

Several limitations might explain the discrepancies between our expectations and the results. The first limitation is the medium Cronbach's alpha for the AQ (α = .70). An alpha between .7 and .8 is usually considered as acceptable, so this means that our Cronbach's alpha is at the lower border of medium. The Cronbach's alpha is a measure of internal consistency (thus, reliability), and a low Cronbach's alpha could be caused by a low number of items, poor inter-relatedness between items or heterogeneous constructs (Tavakol & Dennick, 2011). In this case, it is not clear why the Cronbach's alpha is at the lower border since the AQ contains 50 items. Therefore, the value of the Cronbach's alpha might be explained by the inter-relatedness between items or heterogeneous constructs.

A second limitation was that for this study, we strictly looked at a healthy population. None of the participants even reached the cut-off score of 32 points on the AQ, which indicates that they did not report high levels of autistic traits. The question thus remains whether the results would also apply to a clinical population. Moreover, the sample existed of mostly first year psychology students, of which most were Dutch and/or female. The nature of the sample might have influenced the results. This is mostly visible in previous research, where neurotypical groups were compared with clinically diagnosed ASD groups (Forkmann et al., 2016; Garfinkel et al., 2015; Mul et al., 2018). These studies have found that the groups differed significantly from each other in autistic trait levels, while this difference is not present in our study. This difference in autistic trait levels could be an explanation as to why we did not find interoceptive ability a predictor of autistic traits.

A third limitation might be that the tasks were not sufficient in measuring the respective dimensions of interoception. The HDT might have been too difficult, as one study pointed out that subjects are unable to discriminate their own heartbeat without proper training (Katkin et al., 1982). Considering that our participants were not trained in discriminating their own heartbeat, this might explain the frequent low scores on the HDT in our sample.

In addition, as seen in other studies, an option is to divide the sample into two groups to do a comparison study, as other studies have found significant differences between groups when doing so (Forkmann et al., 2016; Garfinkel et al., 2015; Mul et al., 2018). Many studies have divided their sample into individuals scoring high vs. low on the AQ, or high vs. low HDT perceivers. A problem with this, is that the validity of the study will be reduced. This preselection of participants might influence the results, and the cut-off score for dividing the participants into groups can be arbitrary. Moreover, a distribution with data mainly at the extremes is needed for a comparison study, whereas in our sample we have a normal distribution. Therefore, it is recommended to look at our variables as continuous variables.

Though not being our main focus initially, alexithymia is often considered when discussing ASD and interoception. ASD might be a concept that is too broad on itself and moreover, co-existing with other factors from other disorders, to be able to be predicted by a single test. However, distinct components of ASD might be specific enough to predict ASD, such as alexithymia. Future research could discern between the different components associated with ASD, as a more specific angle could provide a clearer view of existing relationships between variables.

Conclusion

In conclusion, interoceptive ability (interoceptive awareness as well as interoceptive sensibility) did not seem to be related to autistic trait levels in our study. Our results are mostly not in line with previous studies which found mainly negative relationships. However, in contrast to these studies in clinical populations, our sample existed of a neurotypical population with a tendency towards low scores on autistic traits. In such a healthy population, the chosen measurements, i.e., BPQ awareness subscale and HDT, might not be suitable for using as a screening instrument for ASD. However, it would be interesting to further investigate it in a clinical population, as previous literature has shown significant relationships between autistic trait levels and interoceptive ability in such a population. Nevertheless, our results provide to the growing body of knowledge on interoception in ASD. In addition, alexithymia trait levels proved to be predictive of autistic trait levels. Therefore, future research could investigate whether a measure for alexithymia levels (i.e., the TAS-20) could be used as a predictive screening tool for ASD.

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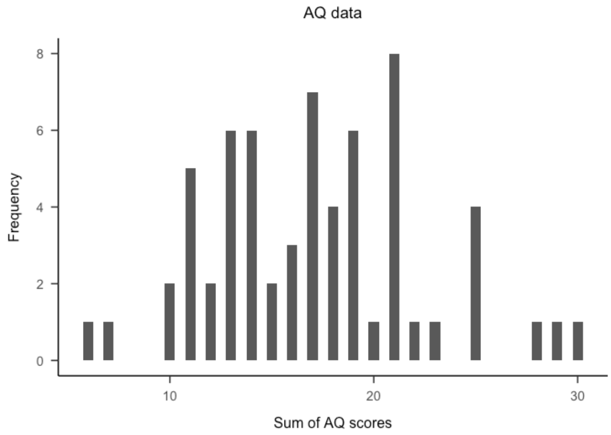
Appendix A

Visualisation of the data

Figure 1

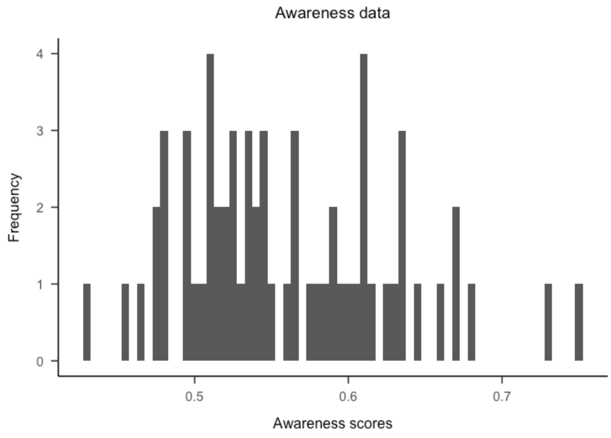
Distribution of the AQ data (N = 63)



Note. The frequency of the summed AQ scores, measuring autistic trait levels through a questionnaire.

Figure 2

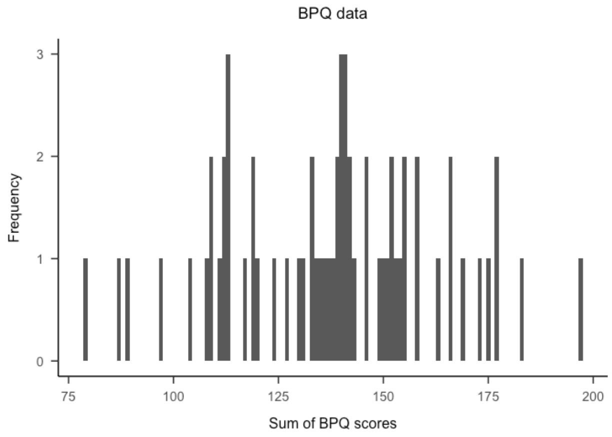
Distribution of the awareness data (N = 63)



Note. The frequency of the summed awareness scores, which is the interoceptive awareness assessed through the correspondence between the interoceptive accuracy (as measured through the HDT) and the associated confidence ratings.

Figure 3

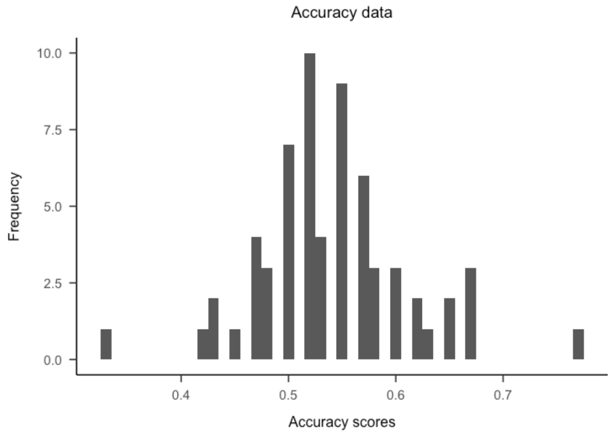
Distribution of the BPQ awareness subscale data (N = 63)



Note. The frequency of the summed BPQ awareness subscale scores, as measured through a questionnaire for assessing interoceptive sensibility.

Figure 4

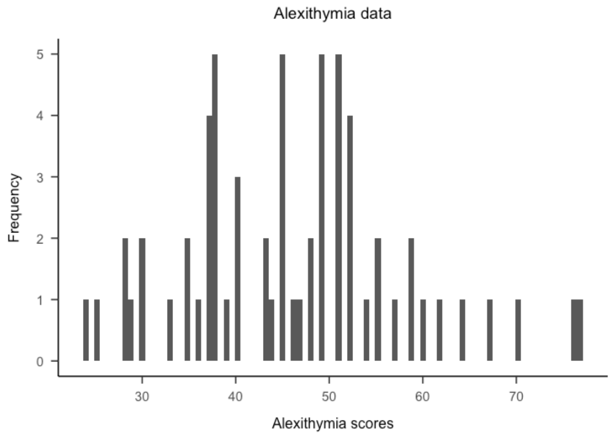
Distribution of the accuracy data (N = 63)



Note. The frequency of the summed accuracy scores, which assesses interoceptive accuracy through the performance on the HDT.

Figure 5

Distribution of the alexithymia data (N = 63)



Note. The frequency of the summed alexithymia scores, as assessed by the TAS-20 questionnaire.

Figure 6

Plots for checking assumptions of the AQ (outcome) - Awareness (predictor) model for regression analysis

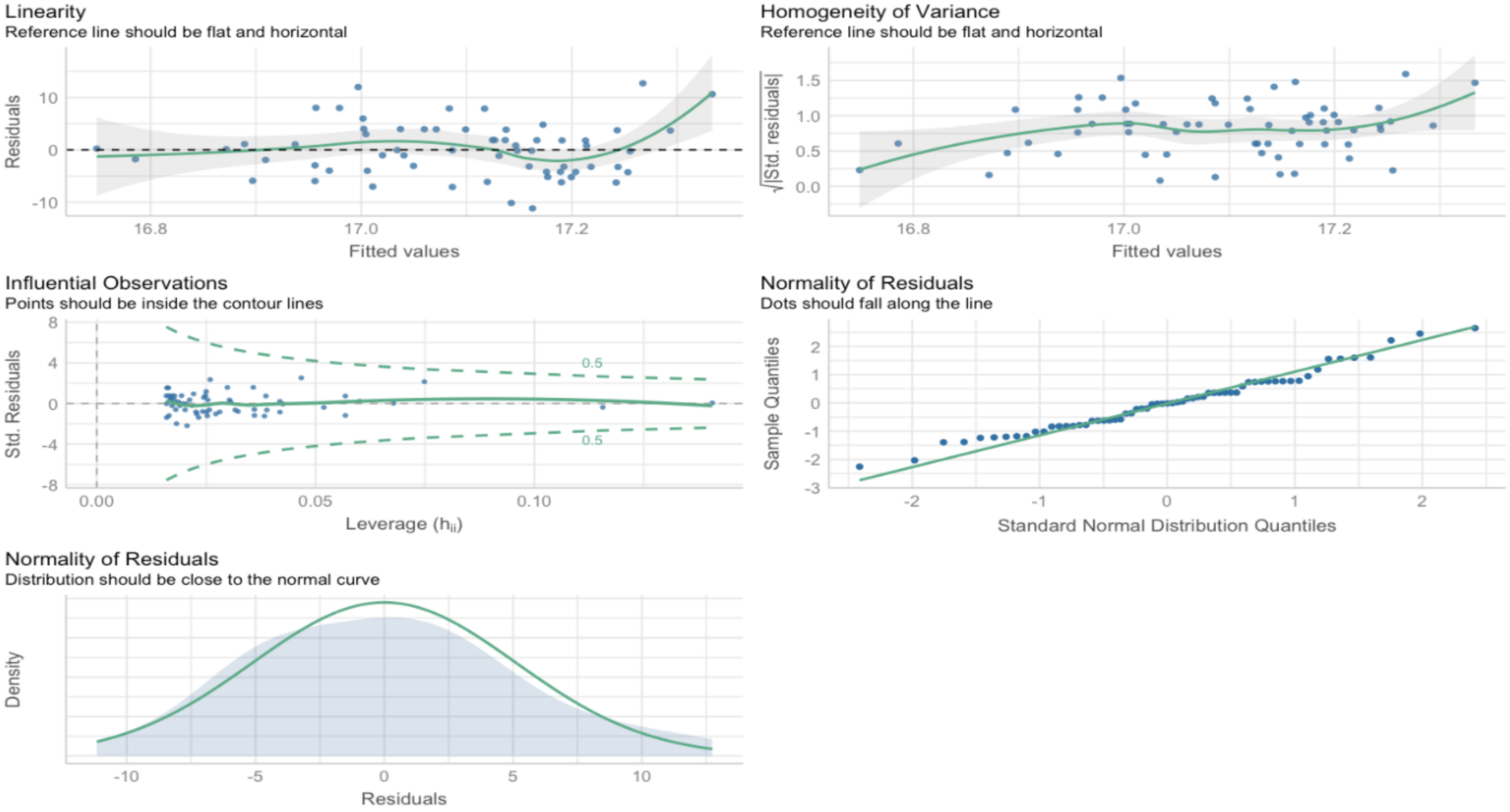
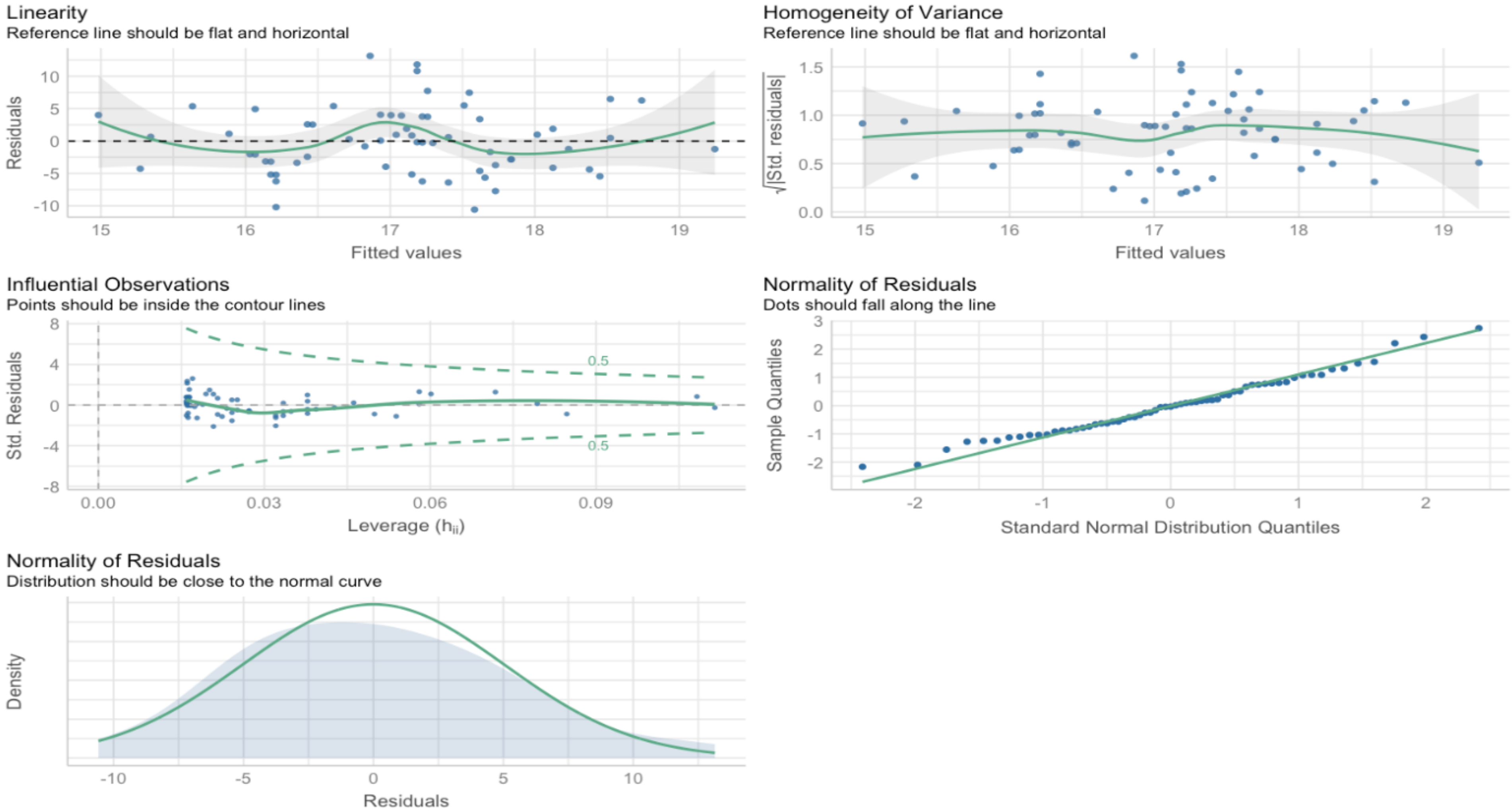


Figure 7

Plots for checking assumptions of the AQ (outcome) - BPQ (predictor) model for regression analysis



Linearity
Reference line should be flat and horizontal

Homogeneity of Variance
Reference line should be flat and horizontal

Influential Observations
Points should be inside the contour lines

Normality of Residuals
Dots should fall along the line

Normality of Residuals
Distribution should be close to the normal curve

Figure 8

Plots for checking assumptions of the AQ (outcome) - Accuracy (predictor) model for regression analysis

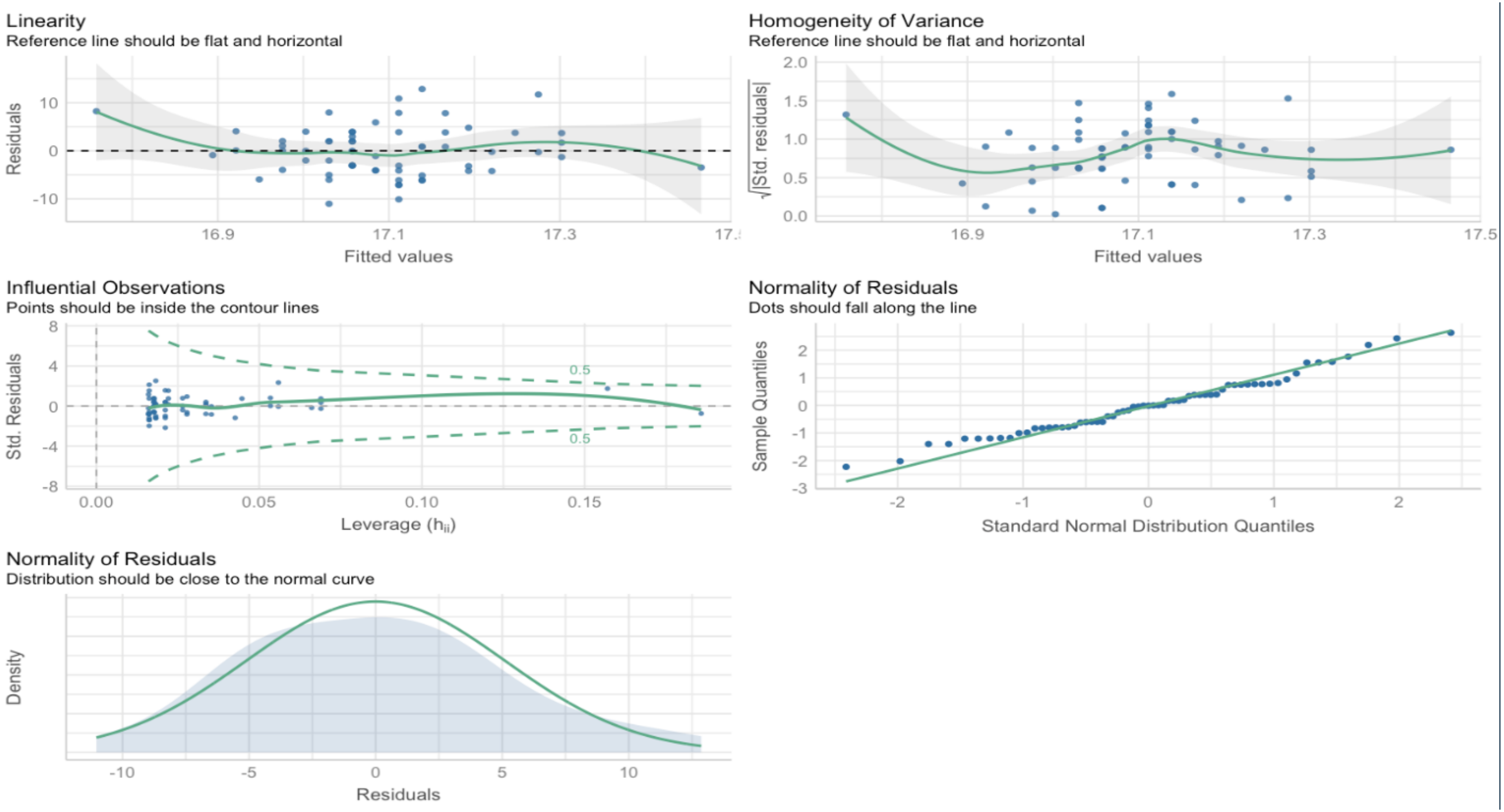


Figure 9

Plots for checking assumptions of the AQ (outcome) - Alexithymia (predictor) model for regression analysis