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ORIGINAL PAPER

The Impact of a Short Body–Focused Meditation on Body Ownership and Interoceptive Abilities

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Abstract

Objectives The aim of the present study was to investigate the effects of a brief body-focused meditation on body ownership, while considering interoceptive abilities, dissociative experiences, mood, trait mindfulness, and meditation experience.

Method The sample consisted of 111 healthy students who participated in a randomized controlled trial and either listened to a 20-min meditation or audio-book reading. Before and after the intervention, the rubber hand illusion and a heartbeat detection task were completed. The rubber hand illusion consisted of a synchronous and an asynchronous condition and the illusion intensity was measured using a questionnaire and by assessing the proprioceptive drift. In the heartbeat detection task, participants were instructed to count their heartbeats, so interoceptive accuracy of their counting, confidence in their own abilities (interoceptive sensibility), and the correspondence between both measures (interoceptive awareness) could be determined.

Results The intervention type had no effect on mood and interoceptive abilities. Independent of intervention type, valence increased, arousal decreased, and interoceptive accuracy and interoceptive sensibility improved over time. Additionally, trait mindfulness and interoceptive accuracy were negatively related to the subjective rubber hand illusion intensity. There was not a mere effect of the intervention on the rubber hand illusion, but an interaction of synchrony, time, group, and interoceptive awareness was found for both measures, showing that only participants with high interoceptive awareness experienced a weaker illusion following the meditation.

Conclusions We concluded that meta-awareness of interoceptive abilities may help protecting oneself against manipulations of the body boundaries.

Preregistration Open Science Framework (https://osf.io/6dvh5).

Keywords Rubber hand illusion · Interoception · Heartbeat detection · Meditation

The immediate experience of the self, which was previously described as *minimal self* (Gallagher, 2000), is a central component in many psychological processes. An important concept of the minimal self is the sense of ownership, which is characterized as the feeling that body parts, e.g., a foot or an arm, belong to the self — and are *mine*, which is why it has also often been called the feeling of *mineness* (Gallagher, 2017). It was found to be related to mechanisms, such as emotion processing and interoception (Filippetti & Tsakiris, 2017; Schroter et al., 2021). Past research has already made considerable efforts to illuminate these concepts more closely. One popular approach to investigate the sense of ownership is the rubber hand illusion (RHI) paradigm (Botvinick & Cohen, 1998). In the scope of this task, a rubber hand is presented to the participant in an anatomically congruent position (Tsakiris & Haggard, 2005), while the own hand is hidden from view. Own hand and rubber hand are stroked simultaneously, evoking the illusion that the rubber hand belongs to the own body (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005). Usually, a control condition is applied as well to ensure that ratings were not biased by expectation effects. In most cases, an asynchronous stimulation condition is used as control condition where real hand and rubber hand are stroked with a time-delay (Riemer et al., 2019). One explanatory approach for the development of the illusion proposes a multisensory integration mechanism of the sensory domains vision, touch, and proprioception (Botvinick & Cohen, 1998; Maravita et al., 2003). When touch and vision match as a consequence of simultaneous stroking,

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the proprioceptive estimation is biased toward the rubber hand and the illusion of ownership arises (Maravita et al., 2003). To assess if the illusion was successfully induced, a subjective questionnaire measure can be used. Besides, proprioceptive tasks have been applied in the past, showing that following the illusion induction, proprioceptive estimations usually shift in the direction of the rubber hand (Botvinick & Cohen, 1998). However, both measures do not necessarily correlate, since they depend on slightly different multisensory integration mechanisms (Rohde et al., 2011). One potentially important concept, which has been discussed previously in connection with the RHI, is the concept of interoception. Interoception is defined as the afferent body signals we perceive, the processing and the mental representation of these signals, such as pain, temperature, touch, heartbeat, sweat, and many more (Craig, 2002; Critchley & Garfinkel, 2017). Since multiple conceptualizations of interoceptive abilities were used in the past, we will follow the definitions of Garfinkel et al. (2015), who distinguish between interoceptive *accuracy*, *sensibility*, and *awareness*. Accordingly, the term interoceptive *accuracy* (IAc) will be used to describe the performance in tasks like the heartbeat detection task (HDT), where participants are instructed to silently count their heartbeats in predefined intervals while the actual heartbeat is measured (Garfinkel et al., 2015; Schandry, 1981). Interoceptive *sensibility* (IS) can be measured either by using self-report questionnaires or by asking how confident participants are about their responses, e.g., in the HDT. Finally, interoceptive *awareness* (IAw) characterizes the correlation between IAc and confidence (IS), hence the meta-awareness of one's own interoceptive abilities (Garfinkel et al., 2015).

Evidence on the relation between interoception and the rubber hand illusion is still inconsistent. While some studies found a negative relationship between the illusion strength and IAc (Filippetti & Tsakiris, 2017; Schauder et al., 2015; Tsakiris et al., 2011), others could not find this connection (Crucianelli et al., 2018; Horváth et al., 2020). For instance, Tsakiris et al. (2011) showed that participants with a high IAc had a lower proprioceptive drift and lower scores in the RHI questionnaire compared to subjects with a poorer performance in the HDT. Despite the inconsistencies in this research field, examining interoceptive abilities and the RHI could provide promising insights for the treatment of mental disorders. Alternations in the sense of ownership have frequently been observed in specific psychological disorders associated with self-experience disruptions, especially in dissociation. Typical symptoms would be derealization, an alienation of the environment, and depersonalization, an alienation of oneself and the own body (e.g., resulting in the feeling to be out of the body and observing everything from a distance) (Spitzer et al., 2006). With regard to the RHI, there is increasing evidence that the illusion is stronger in patients with dissociative symptoms compared to healthy participants and patients without dissociative symptoms (Bekrater-Bodmann et al., 2016; Hirschmann & Lev Ari, 2016). Additionally, patients with dissociative symptoms had a reduced IAc and a lower confidence in their ratings (Pick et al., 2020; Schäflein et al., 2018; Sedeño et al., 2014).

An interesting question is whether interventions, like mindfulness meditations, can help to restore interoceptive abilities and embodiment processes. Mindfulness has received growing attention in research and clinical practice throughout the last years. Mindfulness-based interventions like Mindfulness Based Stress Reduction (Kabat-Zinn, 2013) are related to third-wave of cognitive behavioral therapies (Hayes, 2004). Mindfulness is often defined as the intentional, non-judging orientation of attention to the present moment (Kabat-Zinn, 2013). Many features of dissociation and mindfulness are opposed to each other, e.g., awareness vs. lack of awareness, presence vs. detachment, and connection vs. fragmentation (Zerubavel & Messman-Moore, 2015). Accordingly, it is not surprising that disruptions of the self might be treated using mindfulness techniques. In acute dissociative states, skills are used which show many parallels to mindfulness meditation; e.g., an important technique to interrupt present dissociative experiences is to direct attention to internal sensations or external objects (Zerubavel & Messman-Moore, 2015). According to Zerubavel and Messman-Moore (2015), mindfulness exercises can serve as grounding tools for dissociative states. Dissociative experiences, and therefore disruptions of self-experience, already exist in non-clinical samples, which is why theories regarding a dissociative continuum have been discussed in the past (Spitzer et al., 2006). For this reason, we are interested in the question whether meditation can have an immediate effect on self-experience in healthy subjects.

Because the underlying mechanisms of mindfulness are still not yet fully understood, a large study by Kok and Singer (2017) analyzed the effects of different mindfulness meditation practices on various outcome variables. All three modules (presence-focused, affect-focused, and perspective-focused) led to improved positivity and energy, a higher present focus, and lower thought distraction. The presence module, which included breathing meditation and body-scan, especially led to improved body awareness, e.g., IS and IAc (Bornemann & Singer, 2017; Bornemann et al., 2015; Kok & Singer, 2017). Besides, following an 8-week body-scan intervention (20 min per day), Fischer et al. (2017) found an increase in IAc and confidence (IS). But not only long-term interventions had an effect on interoceptive abilities: After only 1 week of daily 15-min body-scan practice, participants' sensitivity in a somatic signal detection task was improved compared to the audio book control group (Mirams et al., 2013). Despite those findings, evidence on meditation and interoception is mixed. Parkin et al. (2014) found no effects of a 1-week body-scan meditation on the performance in the HDT. Additionally, a meta-analysis examining the relation of mindfulness and interoceptive abilities found evidence for small effects on IAc (Treves et al., 2019). Dispositional mindfulness (assessed with the Five Facet Mindfulness Questionnaire, FFMQ; Baer et al., 2006) was related to a greater IS (assessed with the Multidimensional Assessment of Interoceptive Awareness; MAIA; Bornemann et al., 2015; Mehling et al., 2012) and a greater confidence (IS) in the HDT (Parkin et al., 2014). To our best knowledge, only one study investigated the immediate effects of a short meditation in comparison to a control group: Aaron et al. (2020) presented either a 10-min body-scan meditation or a natural history reading via audio recordings. No effects were found on IAc and IS. However, the sample size was rather small, and a common body-scan intervention does not necessarily involve a focus on the heartbeat, which may contribute to an improved heartbeat awareness.

So far, mainly correlational and quasi-experimental studies have addressed the relation of mindfulness meditations and the sense of ownership. One study with Tai Chi practitioners showed that the number of practice hours was negatively related to the subjective misattribution of the stimulation to the rubber hand, but it was not related to proprioceptive drift (Kerr et al., 2016). Another correlational study demonstrated that compared to non-meditators, experienced meditators (with minimum 5 years of meditation experience) had a lower sense of agency in the rubber hand and a marginally significant lower proprioceptive drift (Cebolla et al., 2016). Additionally, the sense of ownership was negatively correlated to the subdimension "acting with awareness" of the FFMQ in this study. Similarly, Xu et al. (2018) found lower subjective ownership scores in meditators compared to non-meditators in the synchronous stimulation condition, but again, no differences in the proprioceptive drift could be detected. They also reported negative correlations between subdimensions of the MAIA questionnaire and disownership feelings in the own hand. To our best knowledge, only one study has adopted an experimental approach. Guthrie et al. (2022) conducted a study where they tested the effects of a state 20-min body-scan meditation and longer-term 2-week body-scan training. They found a reduction in the illusion after the 2 weeks training compared to a control group. The immediate effects of the state intervention suggest a higher illusion in the meditation group, but because there was no RHI measurement before the state intervention, this could also be due to baseline group differences.

However, further experimental studies are needed to evaluate the effects of body-focused mindfulness interventions on the sense of ownership. For this reason, the main goal of the present study is to evaluate the immediate effects of a short mindfulness meditation on the sense of ownership in healthy participants. Furthermore, the effects on interoceptive abilities, such as IAc, IS, (confidence in ratings) and IAw are investigated. Based on the abovementioned findings, a lower score in the rubber hand illusion questionnaire in synchronous compared to asynchronous trials and a higher IAc and IS are expected following a body-focused meditation as compared to an audio book reading (Fig. 1). Additionally, we assumed that the changes in the RHI following the intervention were mediated by the change in interoceptive abilities. As a manipulation check, valence and arousal changes were analyzed. Meditation experience, dispositional mindfulness, and dissociative experiences were also measured, since a lower subjective illusion is expected for participants with higher dispositional mindfulness and meditation experience, higher IAc and IAw, lower dissociative experiences, and a less negative valence. Regarding interoceptive abilities, we expected a positive relation between IS and dispositional mindfulness and a negative relation between IS/IAc and dissociative experiences. Furthermore, we explored to what extent participants with more dissociative experiences, lower meditation experience, and lower trait mindfulness showed a higher change in the outcome variables (Fig. 1).

Method

Participants

For our main research question concerning the effect of a short meditation intervention on the subjective RHI, no previous studies with a pre-post design are available as a basis for the sample-size calculation of a three-way interaction (time x group x stroking style). Therefore, means were estimated based on the results of Tsakiris et al. (2011) and an expected medium effect of the intervention. A total of 116 participants were tested, which according to the power analysis using the *superpower* package for R is sufficient to

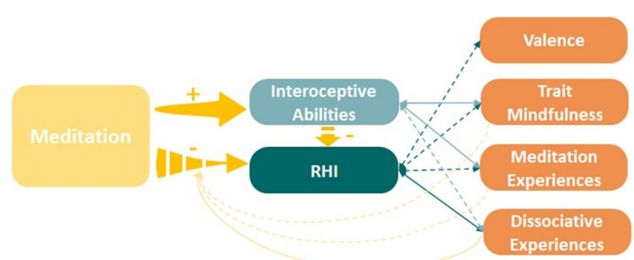

Fig. 1 Expected effects and correlations. Solid lines represent expected positive relations or increasing effects; dashed lines represent expected negative relations or decreasing effects

achieve a power of 80% (Lakens & Caldwell, 2021). Four participants had to be excluded during data collection due to technical difficulties in the HDT, and one additional participant was excluded due to insufficient commitment to the intervention (< 30%). The sample was comprised of undergraduate students in the Applied Movement Science program from the University of Regensburg. In total, 66 females and 45 males within an age range between 18 and 29 ($M = 22.29$, $SD = 2.02$) participated in this study and were randomly assigned to either the meditation group or the control group. The characteristics of each experimental group are shown in Table 1. Groups were not significantly different regarding the variables age, gender, trait mindfulness, dissociative experiences, or meditation practice/experience (Table 1).

Procedure

To avoid spill-over effects on the experimental tasks, participants were asked to complete the FFMQ and FDS questionnaires 2 days in advance to their actual testing appointment via an online survey system (sosci survey, Leiner, 2019).

At the testing date, participants first completed the demographic questions and the affect grid. Subsequently, the baseline measurements of the HDT and the RHI were performed. The order of these tasks was randomized (see Supplementary Fig. S1). After this baseline assessment, participants were allocated either to the meditation or to the reading control group. The intervention lasted 20 min. Afterwards, affect grid, RHI and HDT were repeated in the same order as before the intervention and in the end, questions on compliance and experiences with the intervention were asked.

Rubber Hand Illusion Induction

Two RHI trials (synchronous and asynchronous) were conducted. For this purpose, a wooden box frame (39.5 cm × 19 cm × 29 cm), adapted from Tsakiris et al. (2011), was used (Fig. 2A). It was separated in two halves by a wooden plank, so the real left hand of the participant could be placed in one and the rubber hand (Killerink, Liverpool, UK) in the other part of the box. It was open on opposite sides, so the participant's hand and the rubber hand could be placed inside the box from one side and the experimenter could stroke the hands from the

Table 1 Demographic differences between control and meditation groups

Characteristic	Control Group *M* (*SD*)/absolute (relative) frequency	Meditation Group *M* (SD)/absolute (relative) frequency	Test Statistic	*p*
Age	22.21 (1.88)	22.37 (2.18)	1538.5[a]	0.998
Gender	Female: 33 (57.89%)	Female: 33 (61.11%)	0.02[b]	0.880
	Male: 24 (42.11%)	Male: 21 (38.89%)		
FDS mean	9.97 (6.50)	10.39 (6.96)	1520.5[a]	0.913
FFMQ mean	3.42 (0.45)	3.31 (0.41)	1.26[c]	0.209
Meditation Practice (Min/Week)	6.27 (12.19)	4.88 (11.92)	1681.5[a]	0.341
Meditation Experience (Years)	1.79 (1.51)	1.59 (1.47)	1622.5[a]	0.497

Note. [a]Mann-Whitney *U* test, [b]Chi-square test; [c]Independent sample *t*-test

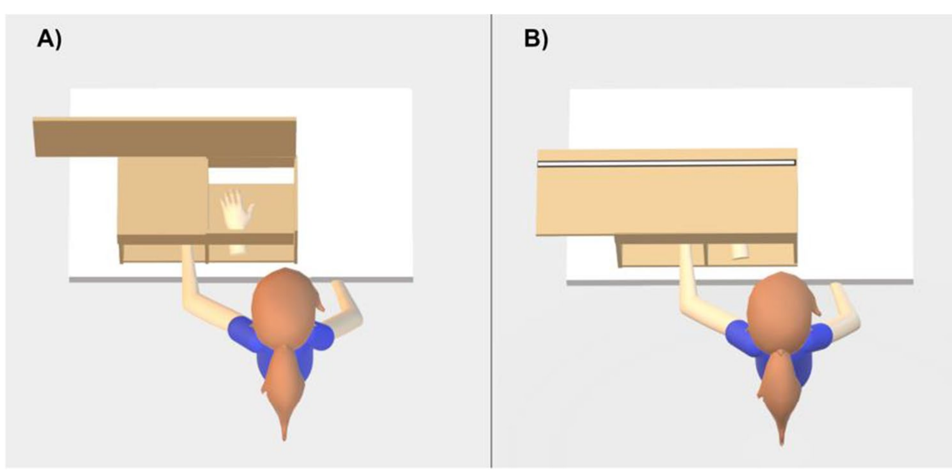

Fig. 2 Visualization of the setup. (**A**) RHI stimulation setup. (**B**) Proprioception setup

other side. The distance between both index fingers was 17.5 cm (Tsakiris & Haggard, 2005). Through a hole on top of the box, participants could see the rubber hand. The other part of the box, where the own hand was lying beneath, was covered. Participants wore a black hairdresser's gown, which was taped to the upper edge of the box so the arms were covered. The experimenter sat on the opposite side of the table, hidden behind a wooden plank, attached to the setup, and stroked the index fingers of the participant and of the rubber hand from the proximal interphalangeal joint to the fingertip, using two identical paint brushes. Stroking was applied with random delay intervals, since it was found to evoke a stronger illusion effect than fixed intervals (Riemer et al., 2019). One stroke lasted approximately 1–1.5 s. The stimulation lasted 120 s and was applied either in synchrony or in a 1-s asynchrony. The order of the trials (synchronous vs. asynchronous) was randomized across participants. Following each RHI trial, the rubber hand illusion questionnaire was completed. Additionally, before and after the RHI, a proprioceptive measurement was taken.

Intervention

The experimenter left the room for the intervention after explaining the task, so blinding was enabled using a program, which randomly assigned the participants either to the meditation or the control condition.

A short introduction was given in the beginning of both audios, in which participants were asked to sit down on a chair, a yoga mat, or a meditation cushion and to find a comfortable position. Subsequently, the meditation group heard a 20-min meditation, which was guided by a trained MBSR instructor with more than 10 years of experience. The meditation was focused on the body as a whole, on body sensations, and on the perception of the hands. As in the study of Aaron et al. (2020), the control group heard a 20-min reading about natural history ("A Short History of Nearly Everything"; Bryson, 2004). The control group audio was read by the same instructor as the meditation audio.

Measures

Five Facet Mindfulness Questionnaire (FFMQ)

The FFMQ (Baer et al., 2006) is composed of 39 items, which can be assigned to five different facets: Observing, Non-judging, Non-reactivity, Acting with awareness, and Describing. The items can be rated on a 5-point Likert scale from 1 = *never/rarely applies* to 5 = *applies always/very often*. Adequate validity measures and internal consistencies for the subscales were found in the German version, internal consistency ranging between $\alpha = 0.74$ and $\alpha = 0.90$ (Michalak et al., 2016). In the present study, the R-package *psych* (version 2.9.1, Revelle, 2021) was used to calculate Cronbach's alpha and McDonald's total omega. Reliability for the total score was $\omega = 0.92$ / $\alpha = 0.90$, the subscales ranged between $\omega = 0.86$ and $\omega = 0.94$ / $\alpha = 0.79$ and $\alpha = 0.93$.

Questionnaire on Dissociative Symptoms (FDS)

The FDS is a German questionnaire on dissociative symptoms, based on the frequently used Dissociative Experience Scale (DES; Bernstein & Putnam, 1986). It includes 44 items, which are rated from 0% (*never*) to 100% (*always*) in steps of 10%. An overall score of the FDS can be used to indicate overall symptom burden, but it can also be divided into four categories: "amnesia", "absorption", "derealization", and "depersonalization", each subdimension comprising six to nine items. Internal consistency of the overall score was 0.93; test–retest reliability was 0.88 in a sample of 813 participants (Freyberger et al., 1998). In the present sample, omega for the total score was $\omega = 0.93$, alpha was $\alpha = 0.91$, and the subscales ranged between $\omega = 0.77$ and $\omega = 0.87$ / $\alpha = 0.64$ and $\alpha = 0.82$.

Demographic Questionnaire

In the beginning of the experiment, participants were asked to complete questions on their demographical background. The items included questions on participants' age, gender, previous RHI experience, handedness, job/studies, psychological or neurological diseases, and previous meditation and yoga practice/experiences.

Affect Grid

Using this single-item scale, mood was assessed on two dimensions: valence and arousal. The two dimensions were rated by ticking a box in a grid with nine columns, ranging from *pleasure* to *displeasure* (valence) and nine rows, ranging from *arousal* to *sleepiness* (arousal). The Affect Grid showed strong evidence for convergent and discriminant validity in the study of Russell et al. (1989).

Proprioceptive Drift

Before and after each RHI stimulation trial, a proprioceptive measurement was conducted. A 60 cm × 29 cm board was attached to the box with two hinges, which was open during the illusion induction and closed during the proprioceptive measurement (Fig. 2B). A tape measure was placed on the upper end of the box with a random offset to avoid that participants' judgements are biased by their judgement in previous trials. Participants were instructed to report the number on the tape measure where they felt their own left index finger (Tsakiris et al., 2011). The proprioceptive drift was calculated as follows: pre-proprioception – post-proprioception. Since only weak relations to the proprioceptive drift were found in the past, drift was analyzed exploratorily.

Rubber Hand Illusion Questionnaire

To assess the subjectively perceived strength of the rubber hand illusion, eight items of the questionnaire from Longo et al., (2008) were translated into German and used in the present study, as in the study of Tsakiris et al. (2011). From originally 10 items loading on the component "embodiment of the rubber hand", five items of the subdimension "ownership" and three items of the subdimension "location" were used. Each item was rated on a 7-point Likert scale, ranging from – 3 = *strongly disagreed*, 0 = *neither agreed nor disagreed*, to 3 = *strongly agreed* (Longo et al., 2008). Reliabilities were calculated for the mean score, separately for each group, timepoint, and synchrony condition, revealing omegas between $\omega = 0.93$ and $\omega = 0.97$ and alphas between $\alpha = 0.88$ and $\alpha = 0.96$.

Heartbeat Detection Task (HDT)

Interoceptive accuracy (IAc) and confidence (Interoceptive Sensibility = IS) were assessed using the heartbeat detection task, developed by Schandry (1981). For this purpose, the ECG signal was recorded using two bipolar electrodes and one ground electrode, following lead-II electrode placement procedure, and a sampling rate of 1000 Hz (actiChamp 32 (BIPAUX), Brain Products GmbH, Gilching, Germany). Before and after the intervention, six trials (25 s, 30 s, 35 s, 40 s, 45 s, 50 s) were completed in a randomized order (Garfinkel et al., 2015). Additionally, in the beginning, a short practice trial of 15 s was completed (Tsakiris et al., 2011). Participants were instructed to sit in a standardized position, to move as little as possible, and to silently count their heartbeats without physically measuring their pulse, counting seconds, or guessing (Desmedt et al., 2020). The beginning and the end of the intervals were marked using audio cues (Filippetti & Tsakiris, 2017). Following each interval, participants were asked to indicate the number of perceived heartbeats. Subsequently, a visual analogue scale was presented on the screen where participants should rate the confidence in their answer from 0 = *Total guess/No heartbeat awareness* to 100 = *Complete confidence/Full perception of heartbeat* (Garfinkel et al., 2015). Following Tsakiris et al. (2011), the accuracy equation of Schandry (1981) was used: $^{1}/_{6} \sum \left[1 - \frac{(|\text{recorded heartbeats} - \text{perceived heartbeats}|)}{\text{recorded heartbeats}}\right]$. The correlation coefficient between IAc and confidence (IS) was used as an indicator for interoceptive awareness (IAw; Garfinkel et al., 2015).

Compliance to the Interventions

The compliance to the interventions was measured with the item "on a scale of 0–100%, how much did you commit to the exercise?" using a 10-point Likert scale. Additionally, participants were asked to summarize the content and their experience with the intervention in one to two sentences.

Data Analyses

In the beginning, we tested if both groups differed regarding their commitment to the intervention using the Mann–Whitney *U* test.

To analyze the effects of the intervention type on the illusion and on measures of interoception, we conducted separate linear mixed models. For the outcome variables IAc, IS, and IAw, the main effects and interactions of time and group with the variables dissociative experiences, meditation experience, trait mindfulness, and mood (valence, arousal) were analyzed. For the subjective illusion, synchrony, IAc, IS, and IAw were also included as fixed factors. For the analysis of the proprioceptive drift, it was preregistered on OSF that proprioception would be used as a dependent variable and the factor pre vs. post stroking would also be included in the analysis to determine the drift. During analysis, five-way interactions turned out to be significant. For the sake of a greater interpretability, we decided to directly examine the difference between proprioception before and after stroking, hence the proprioceptive drift as a dependent variable. Before subtracting the post-stimulation proprioceptive estimation from the pre-stimulation value, it was analyzed using ANOVA if the stimulation led to the expected drift in the synchronous conditions.

Linear mixed models were performed using *LME4* package for R (Bates et al., 2015; R Core Team, 2020) with the wrapper optimix (Jost & Jansen, 2020; Nash, 2014). As random effect, interindividual differences between participants were included in the models. First, a maximum model was defined including all random slopes and fixed effects. Subsequently, random slopes were reduced stepwise following the procedure of Matuschek et al. (2017). Thereby, non-significant variance components were dropped and after each reduction, the goodness of fit of the new model was compared to the fit of the previous model. In case of a loss in goodness of fit, indicated by $p < 0.200$ (Matuschek et al., 2017), complexity reductions were stopped, unless convergence issues persisted. Subsequently, non-significant fixed effects were removed from the model, in a stepwise manner as well, using likelihood ratio test and a *p*-value of < 0.05. In case of significant interactions, the respective main effects and lower-order interactions remained in the model regardless of their significance. Assumptions of normality, linearity, and homoscedasticy were checked visually.

If significant interaction effects were found, Bonferroni-Holm corrected post-hoc linear mixed effect models were calculated (Holm, 1979). Following the procedure of Tsakiris et al. (2011) and Horváth et al. (2020), difference scores of the RHIQ and the proprioceptive drift were built for this purpose by subtracting asynchronous from synchronous trials, as the illusion can be quantified by the difference of these trials (Riemer et al., 2019; Tsakiris & Haggard, 2005). Subsequently, the effect of the interacting variable on this difference was determined. For three- or four-way interactions, subsets of the data were created either based on different categories (e.g., control vs. meditation) or, in the case of continuous variables, based on a median split (e.g., low IAc vs. high IAc) to isolate the effect of a variable under specific conditions. If models failed to converge due to the small data subsets, Bonferroni-Holm corrected linear regression models were used. For significant effects, figures were created based on the difference score. For non-significant post-hoc tests, original values were used and further post-hoc comparisons were computed to localize the source of the interaction.

In the case of categorical data, such as valence and arousal, the cumulative link mixed models from the package *ordinal* by Christensen (2022) were calculated. Equidistant thresholds were used and model building was performed based on the procedure of Matuschek et al. (2017), as well.

In general, outliers above or below 3 *SD* were excluded from the respective analyses in IAc, IAw, and IS, as well as in the difference variables of the RHIQ and the proprioceptive drift.

Results

Effects on Mood and Subjective Experiences

Cumulative link mixed models were used for valence and arousal. Model building resulted in one random intercept model each. Both variables were significantly predicted by time, but not by group. In the case of valence, a significant increase was observed from baseline ($Mdn = 6$) to post-intervention ($Mdn = 7$), $\beta = 1.30$, $SE = 0.17$, $z = 7.52$, $p < 0.001$, 95% CI [0.96, 1.64]. In contrast, a significant decrease from baseline ($Mdn = 6$) to post-intervention ($Mdn = 4$) was found for the variable arousal, $\beta = -1.50$, $SE = 0.18$, $z = -8.49$, $p < 0.001$, 95% CI [−1.84, −1.15].

Regarding the commitment to the intervention, participants achieved a mean commitment score of $M = 83.64\%$, with a standard deviation of $SD = 14.82\%$. Commitment was significantly higher in the control group ($Mdn = 90\%$) than in the meditation group ($Mdn = 80\%$), $U = 1836.5$, $p = 0.046$. In their subjective experience reports, participants of the meditation group often stated a feeling of warmth, tingling or pulsation in the hands, a higher focus on body sensations (e.g., the heartbeat), relaxation effects, but also difficulties with concentration and wandering thoughts. Participants in the control group often reported that they found the story interesting, but many of them also reported relaxing effects or drowsiness.

Effects on Interoceptive Abilities

Interoceptive Accuracy (IAc)

The effect of the intervention on interoceptive accuracy was determined using linear mixed models. Model building resulted in a random intercept model, including the fixed factor time, $\beta = 0.07$, $SE = 0.01$, $t(111) = 6.66$, $p < 0.001$, 95% CI [0.05, 0.09], showing that IAc increased from baseline ($M = 0.64$, $SD = 0.18$) to post-intervention ($M = 0.71$, $SD = 0.18$). Variance explained by the participants, $\tau_{00} = 0.03$, accounted for 81% of the total variance. The proportion of the variance explained by the fixed factors was $R^2_{\text{marginal}} = 0.04$, the proportion explained by the whole model was $R^2_{\text{conditional}} = 0.82$.

Interoceptive Sensibility (IS)

The model reduction procedure also resulted in a random intercept model for the variable IS. The fixed factors time, $\beta = 12.38$, $SE = 3.51$, $t(118.16) = 3.52$, $p = 0.001$, 95% CI [5.77, 19.47], arousal, $\beta = 1.27$, $SE = 0.60$, $t(127.34) = 2.13$, $p = 0.035$, 95% CI [0.06, 2.39], as well as the interaction of time and arousal, $\beta = -1.99$, $SE = 0.73$, $t(117.82) = -2.74$, $p = 0.007$, 95% CI [−3.53, −0.63], significantly predicted IS. In addition, trait mindfulness remained in the model, although it only showed a trend toward significance, $\beta = 7.78$, $SE = 3.93$, $t(110.86) = 1.98$, $p = 0.050$, 95% CI [−0.06, 15.62]. The positive connection between the main effect time with IS shows that an improvement can be observed over time (baseline: $M = 55.46$, $SD = 18.54$; post-intervention: $M = 58.27$, $SD = 18.99$). A closer inspection of the interaction effect using Bonferroni-Holm corrected post-hoc regressions showed neithar an effect of time in participants with low or high arousal ($p = 1.00$) nor an effect of arousal at pre or post intervention ($p \geq 0.386$). Variance explained by the participants, $\tau_{00} = 298.86$, accounted for 89% of the total variance. The proportion of the variance explained by the fixed factors was $R^2_{\text{marginal}} = 0.04$; the proportion explained by the whole model was $R^2_{\text{conditional}} = 0.90$. To rule out the possibility that heart rate predicts the IS better than the variable arousal, it was included in an exploratory model. The arousal effect and the interaction with time remained significant; heart rate had no significant effect.

Interoceptive Awareness (IAw)

For the dependent variable IAw, convergence issues remained even after reducing the model to random intercepts. Consequently, a backward linear regression was calculated. Overall, the model was not significant, $R^2 = 0.03$, $R^2_{adjusted} = -0.008$, $F(9, 212) = 0.81$, $p = 0.605$ and none of the predictors reached significance (Supplementary Table 1).

Effects on Measures of the RHI

Rubber Hand Illusion Questionnaire (RHIQ)

Linear mixed models with the predictors time, group, synchrony, dissociative experiences, trait mindfulness, meditation practice, IAc, IS, and IAw, as well as valence and arousal were calculated. Model reduction resulted in a random intercept model. The predictors which remained in the model after model reduction can be found in Table 2. Significant main effects of synchrony, group, and trait mindfulness emerged. Synchronous stimulation ($M = 0.96$, $SD = 1.40$) led to a stronger subjective illusion score compared to asynchronous stimulation ($M = -0.72$, $SD = 1.49$), and the control group ($M = 0.39$, $SD = 1.61$) showed a higher RHIQ score than the meditation group ($M = -0.16$, $SD = 1.70$). Additionally, trait mindfulness was negatively associated with the RHIQ score (Table 2). Looking at the two-way interactions, it can also be observed that trait mindfulness interacts with synchrony. In a post-hoc linear mixed model, it was examined if trait mindfulness predicts the difference between synchronous and asynchronous trials, revealing no significant effect ($p = 0.278$). Further post-hoc linear mixed models regarding the mean RHIQ score showed only a significant effect of the FFMQ

Table 2 Final linear mixed model for the dependent variable RHIQ

Predictors	RHIQ mean					
	Estimate	*SE*	*95% CI [LL, UL]*	*t*	*p*	*df*
Intercept	5.17	1.06	[3.18, 7.31]	4.87	< 0.000	169.81
Synchrony	− 4.31	0.77	[− 5.83, − 2.73]	− 5.59	< 0.000	325.10
Time	− 0.21	0.21	[− 0.60, 0.20]	− 1.02	0.308	352.74
Group	− 0.73	0.28	[− 1.28, − 0.19]	− 2.64	0.009	240.07
FFMQ mean	− 1.02	0.28	[− 1.58, − 0.49]	− 3.71	< 0.000	141.09
IAc	− 0.55	0.55	[− 1.65, 0.54]	− 0.99	0.321	356.86
IAw	− 0.01	0.25	[− 0.49, 0.51]	− 0.03	0.978	375.98
Synchrony * IAc	1.48	0.46	[0.53, 2.39]	3.20	0.002	325.10
Synchrony * IAw	− 0.22	0.30	[− 0.84, 0.39]	− 0.72	0.473	325.10
Synchrony * Time	0.11	0.28	[− 0.44, 0.67]	0.41	0.685	325.10
Synchrony * Group	0.06	0.25	[− 0.41, 0.62]	0.23	0.817	325.10
Time * Group	0.12	0.27	[− 0.40, 0.64]	0.42	0.672	341.51
Synchrony * FFMQ mean	0.48	0.19	[0.11, 0.87]	2.52	0.012	325.10
Group * IAw	0.56	0.37	[− 0.15, 1.25]	1.53	0.127	377.95
Time * IAw	0.13	0.40	[− 0.71, 0.92]	0.33	0.738	361.29
Synchrony * Time * Group	− 0.08	0.37	[− 0.81, 0.66]	− 0.23	0.820	325.10
Synchrony * Group * IAw	− 0.33	0.44	[− 1.17, 0.57]	− 0.75	0.457	325.10
Synchrony * Time * IAw	0.01	0.50	[− 1.04, 1.07]	0.02	0.986	325.10
Time * Group * IAw	− 1.31	0.56	[− 2.36, − 0.23]	− 2.33	0.020	380.06
Synchrony * Time * Group * IAw	1.38	0.67	[0.00, 2.68]	2.06	0.040	325.10
Random Effects						
σ^2	0.68					
$\tau_{00\ Participant}$	1.13					
ICC	0.62					
$N_{Participant}$	109					
Observations	436					
Marginal R^2/Conditional R^2	0.35/0.75					

Note. *IAc*, Interoceptive Accuracy; *IAw*, Interoceptive Awareness

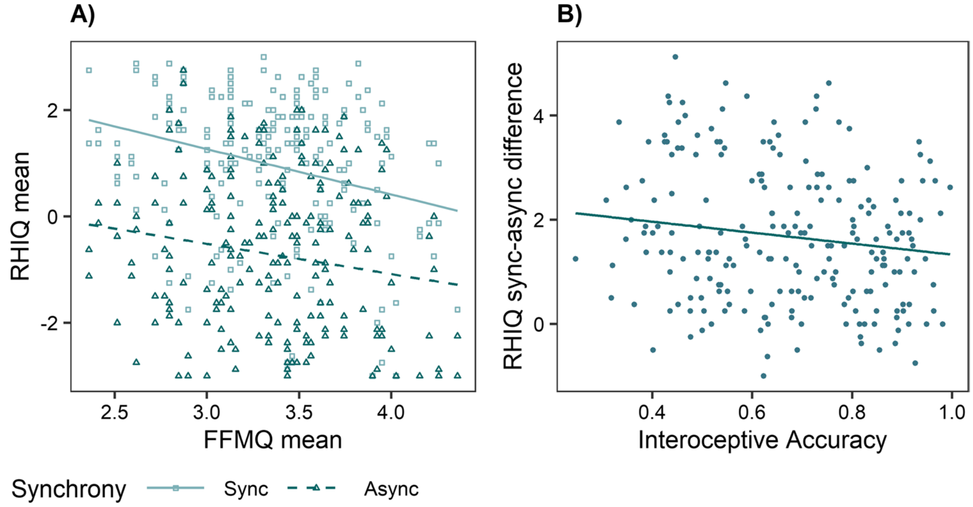

Fig. 3 (**A**) Effect of trait mindfulness (FFMQ mean) and synchrony on the RHIQ mean. (**B**) Effect of IAc on the difference in the RHIQ between synchronous and asynchronous trials. Lines were fitted based on linear mixed model coefficients

on synchronous ($p = 0.006$), not on asynchronous trials ($p = 0.069$) (Fig. 3A).

A significant interaction with synchrony was also found for the variable IAc (Table 2). As the post-hoc comparison demonstrates, a higher IAc was associated with a smaller difference between synchronous and asynchronous trials ($p = 0.008$, Fig. 3B).

A three-way interaction of group, time, and IAw and a four-way interaction of synchrony, group, time, and IAw were found (Fig. 4A). Post-hoc comparisons for the difference between synchronous and asynchronous trials were performed for the higher order interaction, separately for each group and timepoint. Post-hoc tests could not be calculated using lmer due to convergence issues in the small data subsets. Instead, linear regression models with Bonferroni-Holm corrected *p*-values were performed and showed that IAw was associated negatively with the RHIQ difference score in the meditation group post intervention ($p = 0.004$). An effect of time only applied to participants with high IAw in the meditation group ($p < 0.001$), showing a decrease in the illusion from baseline to post-intervention. Group differences were not significant showing only a trend for participants with high IAw post intervention ($p = 0.087$), in terms of a lower illusion in the meditation group compared to the control group (Fig. 4A).

No mediation analysis was performed, since IAw itself did not change through the intervention.

Proprioceptive Drift

Before the proprioceptive drift was calculated, it was first examined whether there were significant differences in the proprioceptive estimates between pre- and post-stroking. A mixed ANOVA confirmed a significant drift from pre- ($M = 0.89$, $SD = 3.47$) to post- ($M = 2.99$, $SD = 5.02$) stroking, $F\ (1, 213) = 77.60$, $p = < 0.001$, $\eta^2_p = 0.267$, in the direction of the rubber hand. Additionally, the main effect of synchrony, $F\ (1, 213) = 18.68$, $p < 0.001$, $\eta^2_p = 0.081$, and

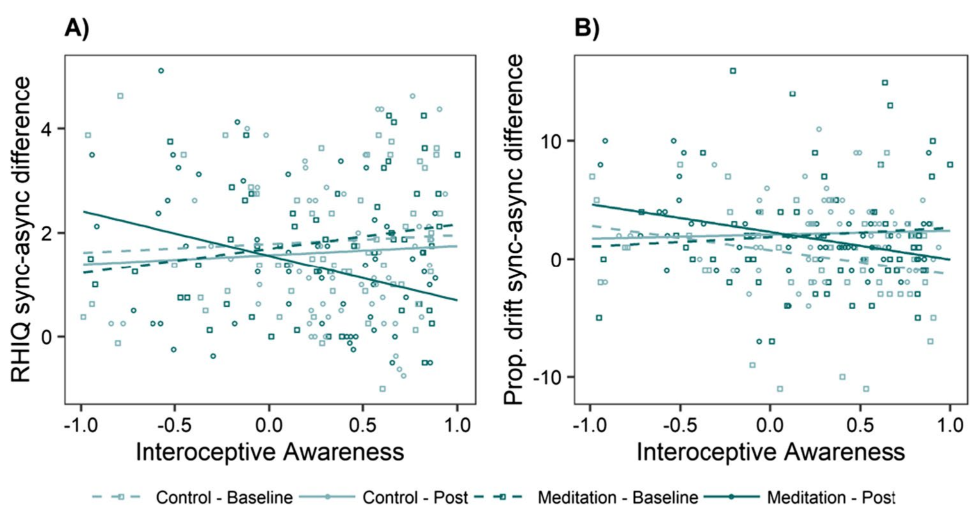

Fig. 4 Effect of time, group, and IAw on (**A**) the difference in the RHIQ between synchronous and asynchronous trials, and (**B**) the difference in the proprioceptive drift between synchronous and asynchronous trials. The real hand was positioned at 0, the rubber hand at 17.5. More positive values indicate a stronger drift toward the rubber hand in synchronous compared to asynchronous trials. Lines were fitted based on linear regression

the interaction of time and synchrony, F (1, 213) = 31.27, $p < 0.001$, $\eta^2_p = 0.128$, show that the drift was stronger in synchronous (pre: $M = 0.83$, $SD = 3.43$; post: $M = 3.73$, $SD = 5.02$), compared to asynchronous trials (pre: $M = 0.94$, $SD = 3.52$; post: $M = 2.24$, $SD = 4.92$).

As a next step, linear mixed models were calculated. The models were reduced again until a random intercept model resulted. The remaining fixed factors can be seen in Table 3. It was found that the main effects of IAc and IS significantly predicted the proprioceptive drift independent of synchrony. In this regard, IAc appeared to be positively related to the drift, whereas IS was negatively associated with it (Table 3). Additionally, an interaction between IAw and synchrony was detected and a four-way interaction of synchrony, time, group, and IAw was also found for the proprioceptive drift (Fig. 4B). Due to convergence problems, linear mixed models could not be calculated as post-hoc tests for this interaction. Instead, Bonferroni-Holm corrected regressions were used again. IAw was negatively associated with the difference score of the proprioceptive drift in the meditation group post-intervention ($p < 0.001$). The effect of group was only significant in the high IAw group before the intervention, with the control group showing a smaller difference in the drift ($p = 0.028$). Besides, a time difference indicated an increase in the difference score from baseline to post-intervention for participants with a high IAw in the control group ($p < 0.001$) (Fig. 4B).

Discussion

The aim of the present study was the evaluation of the effects of a short mindfulness meditation on the sense of body ownership under the consideration of interoceptive abilities, dissociative experiences, mood, trait mindfulness, and meditation experience. For this purpose, the effects of the interventions on mood, interoceptive abilities, and the rubber hand illusion were analyzed. We found a general increase in valence and a reduction in arousal, although this was only expected in the meditation group, not the control

Table 3 Final linear mixed model for the dependent variable proprioceptive drift

Predictors	Proprioceptive Drift					
	Estimate	*SE*	*95% CI [LL, UL]*	*t*	*p*	*df*
Intercept	2.79	1.21	[0.33, 5.08]	2.31	0.022	222.67
Synchrony	−0.77	0.60	[−1.94, 0.33]	−1.29	0.200	318.82
Time	0.56	0.66	[−0.80, 1.90]	0.85	0.396	349.84
Group	−0.02	0.82	[−1.69, 1.56]	−0.03	0.977	290.03
IAc	3.05	1.51	[0.22, 6.21]	2.02	0.044	204.64
IS	−0.03	0.02	[−0.06, 0.00]	−2.21	0.029	156.70
IAw	0.13	0.83	[−1.59, 1.77]	0.16	0.871	387.27
Synchrony * IAw	2.07	1.02	[0.15, 4.17]	2.04	0.042	318.82
Synchrony * Time	−1.31	0.89	[−3.12, 0.43]	−1.47	0.143	318.82
Synchrony * Group	−1.09	0.85	[−2.74, 0.62]	−1.28	0.200	318.82
Time * Group	−1.11	0.89	[−2.92, 0.69]	−1.25	0.214	339.49
Group * IAw	0.75	1.21	[−1.54, 3.15]	0.62	0.538	388.86
Time * IAw	−0.35	1.28	[−2.83, 2.20]	−0.27	0.785	370.97
Synchrony * Time * Group	0.86	1.22	[−1.37, 3.15]	0.70	0.483	318.82
Synchrony * Group * IAw	−2.87	1.47	[−5.88, −0.14]	−1.95	0.052	318.82
Synchrony* Time * IAw	−2.41	1.61	[−5.48, 0.81]	−1.50	0.135	318.82
Time * Group * IAw	−2.24	1.80	[−5.89, 1.39]	−1.24	0.216	392.54
Synchrony * Time * Group * IAw	5.55	2.19	[1.20, 9.58]	2.54	0.012	318.82
Random eEffects						
σ^2	7.67					
$\tau_{00 \text{ Participant}}$	7.45					
ICC	0.50					
$N_{\text{Participant}}$	107					
Observations	428					
Marginal R^2/Conditional R^2	0.11/0.55					

Note. *IAc*, Interoceptive Accuracy; *IAw*, Interoceptive Awareness; *IS*, Interoceptive Sensibility group (Zeidan et al., 2010), and therefore could also reflect habituation to the experimental environment.

Regarding interoceptive abilities, the expected effect of the intervention was not found. Instead, a time effect on IAc and IS indicates a general improvement from baseline to post-intervention which might be a training effect. This result is in line with the findings of Aaron et al. (2020) who conducted even shorter meditation vs. natural history interventions and found an improvement in IAc and IS independent from group. Parkin et al. (2014), who conducted two studies with 1-week body-focused meditation vs. control interventions, did not even find a time effect. The authors suggested that cardiac perception might be a stable trait. Therefore, repeating the HDT at the same day may reflect training effects that are less persisting. Brief mindfulness interventions do not appear to substantially enhance these short-term improvements. Instead, changing interoceptive abilities may require long-term interventions as in the study of Fischer et al. (2017) who conducted an 8-week body-scan intervention and showed an improvement in IAc and IS.

In our study, IS was further predicted by the level of arousal and an interaction of time and arousal, whereby the second relation was no longer evident in the post-hoc analyses. Although this was not part of the hypotheses, relations of interoception and arousal have also been found in previous literature, such as higher subjective arousal was associated with a higher IAc (Pollatos et al., 2007). To our knowledge, the relation between IS, measured by confidence, and arousal is new: Participants who experience higher levels of subjective arousal may overestimate their ability to perceive their own heartbeat.

In contrast to our expectations, no relation of IS or IAc to dissociative experiences (Pick et al., 2020) was found, but a trend toward a positive relation of IS with trait mindfulness. This is in line with the study of Parkin et al. (2014) who found large effects of an 8-week body-scan intervention on IS and a relation of confidence and trait mindfulness.

No significant predictors were found for IAw and it did not even improve over time. Thus, IAw seems to be unaffected by immediate meditation practice and by repetitions of the same task within a short period of time. This is in line with the literature, which only reported a relation of trait mindfulness with IAw so far: Parkin et al. (2014) showed that IAw was not affected by 1- or 8-week mindfulness interventions, but it was positively related to the FFMQ facets Describing, Acting with awareness, Non-judging, and the total score, while Observing was connected to a lower IAw. Accordingly, this variable appears to be rather related to more complex mindfulness skills than to mere body awareness. A short body–focused meditation training might not be enough to enhance IAw. Instead, whole mindfulness interventions, like MBSR or MBCT, including not only body-focused meditation, but also exercises focusing on thoughts, emotions, and compassion (Baer, 2003; Kok & Singer, 2017) might be necessary. According to Hölzel et al. (2011), mindfulness interventions entail the promotion of attention and emotion regulation, body awareness, and change in the perspective of the self, such as through developing meta-awareness. For example, the intervention program of Kok and Singer (2017) showed that observing-thoughts meditation can lead to an increase in meta-cognitive awareness of thoughts. Especially the interaction of meta-cognitive abilities with attention on the body might be relevant for IAw and should therefore be targeted by mindfulness interventions, aiming for improving interoceptive skills (Khalsa et al., 2018). It is often criticized that the underlying mechanisms of mindfulness are not sufficiently identified (van Dam et al., 2018). However, this interplay of body- and meta-awareness indicates that individual components cannot always be clearly separated from each other, but rather unfold their effect through their interaction. This should be given attention in future research.

Regarding the rubber hand illusion, we did find the expected effects of synchrony on both measures. Furthermore, a main effect of group on the RHIQ was found, indicating baseline differences between both groups, with the meditation group showing a lower illusion score regardless of the time of measurement. The effects of the intervention may be weakened by these pre-existing differences. Additionally, dispositional mindfulness was negatively related to the subjective illusion in synchronous trials as in the study of Xu et al. (2018). Meditation experience did not affect the illusion, although this might be because of a rather low mean meditation practice in the present study, while the study of Xu et al. (2018) explicitly compared novices with experienced meditators. Similarly, no effect of dissociation was found, which could also be due to the fact that mainly subclinical scores were found in the healthy student sample in this study. In contrast, other studies like the one of Bekrater-Bodmann et al. (2016) investigated patients with borderline personality disorder compared to healthy participants. An effect of mood could also not be determined (Schroter et al., 2021), possibly because other related variables like interoception explain more variance in our models. IAc was negatively related with the difference between synchronous and asynchronous trials, which is in line with the literature (Tsakiris et al., 2011). The proprioceptive drift did not show this effect, instead a positive relation to IAc and a negative relation to IS independent of synchrony was shown. Since synchrony is missing in this connection, expectation effects or affirmative tendencies cannot be ruled out (Riemer et al., 2019). It may be speculated that a general bias toward the body centre among good heartbeat perceivers and a greater confidence in the stability of the body representation in participants with a high interoceptive sensibility explain these results.

Regarding IAw, the abovementioned relevance of improving meta-awareness alongside with body-focused meditations becomes even more evident regarding the main findings of this paper: Neither the subjective illusion nor the proprioceptive drift showed a mere significant interaction of synchrony, time, and group. Instead, for both the proprioceptive drift and the subjective illusion, a four-way interaction of synchrony, time, group, and IAw showed that a brief meditation had no direct effect on sense of ownership. Instead, this effect depended on the level of IAw. Only subjects with higher IAw showed a stabilization of the body representation after the meditation as indicated by a lower subjective rubber hand illusion or proprioceptive drift. The post-hoc comparison of baseline and post-intervention RHIQ scores was significant for participants with high IAw in the meditation group. The difference between groups at post-intervention only showed a trend in the RHIQ, which might be due to the baseline differences between groups. For the proprioceptive drift, some unexpected effects were found: post-hoc tests showed that in subjects with high IAw, the control group had a smaller difference in drift between synchronous and asynchronous trials at baseline, but this difference converged to the level of the meditation group's baseline measurement at the second measurement. Although these baseline group differences only affected subjects with high IAw, they still limit the generalizability of the results.

Overall, the four-way interactions suggest that IAw plays a large role concerning the effectiveness of brief mindfulness meditations. In contrary to our expectation, IAw was not a mediator in this relationship, as it was not influenced by the intervention itself. Instead, our results may suggest that meta-awareness is a necessary skill to effectively enhance body awareness, which cannot be changed by short interventions. This stresses the importance of including exercises which promote one's ability to monitor mental processes, to identify, and to detach from one's thoughts and the static sense of self (Hölzel et al., 2011; Kok & Singer, 2017). A study of Farb et al. (2007) investigated differences between novices and mindfulness-experienced participants regarding self-referential processing. When instructed to engage in present-moment experience of the self, by concentrating on the own thoughts, emotions, and body sensations, mindfulness-experienced individuals showed a higher activation in brain regions associated with a more objective analysis of interoceptive and exteroceptive sensory events, compared to novices. This more objective focus on the self might not indicate a detachment from the self as in depersonalization (Farb et al., 2007), or a generally more plastic self (Hölzel et al., 2011), but rather an enhanced control over the weighting of interoceptive and exteroceptive information. Meta-awareness combined with attention on the body may protect the individual from outer manipulations of the sense of self by providing the individual with the ability to balance exteroceptive and interoceptive sensations. Bekrater-Bodmann et al. (2020) manipulated the bodily self-location by presenting via head-mounted display either a third- or first-person perspective of oneself sitting in a chair and being touched in synchrony or in asynchrony by a brush. The results of this study demonstrated that participants with a higher IAw had a lower malleability of the self-location by exteroceptive input. These findings are in line with our results and emphasize the necessity to include interventions targeting IAw alongside exercises targeting body awareness, to restore the balance of interoceptive and exteroceptive influences. Effectively enhancing body awareness may provide a protective effect against external manipulations of the sense of self, possibly by improving the control over the weighting of interoceptive and exteroceptive information. This might be especially helpful in patient populations, such as in participants with strong dissociative symptoms (Bekrater-Bodmann et al., 2020; Pick et al., 2020; Schäflein et al., 2018; Sedeño et al., 2014). Overall, our results emphasize the need to expand the intervention with exercises that improve meta-awareness.

Limitations and Future Research

As stated above, the shortness of the intervention is the main limitation of this study. Brief interventions do not seem to impact interoceptive abilities and only have a limited influence on the sense of body ownership, which depends on trait IAw. It would therefore be interesting to investigate the effects of long-term interventions on the RHI. Additionally, including exercises that promote meta-awareness would be a promising future research issue. In addition, a replication of the study with patients suffering from clinically relevant dissociative symptoms could provide further interesting insights into the treatment of unstable self-representation, as we used a healthy sample here which may not provide enough variance to investigate interactions with dissociative experiences appropriately.

Regarding the effect of arousal on IS, we tried to rule out that this effect was due to cardiac arousal by including the heart rate into the model. However, other measures of physiological arousal, like blood pressure, need to be investigated, since systolic blood pressure in particular has been associated with increased IAc in the past (Murphy et al., 2018), possibly because of an improved detectability of the pulse. Additionally, our sample consisted of very young participants. Studies with different age cohorts showed that the RHI is rather high among this group and declines with age (Ferracci & Brancucci, 2019). Accordingly, our results may not be generalizable to older participants. Finally, this study includes multiple self-report measures, which could cause a methods bias, e.g., through certain response styles, item context, proximity, and wording which may lead to changes in reliability and validity of the scales and may also influence the covariance of latent constructs (Podsakoff et al., 2012).

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12671-022-02039-7.

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Author Contribution FAS designed and executed the study; performed the data collection, preparation, analysis, and visualization; and wrote the paper. MS helped developing the methodology and the code for data preparation. PJ co-designed and supervised the study, reviewed, and edited the manuscript.

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Data Availability The datasets generated during and analyzed during the current study are available in the OSF repository (https://osf.io/c4sf8/).

Declarations

Ethics Approval The present study was approved by the ethical committee and was therefore in accordance with the 1964 Declaration of Helsinki. The study was approved by the ethical committee of the University of Regensburg (protocol number: 20–1651-101).

Informed Consent All participants gave their written informed consent prior to study participation.

Conflict of Interest The authors declare no competing interests.

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