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First-person thought is associated with body awareness in daily life

Alexandra MacVittie[1]✉, Ewa Kochanowska[1,2], Julia W. Y. Kam[3], Laura Allen[4], Caitlin Mills[4] & Jolie B. Wormwood[1]

Sensations from the body are thought to play a critical role in many aspects of conscious experience, including first-person thought. In the present set of studies, we examined within-person relationships between in-the-moment subjective awareness of sensations from the body and self-reported first-person thought in real-world settings using ecological momentary assessment (EMA) protocols. In Study 1, participants reported experiencing greater first-person thoughts in moments when they also reported heightened awareness of sensations from their body, and this relationship was stable over a 4-week period even with mean-level changes in body awareness and first-person thought. In Study 2, we replicated this association in a 1-week EMA protocol using both self-report measures and measures derived from participants' open-ended descriptions of their ongoing thoughts using a natural language processing approach. Taken together, findings shed light on the role of subjective body awareness in other facets of conscious experience.

Keywords Body awareness, First-person thought, Self-referential thought, Ecological Momentary Assessment

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The study of phenomenological experience has been primarily focused on the brain as the seat of cognition and conscious experience (see, e.g.[1,2]). However, the brain does not function in isolation from the body which houses it; the brain and body are inextricably intertwined both physically/biologically and functionally[3,4]. For example, many theories suggest that the brain's primary function is to guide allostasis, or the predictive regulatory processes of the body[5–10], and that in turn, body activity (and the brain's processing of body activity) may be an important component of a variety of mental experiences, including emotion[11–14], decision making[15–17], and perception[18–21]. In the present set of studies, we examine the role of sensations from the body in one specific component of mental experience: first-person thought. First-person thought is a critical component of the experience of the self, reflecting the perspective from which we experience the world[22], and it is theorized to be closely tied to our experience of our bodies[23–25]. Indeed, prior work posits that the processing of incoming sensory information from the body may be the basis of experiencing the self as a stable and cohesive entity[26]. Here, we adopt an ecological momentary assessment (EMA) approach to examine whether first-person thoughts and heightened awareness of sensory information from the body covary in the moment across different contexts in everyday life and over time.

Thoughts from the first-person perspective involve the self as the actor or agent in the thought and are sometimes referred to as "I" centered thoughts (e.g., "I am reading this paper" or "I am happy")[23,27]. Numerous studies have demonstrated that neural processing of body sensations is related to first-person thought[23–25]. For example, research has shown that greater activity in the ventral precuneus and right interior insula time-locked to one's heartbeats is associated with a greater prevalence of "I" centered thoughts[23,24]. Moreover, subjective first-person experience in these studies was not associated with concurrent changes in heartrate, suggesting that it is the neural processing of sensory input from the heart and not cardiac activity itself that is related to changes in first-person experience[23,24]. In other words, the *processing* of body sensations, conscious or not, may play an important role in the prevalence of first-person thoughts.

Further evidence for the relationship between body sensations and first-person thought comes from visual perception studies designed to capture neural and physiological correlates of the first-person subjective experience of seeing visual stimuli. Specifically, studies assess participants' subjective awareness of seeing visual

[1]Department of Psychology, University of New Hampshire, Durham, USA. [2]Department of Marketing, IESE Business School, University of Navarra, Barcelona, Spain. [3]Department of Psychology, Hotchkiss Brain Institute, University of Calgary, Calgary, Canada. [4]Department of Educational Psychology, University of Minnesota, Twin Cities, USA. ✉email: alexandra.ecker@unh.edu

stimuli (e.g., participants report or indicate "I see the stimulus")[26,28,29]. First person experience (i.e., subjective awareness) in visual perception is thought to be represented by the neural subjective framework, a network of brain regions that aid in tagging an experience as one's own, including the ventral anterior cingulate cortex and amygdala[25,30]. Research has found that increased neural activity time-locked to heartbeats in regions of the neural subjective framework directly preceding stimulus presentation is associated with an increased likelihood of reporting first-person subjective experience of the stimulus[18,26]. In addition, numerous studies have demonstrated changes in the first-person subjective experience of visual stimuli presented at different phases of the cardiac cycle[18], such that hard-to-detect visual stimuli are more likely to be perceived/experienced when presented directly following cardiac systole, as systole is when the baroreceptors in the heart are providing information to the brain concerning current heart rate and blood pressure[19,20,31]. These findings provide further evidence that the neural processing of sensory input from the internal organs of the body plays an important role in first-person experience.

While converging evidence points towards the importance of neural processing of internal sensations in first-person experience and thought, little is known about how the *subjective experience* of the body may be related to first-person thought. Most theories of interoception distinguish these constructs as discrete dimensions of interoception[32–37]. For example, the multi-dimensional framework of interoception[37] defines interoception as comprising multiple distinct facets, including (among others) subjective awareness of internal sensations, objective detection of internal sensations, and neural processing of internal sensations. Empirical evidence also suggests the individual facets of interoception are distinct, both in terms of their associations with each other[32,38–44], and in their associations with other outcomes of relevance (e.g. with alexithymia[45]). Moreover, these different interoceptive processes operate on different time scales and levels of granularity. For example, the brain receives input from the heart during every heartbeat[46,47], but subjective awareness of one's heart does not occur with every heartbeat; you may be more aware of your heart at certain times (e.g., before an important presentation) than others (e.g., when relaxing). Indeed, predictive coding perspectives on interoception have theorized that subjective awareness of internal sensations may reflect prediction errors, such that we are only aware of internal sensations when they are unexpected in some way[48]. As first-person experience also does not occur with every heartbeat, it seems likely that fluctuations in first-person experience occur at a timescale more in line with fluctuations in subjective awareness of bodily sensations than neural processing of bodily activity. Therefore, *subjective awareness* of bodily activity may have a stronger relationship to first-person thought than neural processing of bodily activity. To the extent this is true, subjective awareness of bodily activity (as opposed to neural processing of such activity) may offer a more effective and easier to intervene upon treatment target for psychiatric conditions marked by alterations in first-person experience and memory, such as dissociative disorders[49].

In the present set of studies, we aimed to investigate associations between subjective awareness of ongoing sensations from the body and first-person thought using an ecological momentary assessment (EMA) protocol. This approach has advantages over much of the current research which relies on cross-sectional studies conducted in lab settings (see, e.g.[25,30,50,51]. In particular, neuroimaging studies that use headcaps or fMRI machines necessitate putting participants in a highly unusual context, which may disrupt the ability to probe typical experiential processes. Participants are also typically supine during neuroimaging studies, which reflects a unique and limited physiological context for measuring experience relative to most of waking life. In the current study, we address this by taking measurements periodically during participants' everyday experiences, allowing us to examine how variables are related "in the wild"[52]. Additionally, repeated measurement of participants' experiences over time allows us to assess whether first-person thought and awareness of body sensations covary *within* people. Specifically, we can examine if a person is more likely to have first-person thoughts at times when they are more aware of their body sensations than usual relative to their own average level of awareness, and patterns of association at this moment-to-moment level can reveal relationships that are masked at the mean or between-subjects level[52–54].

Across two EMA studies, we asked participants to report on the extent to which they were experiencing themselves as the actor/author of their thoughts and their awareness of ongoing body sensations multiple times per day throughout their daily life. Across both studies, we predicted that at moments of heightened body awareness, participants would also report experiencing more first-person thoughts. In Study 1, we used a lengthy EMA protocol (4-weeks) which enabled us to also explore how repeated prompting to report on body awareness and first-person experience might impact both experiences of these constructs themselves as well as their relationship to one another over time. In Study 2, using a shorter EMA protocol (1-week), we sought to replicate and extend Study 1 by having participants describe their ongoing thoughts at the beginning of each EMA survey. We then derived indices of first-person thought and body awareness from the descriptions using a natural language processing (NLP) approach, which allowed us to examine in-the-moment associations among first-person experience and concurrent body awareness without relying solely on self-report. While prior work has measured first-person thought using NLP approaches (e.g., counting use of the word "I";[55–57]), to our knowledge this is the first study to introduce and validate an index of body awareness derived from natural language descriptions.

Transparency and openness

The measures reported in both studies were collected as part of a larger investigation designed to assess several unrelated research questions in an effort to mitigate the cost of conducting separate lengthy EMA protocols. A description of all tasks and measures in both studies included in the full protocols can be found in the supplemental online materials; only measures relevant to the current investigation are reported below. The studies and primary analyses were not pre-registered, though some supplemental analyses were, and all data and materials related to the present investigation are publicly available on OSF (https://osf.io/4ft37/). Data from both studies have been reported in part in other publications (Studies 1 and 2: Study 2:[58–60]). All experimental protocols were approved by the University of New Hampshire Institutional Review Board for the Protection of Human Subjects in Research (Study 1 protocol number: IRB-FY2022-162; Study 2 protocol number: IRB-FY2021-8422). All methods were carried out in accordance with the Institutional Review Board guidelines and regulations, in accordance with the Declaration of Helsinki.

Study 1

In Study 1, we used a 4-week EMA protocol assessing self-reported body awareness and subjective first-person experience multiple times per day as participants went about their daily lives. We predicted that in moments of higher body awareness, participants would also report experiencing greater first-person thoughts. At the beginning of the study, participants also completed a more standard, questionnaire-based measure of body awareness, which we predicted would be correlated with participants' average reported body awareness throughout the EMA portion of the study, providing some evidence of convergent validity for our EMA-based measure of body awareness.

In addition, given the length of the EMA protocol (spanning 4 weeks), we decided to explore whether participant's ratings of these variables changed over time; some past work has suggested that EMA protocols themselves may serve as a type of intervention such that asking people to reflect on their experiences multiple times per day over several weeks may tune their attention towards these experiences[61,62]. For example, there is evidence that body awareness can increase through specific repeated interventions, such as mindfulness training[63]. As such, we explored whether asking participants multiple times a day about their awareness of their body sensations might impact how aware of these sensations they report being on average. Moreover, to the extent that body awareness or first-person thought change on average in our sample over time, we will also be able to explore whether these mean level changes impact the strength of the relationship between the variables. For example, perhaps the relationship between body awareness and first-person thought is weaker when the mean level of body awareness is low on average. It is important to note, however, that these analyses are purely exploratory and descriptive in nature; we had no specific predictions regarding how the variables in our study might change on a week-to-week basis nor how any such changes might impact the relationship between body awareness and first-person thought.

Methods

Sample size

Simulation studies suggest that multilevel models with an upper-level (i.e., participant level) sample size of at least $N = 100$ are appropriately powered ($\geq 80\%$) to detect even small direct effects at level 1 (i.e., prompt level[64]). To account for attrition, we decided to recruit approximately 150 participants to complete our study with the goal of retaining an analytic sample greater than $N = 100$.

Participants

One hundred and sixty participants ranging in age from 18 to 66 years (46.3% identified as female/woman; 55.5% white, 25.3% Black, 5.6% other; 10.5% Hispanic/Latinx; 3.1% missing/did not answer; $M_{age} = 28.13$ years, $SD_{age} = 9.13$ years) were recruited from Prolific (www.prolific.co). Eligible participants had to be at least 18 years old and speak English fluently. They also had to have access to their own personal smartphone in order to complete the EMA portion of the study. Informed consent was obtained from all participants before the study began. Participants received up to \$112 as compensation for completing all parts of the study: \$10 for the completion of an initial survey, \$15 each for two subsequent surveys at the two-week and four-week marks, \$0.25 for each EMA survey completed over the course of the 4-week experience sampling protocol (up to \$42), and \$1 for each think-aloud prompt they completed (up to \$10). In addition, participants received a bonus payment of \$10 if they completed at least 126 of the 168 (75%) total EMA surveys they received and a second bonus payment of \$10 if they completed at least 7 of the 10 (70%) total think aloud prompts they received, though the follow-up surveys and think-aloud prompts are not relevant to the present analyses (see supplemental online materials for descriptions of these components of the study). Consented participants received payment for the initial survey separately, with the remaining portions of the study, including the EMA protocol, being opt-in.

Of the 160 recruited participants, 42 did not complete any of the EMA portion and 9 completed less than 30 of the EMA prompts (< 3 SD from mean) and so were excluded from analyses. Thus, the final analytic sample size is 109 participants. The remaining 109 participants ranged in age from 18 to 66 years (45.0% identified as female/woman; 54.1% White, 27.5% Black, 4.6% other; 11.0% Hispanic/Latinx, 2.8% missing/did not answer; $M_{age} = 28.47$ years, $SD_{age} = 8.92$ years). Participants in the final sample completed between 31 (18.45%) and 168 (100.00%) experience sampling surveys ($M = 137.12$ (81.61%), $SD = 32.79$ (19.52%)), resulting in a total of 149,946 surveys (81.62% completion rate).

Procedure

In the first portion of the study, participants completed an approximately 1.5-hour online survey via Qualtrics (Provo, UT), in which demographic and individual difference measures were collected. At the end of the initial survey, participants were given instructions for how to download the 'RealLife Exp' application from LifeData (www.lifedatacorp.com) to their smartphone and how to sign-up to participate in the second part of the study, which entailed 28 days of an EMA protocol to be completed via the app. After signing up, each participant went through a brief tutorial on their phone that walked them through a single EMA survey and provided a description of each question and its response scale (see Table S1 in the Supplementary Information for instructions included in the tutorial).

Starting the morning after they completed the tutorial, participants received prompts (i.e., notifications to respond to an EMA survey) at quasi-random times throughout the day on their smartphone via the LifeData app for 28 consecutive days. Participants received 6 prompts each day between the hours of 10am and 8pm (their local time) with the caveat that no two consecutive prompts could occur within a 1-hour period. This resulted in a total of 168 EMA surveys over the 28-day period. For each prompt, a notification appeared on the participant's smartphone every 5 min until the participant responded or 20 min had been reached, at which point participants were no longer able to respond to that particular prompt.

Tasks and measures

Initial survey measures

In the initial survey, participants completed a number of tasks and measures not relevant to the present analyses. All components of the initial survey are described in the supplemental online materials. Of relevance to the present investigation, participants self-reported basic demographic information and completed a measure of body awareness.

Body awareness The Body Awareness Questionnaire (BAQ[65]) assesses awareness of everyday body sensations. Participants responded to 18 statements (e.g., "I notice differences in the way my body reacts to various foods" and "I know in advance when I'm getting the flu") on a scale from 1 (*not at all true of me*) to 7 (*very true of me*). Responses were summed to yield a total body awareness score where higher numbers indicate greater body awareness ($M = 81.60$, $SD = 17.92$; *Range* = 29–119; Cronbach's $\alpha = 0.88$).

Demographics Participants were also asked to report basic demographic characteristics (i.e., age, gender (open-ended), race, ethnicity). They were also asked to report on their mental health. Supplemental analyses examining associations between first-person thought and self-reported anxiety, depression, and stress symptom severity over time can be found in Tables S3 – S5 of the supplemental online materials.

EMA measures

For each EMA prompt, participants completed a 14 to 15-item survey (completion time: $M = 1.68$ min, $SD = 3.72$ min), though the present investigation focuses on only 2 of these items (described below). The exact wording and response scales for all questions in the EMA survey are provided in Table S1 in the online supplemental materials. Each prompt started with the instructions "Please respond to the following questions regarding whatever you were thinking about just before opening this survey."

First-person thought Participants self-reported on first-person thoughts by answering one question on a 7-point scale (from 1 "not at all" to 7 "completely*)*: "To what extent were you experiencing yourself as the *actor/author* of your thoughts? [Reminder: You should use higher ratings when you are adopting your own perspective (i.e., when you are the protagonist or the agent of thought), as in "Tonight I'm doing the laundry." You should use lower ratings when someone else is the actor of the thought (e.g., "His office is far away") or nobody in particular is (e.g., "It is raining").]".

Momentary body awareness Participants rated their in-the-moment body awareness in response to a single question on a 7-point scale (from 1 "not at all aware" to 7 "completely aware"): "How aware are you of any sensations from your body (e.g., your heartbeat, your breathing, your stomach/gut, your skin or muscles)?".

Analytic approach

Inferential analyses

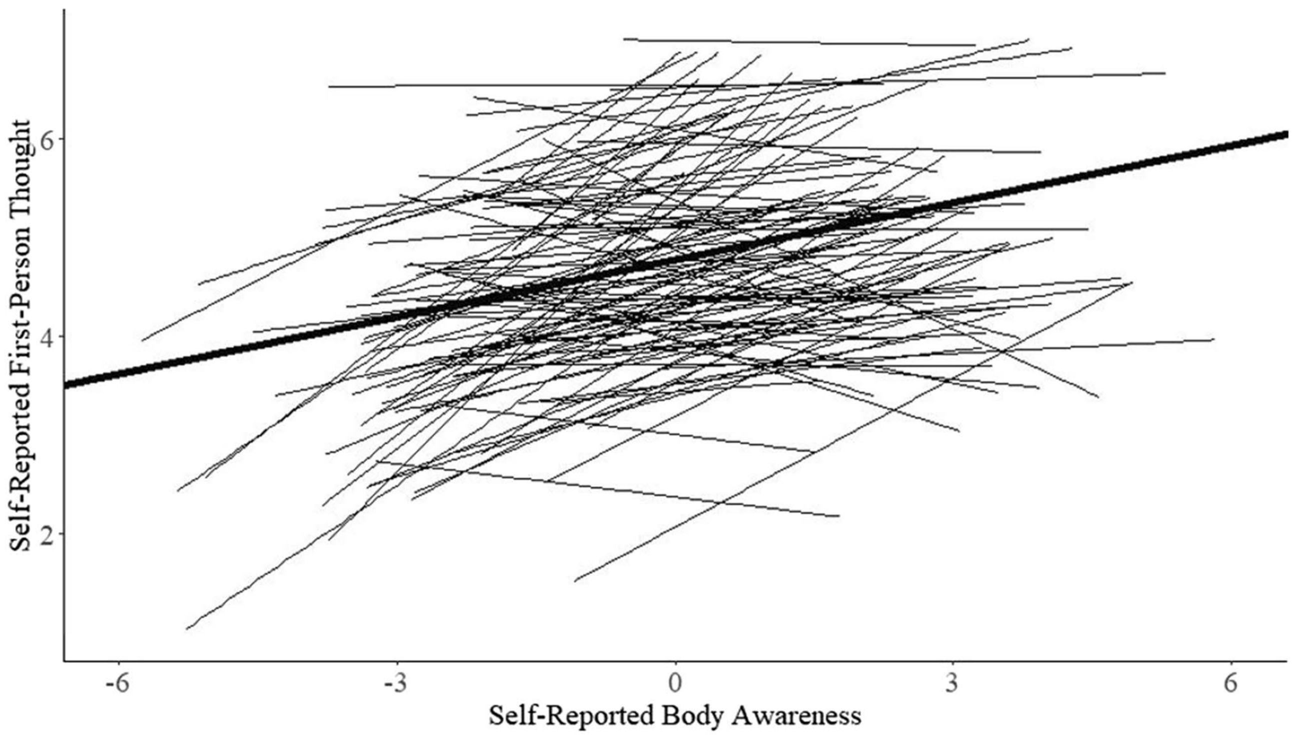
For our preliminary analyses, we adopted a mixed-effects regression approach, which allowed us to nest survey-level information within participants and to examine both within- and across-participant variance in measures simultaneously. All regression analyses were conducted in *R* using the 'lme4' package (v1.1-35[66]). All analyses utilized continuous sampling models with a restricted maximum likelihood method of estimation for model parameters, and Satterthwaite's method[67] for approximating degrees of freedom. Unless otherwise noted, all models assumed both random intercepts and random slopes, and predictor centering followed the recommendations of Enders and Tofighi (2007)[68]: all continuous Level-1 predictor variables (i.e., EMA survey-level variables) were centered around each participant's own mean and all Level-2 variables (i.e., individual difference measures) were grand-mean centered. This centering approach was selected because of our interest in understanding how first-person thought and body awareness covary within a person over time throughout daily life: by centering Level 1 predictor variables around each participant's own mean, we control for potential differences in the mean level of body awareness across participants in the models such that fixed effects reflect solely within-person associations (i.e., are people evidencing more first-person thought when they are also experiencing higher or lower body awareness than usual *for them*). We report marginal (fixed effects only) and conditional (fixed and random effects) pseudo-R^2 values for all models using the approach outlined by Nakagawa & Schielzeth (2013)[69].

Results

Descriptive statistics for body awareness and first-person thought across the entirety of the study are listed in Table 1. As predicted, participants' mean momentary body awareness was positively correlated with their scores on the trait measure of body awareness, the Body Awareness Questionnaire ($r = .23$, $p = .014$).

Variable	Mean	SD	Range	ICC
First-Person Thought				
Individual Ratings	4.82	1.72	1.00–7.00	0.404
pp Mean	4.78	0.98	2.06–6.99	
pp SD	1.34	0.49	0.09–2.47	
Body Awareness				
Individual Ratings	4.33	1.89	1.00–7.00	0.508
pp Mean	4.34	1.36	1.19–6.93	
pp SD	1.21	0.48	0.30–2.48	

Table 1. Descriptive statistics for EMA variables in study 1. Note: pp = per person; For each variable, the sample mean, standard deviation (SD), and range are reported for: the individual ratings across the full data set, the per-participant average, and the per-participant standard deviation. ICC stands for intraclass correlation coefficient, a measure of reliability interpretable as the proportion of variance in the variable at the between-subject level (v. within-subject level).



Note. Graph displays separate best fit lines for each participant's data and, in bold, the fixed effect from the multi-level regression model predicting self-reported first-person thought from momentary self-reported body awareness.

Figure 1. Self-reported first-person thought predicted by momentary self-reported body awareness.

Association between momentary body awareness and first-person thought

As predicted, momentary self-reported first-person thought was positively associated with self-reported body awareness, $b = 0.19$, $SE_b = 0.03$, *95% CI* [0.14, 0.24], $t(95.83) = 7.66$, $p < .001$, *Marginal* $R^2 = 0.021$, *Conditional* $R^2 = 0.366$ (see Fig. 1, see supplemental Table S6 for full model details). Controlling for mean level of body awareness per participant did not change the direction or significance of this association; see supplemental Table S7.

Demographic characteristics

Mean momentary body awareness and mean momentary first-person thought were not significantly associated with participants' age, race/ethnicity, or gender (see Tables S8 – S10 in the supplemental materials). Controlling

Variable	Week 1 ($N=109$)	Week 2 ($N=108$)	Week 3 ($N=108$)	Week 4 ($N=106$)
Body Awareness	4.21 (1.38)[a]	4.38 (1.43)[b]	4.39 (1.47)[b]	4.42 (1.46)[b]
First-Person Thought	4.72 (1.00)[a]	4.72 (1.05)[a]	4.82 (1.09)[b]	4.92 (1.12)[b]

Table 2. Descriptive statistics for EMA measures by week in study 1. Note: Cells report sample means and sample standard deviations of participants' mean momentary rating of each variable. Within a row, weeks that differ significantly from one another have different superscripts.

	b **[95% CI]**
Intercept	**4.74***** [4.55, 4.93]
Body Awareness	**0.19***** [0.13, 0.24]
Week 2	-0.01 [-0.07, 0.06]
Week 3	0.06 [-0.01, 0.12]
Week 4	**0.12***** [0.05, 0.19]
Body Awareness X Week 2	0.00 [-0.04, 0.05]
Body Awareness X Week 3	0.01 [-0.04, 0.06]
Body Awareness X Week 4	-0.00 [-0.05, 0.05]
Conditional R^2 / Marginal R^2	0.022 / 0.362

Table 3. Model assessing changes in relationship between body awareness and first-person thought by week in study 1. Note: Mixed effect linear regression predicting body awareness from first-person thought, week number, and their interaction. Cells report unstandardized coefficient estimates with 95% Confidence Intervals reported in square brackets; * $p<.05$, ** $p<.01$, ***$p<.001$.

for these variables did not impact the direction or significance of the association between momentary body awareness and first-person thought (see supplemental Table S11).

Changes over time

To explore whether engaging in the EMA protocol itself systematically influenced participants' average momentary ratings of body awareness or first-person thought over time, we categorized the prompts by week of the protocol and used mixed effects regression models to compare mean ratings within participants across the 4 weeks of the protocol (see Table 2 for sample means by week; see Table S12 in the supplemental materials for reliability estimates of EMA measures by week). For these analyses, we ran regression models with the "lmer" package (v1.1-26[66]) in R to analyze the effect of week on our variables of interest and then used the "multcomp" package (v.1.4–25[70]) for assessing the significance of all paired comparisons.

Analyses revealed that momentary body awareness increased significantly over time, $F(3, 14674)=16.35$, $p<.001$, *Marginal* $R^2=0.002$, *Conditional* $R^2=0.518$. As seen in Table 2, body awareness increased significantly from week 1 to week 2, $b=0.13$, $SEb=0.03$, *95% CI*[0.05, 0.21], $z=4.22$, $p<.001$, and then stabilized for the remaining two weeks (all other paired comparisons: $bs<0.06$, $ps>0.110$).

First-person thought also increased significantly over time, $F(3, 14628)=11.21$, $p<.001$, *Marginal* $R^2=0.002$, *Conditional* $R^2=0.316$. As seen in Table 2, first-person thought was significantly greater at week 4 and week 3 relative to both week 1 (Week 4 v.1: $b=0.18$, $SE_b=0.03$, *95% CI*[0.09, 0.26], $z=5.22$, $p<.001$; Week 3 v. 1: $b=0.11$, $SE_b=0.03$, *95% CI*[0.02, 0.19], $z=3.26$, $p=.004$), and week 2 (Week 4 v. 2: $b=0.15$, $SE_b=0.03$, *95% CI*[0.06, 0.23], $z=4.38$, $p<.001$; Week 3 v. 2: $M=4.72$, $SD=1.05$), $b=0.08$, $SE_b=0.03$, *95% CI*[-0.00, 0.17], $z=2.42$, $p=.046$). All other paired comparisons were not significant ($bs<0.07$, $ps>0.09$).

Finally, we conducted exploratory moderation analyses to assess whether the relationship between body awareness and first-person thought changed significantly over time by including interaction terms between week and first-person thought in the mixed effects model (see Table 3). As seen in Table 3, the relationship between body awareness and first-person thought was positive and significant during Week 1 of the protocol, and none of the interaction terms in the model were significant, demonstrating that the strength of this association did not change significantly across any of the subsequent 3 weeks. This pattern of results suggests that, although we observed significant changes in both momentary body awareness and first-person thought over time, the *relationship* between body awareness and first-person thought did not change significantly over time.

Discussion

We assessed in-the-moment associations between two aspects of consciousness over a 28-day period throughout participants' daily lives: first-person thought and awareness of sensations from the body. As predicted, we found that in moments of higher body awareness, participants also reported experiencing greater first-person thought. This is consistent with prior work on the role of neural processing of body and interoceptive sensations in subjective experience and "I" centered thought[18,23,24,26]. These findings suggest that we are more likely to be the actor or agent in our ongoing thoughts at times when we are also more aware of sensations from the body.

Secondly, we found preliminary evidence of both the reliability and validity of our novel EMA-based measure of body awareness. Specifically, participants' average momentary body awareness correlated well with a more standard self-report questionnaire assessing individual differences in body awareness, and the overall within-person reliability was moderate ($ICC = 0.51$). These findings are particularly compelling given the lengthy assessment period, which can increase the potential for the introduction of both systematic and error sources of variance to measurements. Interestingly, although significant, the correlation between average momentary body awareness over time and a self-report survey measure of body awareness was relatively small ($r = .23$, $p = .014$). This is consistent with the idea that how aware one *thinks* they are of their body likely differs from how aware of their body they actually are throughout daily life. Critically, prior research has shown that asking about subjective phenomena retroactively (e.g., "how aware you are of your body in general") tends to be less accurate than in-the-moment ratings[71]. As such, our momentary measure of body awareness may offer a more valid method for probing the average awareness of sensations from the body than typical questionnaire-based measures.

In addition, we found evidence that repeatedly prompting participants to assess the extent to which their thoughts were in the first-person perspective and awareness of sensations from their body may have increased the extent to which they have such experiences over time. Momentary body awareness and first-person thought both increased significantly, albeit only modestly, between the first two weeks and the final week of the EMA protocol. Although these analyses were exploratory and we did not have specific predictions concerning how they may change over time, this pattern is consistent with past research showing that prompting participants repetitively about certain experiences (e.g., their emotions) may tune their attention towards these experiences, increasing the reporting or occurrence of these experiences over time[61,62]. In this way, the EMA protocol itself may serve as something of an intervention, increasing subjective awareness of sensations from the body and first-person thought. Critically, however, the relationship between body awareness and first-person thought did not change across weeks in the study, suggesting that this relationship is consistent across contexts and at differing mean levels of first-person thought and body awareness.

Study 2

In Study 2, we once again used an EMA approach to assess within-person associations between in-the-moment experiences of body awareness and first-person thought, though the EMA protocol was shorter in Study 2 (7 days v. 28 days). We sought to replicate the observed within-person association between first-person thought and heightened body awareness while also expanding our measures to complement those of Study 1. First, in Study 1, we relied solely on a self-reported measure of body awareness. Self-reported measures can be biased in many ways, including issues with response bias[72,73]. To address this, in Study 2, we added an open-ended prompt at the beginning of each EMA survey asking participants to describe their current thoughts. By analyzing the content of these verbal descriptions of their thoughts using a natural language processing (NLP) approach, we can attempt to capture aspects of conscious experience (i.e., first-person thought and attention to body sensations) without relying strictly on self-report measures. If successful, this natural language processing approach will allow us to examine associations between body awareness and first-person experience that may be occurring prior to prompting participants to attend to and report on these aspects of their conscious experience. Moreover, to our knowledge this is the first measure of body awareness derived from natural language descriptions of ongoing thought. As such, it may be particularly useful to future researchers looking to assess body awareness without inadvertently drawing awareness to the body by asking about it.

Second, in Study 1, participants provided only a single global rating of body awareness, which requires that participants somehow aggregate information about awareness of different sensations from across the body into a single rating and fails to provide information about the individual sensations that one might be experiencing. To address this, in Study 2, we used a more granular measure of momentary subjective body awareness, asking participants to report on their awareness of eight separate body sensations (e.g., heart rate, breathing). This new measure provides additional information about the types of bodily sensations that participants are v. are not aware of throughout daily life, and also enables us to explore whether subjective awareness of certain body sensations is more closely tied with concurrent first-person thought than others, though we do not have any specific predictions that this will be the case. Most of the prior literature on first-person experience has focused on sensitivity to cardiac sensations[18,26] and the processing of cardiac activity within the brain[23,24], however, interoceptive ability extends beyond sensations from the heart. Interestingly, other modalities of interoception are sometimes associated with cardiac interoceptive ability (i.e., gastric interoceptive ability[74]) and are sometimes not (e.g. respiratory interoceptive ability[33]). Thus, here we explore whether first-person thought is related specifically to cardiac awareness, which would suggest a privileged role for the heart in experiences of the self, or whether first-person thought is related to awareness of any sensations from the body more generally, which would suggest a more generalized role for body sensations in experiences of the self.

Methods

Sample size

Sample size for Study 2 was determined in the same manner as described in Study 1; we aimed to collect data from approximately 150 individuals with the goal of retaining an analytic sample greater than or equal to $N = 100$.

Participants

One hundred and fifty-two participants ranging in age from 18 to 63 years (38.2% identified as female/woman; 87.5% White, 3.3% Asian, 2.6% Black, 6.6% other; 17.1% Hispanic/Latinx; M_{age}=25.8 years, SD_{age}=8.2 years; 73% speaking English as a second language) were recruited from Prolific (www.prolific.co*)*. Eligible participants had to be at least 18 years old and speak English fluently. They also had to have access to their own personal smartphone in order to complete the EMA portion of the study. Informed consent was obtained from all participants before the study began. Participants received up to $30 as compensation for completing all parts of the study: $4 for the completion of an initial survey and $0.50 for each EMA survey completed over the course of the week. In addition, participants received a bonus payment of $5 if they completed at least 32 of the 42 total EMA surveys they received. Consented participants received payment for the initial survey separately, with the remaining portions of the study, including the EMA protocol, being opt-in.

Of the 152 recruited participants, 36 did not complete any of the EMA portion of the study and so were excluded from all analyses. Of the participants who begin the EMA portion, all completed more than 20% of the experience sampling prompts (<9 prompts). Thus, the final sample size was 116 participants ranging in age from 18 to 58 years (43.1% identified as female /woman; 85.3% White, 4.3% Asian, 2.6% Black, 7.7% other; 19.8% Hispanic/Latinx; M_{age} = 24.61 years, SD_{age} = 6.34 years, 76.7% speaking English as a second language). One participant had a technical issue and was asked to redownload the app, resulting in 66 surveys received by this participant as opposed to the 42 surveys received by all other participants. Thus, participants in the final sample completed between 13 and 58 EMA surveys ($M = 35.72$ (85.05%), $SD = 7.71$ (18.36%)), resulting in a total of 4,143 surveys (84.62% completion rate overall; per participant range = 30.95 − 100.00%).

Procedure

The procedure for Study 2 was nearly identical to that of Study 1, with the following exceptions. Participants completed only an initial survey containing questionnaires and did not complete any follow-up surveys or tasks. The EMA portion of the study lasted only 7 days.

Tasks and measures

Initial survey measures

In the initial survey, participants completed a number of tasks and measures not relevant to the present analyses. All components of the initial survey are described in the supplemental online materials. Of relevance to the present investigation, participants self-reported basic demographic and health information and completed two measures of body awareness, which are described below.

Body awareness Participants completed the same Body Awareness Questionnaire (BAQ[65]) as used in Study 1. Responses were summed to yield a total body awareness score ($M = 78.78$, $SD = 16.22$; *Range* = 32–125; Cronbach's $\alpha = 0.84$).

Body vigilance As a second trait-level measure of body awareness, we used the Body Vigilance Scale (BVS[75]), which is a 4-item questionnaire measuring the extent to which one monitors and perceives changes in body activity. This scale was chosen to complement the Body Awareness Questionnaire as it assesses attentional focus towards body sensations as opposed to neutral awareness[36]. Items 1–3 assess the degree of attentional focus, perceived sensitivity to changes in body sensations, and the average amount of time spent attending to body sensations. The fourth item involves separate ratings for attention to 15 sensations (e.g., shortness of breath, upset stomach), which are averaged to yield one overall score for that item. All items were measured on an 11-point Likert-like scale ranging from 0 (*not at all*) to 10 (*extremely*), and responses were summed to yield a total body vigilance score ($M = 20.88$, $SD = 7.72$; *Range* = 0.53–38.60; Cronbach's $\alpha = 0.95$).

Demographics and health Finally, participants were asked to report basic demographic characteristics (i.e., age, gender (open-ended), race, ethnicity) as well as basic questions about their current health and health history (e.g., "Do you have asthma?", "Have you ever been diagnosed with a cardiovascular illness?"). See Table S13 in Supplementary Information for descriptive statistics regarding these variables for the sample. They were also asked questions about their mental health. Supplemental analyses examining associations between self-reported first-person thought and self-reported anxiety, depression, and physical symptom severity can be found in Tables S14-S16 of the supplemental online materials.

EMA measures

For each EMA prompt, participants completed an 18-item survey (completion time: $M = 2.37$ min, $SD = 3.21$ min), though only 10 of these items are relevant to the present investigation. The exact wording and response scales for all questions in the EMA survey are provided in Table S2 in Supplementary Information. Each prompt started with the instructions "Please respond to all questions about your thoughts with regard to whatever you were thinking about just before you received this prompt".

Thought content First, participants provided a brief free-text description of what they were thinking about. Descriptions ranged from 0 to 99 words ($M = 9.48$, $SD = 8.09$).

First-person thought Participants indicated the extent to which they were experiencing themself as the actor/author of their thoughts on a 7-point scale (1 "not at all" to 7 "extremely") using the same item as in Study 1.

Momentary body awareness Participants rated their in-the-moment awareness of the following 8 body sensations: heartbeat, breathing, body temperature, sensations from the stomach or gut, whether they feel hungry or not, how tired or alert their body feels, how dry or moist their skin feels, and how tight or loose their muscles feel (all on a scale from 1 "not at all" to 7 "very"). Except where otherwise noted, for each EMA survey, each participant's awareness ratings for the 8 body sensations were averaged into a single index of momentary body awareness (Cronbach's $\alpha = 0.86$). Descriptive statistics for awareness ratings of the individual body sensations are provided in Table S17 in the supplemental online materials.

Analytic approach

Natural Language Processing (NLP)

The free-text descriptions of ongoing thoughts provided by participants at the start of each EMA survey were analyzed using a natural language processing (NLP) approach to derive indices of body awareness and first-person thought. Prior to deriving body awareness and first-person thought from the narratives, we used the textclean (v0.9.3[76]) and tidytext (v0.4.1[77]) packages in R to correct spelling errors, remove non-ASCII characters, remove contractions, remove punctuation, and tokenize and lemmatize the words in the textual descriptions provided by participants. Correlations between NLP-derived variables and subjective measures are available in Table S18 in the supplemental materials, and the R and python scripts used for analyses are publicly available on OSF (https://osf.io/4ft37/).

NLP body awareness The interoceptive measure from the Lancaster Sensorimotor norms lexicon[78] was used to derive an index of body awareness. This lexicon is a dictionary of 39,707 words with normed ratings for how much a given word is associated with each of six perceptual modalities (touch, hearing, smell, taste, vision, and interoception) and five action effectors (mouth/throat, hand/arm, foot/leg, head excluding mouth/throat, and torso). Here, we used the normed ratings of the interoception perceptual modality to derive our measure of body awareness from participants' thought descriptions. The interoceptive measure norms were generated by asking the extent to which a person experiences a word by 'sensations inside your body' on a scale of 0 (not experienced at all with that sense) to 5 (experienced greatly with that sense). Within our participants' thought descriptions, 45,895 of 46,517 total words generated by participants (98.66%) had normed ratings available in the Lancaster Sensorimotor lexicon. Coverage overall (per thought description) ranged from 0 − 100% (*mean* = 99%, *median* = 100%, *SD* = 6%), and average coverage per person ranged from 92 − 100% (*mean* = 99%, *median* = 99%, *SD* = 1%). To calculate our NLP-derived measure of body awareness, for each thought description, we weighted each word found in the lexicon by its normed interoceptive rating, summed these weighted values across words for the thought description, and then divided this sum by the number of words in the thought description that were in the lexicon. This NLP-derived measure of body awareness could range from 0 to 5. As seen in Table 4, our NLP-derived measure of body awareness covered the full range of possible values, and the mean was just below the midpoint of the scale. Our self-reported measure of body awareness was closer to the midpoint of the scale on average than the NLP-derived measure of body awareness (see Table 4), which may suggest that people

Variable	Mean	SD	Range	ICC
Self-Report First-Person Thought				
Individual Ratings	4.98	1.98	1.00–7.00	0.217
pp Mean	5.01	0.97	2.40–7.00	
pp SD	1.64	0.61	0.00–2.67	
Self-Report Body Awareness				
Individual Ratings	3.58	1.42	1.00–7.00	0.709
pp Mean	3.57	1.19	1.19–6.80	
pp SD	0.71	0.27	0.12–1.63	
NLP First-Person Thought				
Individual Descriptions	1.15	1.01	0.00–8.00	0.474
pp Mean	1.14	0.71	0.00–3.43	
pp SD	0.67	0.30	0.00–1.82	
NLP Body Awareness				
Individual Descriptions	1.68	0.52	0.00–4.90	0.242
pp Mean	1.68	0.52	0.00–4.90	
pp SD	0.41	0.20	0.04–0.98	

Table 4. Descriptive statistics for EMA measures in study 2. Note: pp, per person; For each variable, the sample mean, standard deviation (SD), and range are reported for: the individual ratings across the full data set, the per-participant average, and the per-participant standard deviation. ICC stands for intraclass correlation coefficient, a measure of reliability interpretable as the proportion of variance in the variable at the between-subject level (v. within-subject level).

tend to self-report greater awareness of body sensations than is reflected in the words they use to describe their current thoughts.

First-person thought The number of times participants used a first-person singular subject pronoun ("I") in each thought description was taken as our NLP-derived index of first-person thought. Raw counts of "I" usage have been used as a measure of first-person thought in prior studies[55–57].

Inferential analyses
The analysis plan, including mixed effect model specifications, followed those described above for Study 1.

Results

Descriptive statistics for self-reported and NLP-derived measures of momentary body awareness and first-person thought are provided in Table 4. As predicted, participants' mean self-reported momentary body awareness was positively associated with their scores on each of the two trait-like body awareness measures: Body Vigilance Scale (BVS; $r = .37$, $p < .001$) and Body Awareness Questionnaire (BAQ; $r = .27$, $p = .004$).

Associations between momentary body awareness and first-person thought

We examined associations among self-reported and NLP-derived indices of first-person thought and body awareness using 4 separate mixed effects models. As shown in Table 5, both self-reported and NLP-derived measures of first-person thought were significantly positively associated with both self-reported and NLP-derived measures of momentary body awareness (full model details can be found in Table S19 of the supplemental materials). Controlling for mean level of body awareness per participant did not change the pattern of results nor the significance level of any of the models (see supplemental Table S20). For comparison with Fig. 1 in Study 1, we have also visualized the model predicting self-reported first-person thought from self-reported body awareness in Study 2 in Fig. 2.

Demographic characteristics
Women reported significantly higher average momentary self-reported body awareness ($M = 3.83$, $SD = 1.13$) than men ($M = 3.37$, $SD = 1.21$), $F(1, 114) = 4.43$, $p = .038$, and non-White participants reported significantly higher mean momentary self-reported body awareness ($M = 4.26$, $SD = 1.26$) than White participants ($M = 3.45$, $SD = 1.14$), $F(1, 114) = 7.04$, $p = .009$. There was no significant association between mean momentary self-reported body awareness and participant age, nor any significant associations between mean momentary self-reported first-person thought and age, gender, or race/ethnicity (see Tables S8 – S10 in the supplemental materials). Controlling for these variables did not impact the pattern of results or significance of any of the above associations (see supplemental Tables S21 -S23).

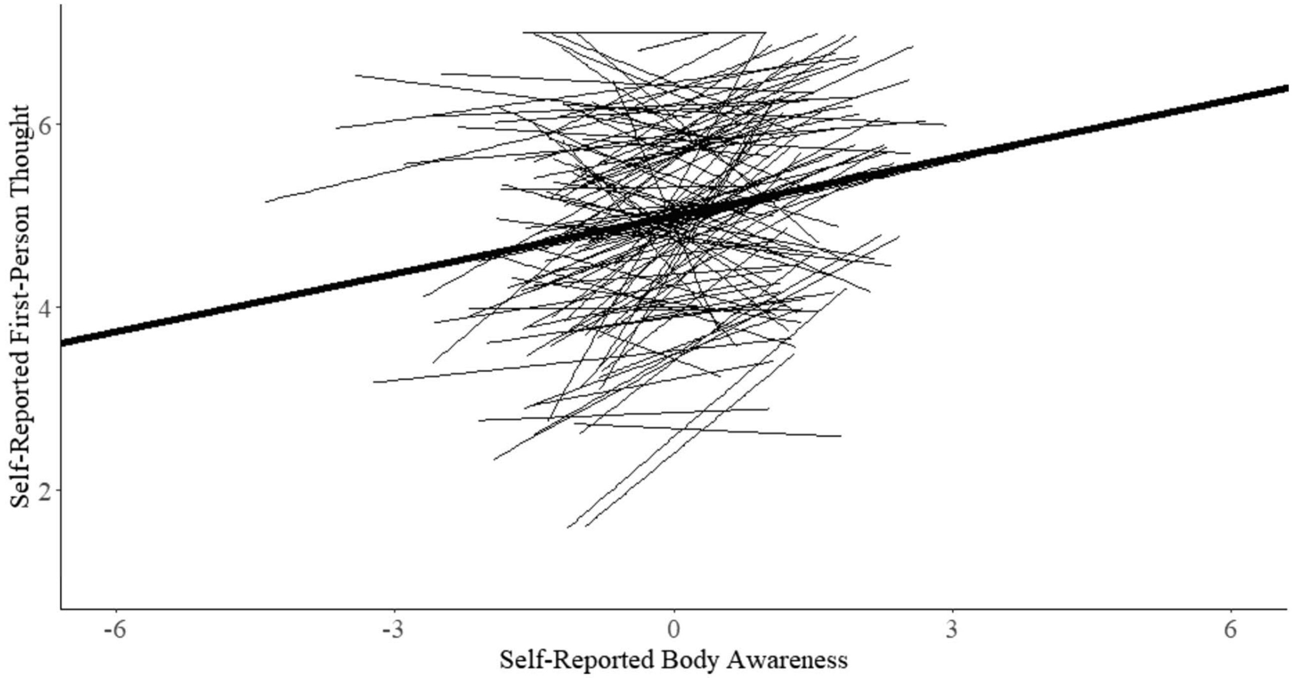
Individual body sensations

Descriptive statistics for reported awareness of the 8 individual body sensations are provided in Table S17 of the supplemental materials. The means of the average self-reported awareness per person ranged from 3.10 (skin moisture) to 4.12 (tiredness/alertness), and values for the per person average awareness ratings covered nearly the full range of possible values (1–7) for each of the individual body sensations. In addition, we calculated per person prevalence rates for reporting awareness of each individual body sensation by taking the number of times the person reported any awareness of the sensation and dividing it by the number of times they could have reported awareness of the sensation (i.e., number of EMA surveys completed). Average prevalence rates ranged from 73% (skin moisture; heartbeat) to 88% (tiredness/alertness). See Table S17.

We used separate linear multilevel models to predict self-reported first-person thought from self-reported momentary awareness of each of the 8 individual body sensations examined (see Table 6). The relationship between momentary self-reported body awareness and self-reported first-person thought was consistently positive across all 8 body sensations, though failed to reach significance for awareness of one's heartbeat and body temperature.

Variable	Self-Reported First-Person Thought	NLP-Derived First-Person Thought
Self-Reported Body Awareness		
b	0.21***	0.04*
95% CI	[0.14, 0.28]	[0.00, 0.08]
Marginal R^2/ Conditional R^2	0.006 / 0.224	0.001 / 0.483
NLP-Derived Body Awareness		
b	0.41***	0.52***
95% CI	[0.24, 0.57]	[0.42, 0.62]
Marginal R^2/ Conditional R^2	0.008 / 0.236	0.050 / 0.544

Table 5. Self-reported and NLP-derived first-person thought predicted by measures of body awareness. Note: B = unstandardized coefficient estimate for the fixed effect; intercept estimates and covariance estimates not shown (full model details can be found in Table S19 of the supplemental materials); ** $p < .01$, ***$p < .001$.



Note. Graph displays separate best fit lines for each participant, and, in bold, the fixed effect from the multi-level regression model.

Figure 2. Self-reported body awareness predicted by self-reported first-person thought.

Body Sensation	Self-Reported First-Person Thought	Marginal R^2/ Conditional R^2
Heartbeat	0.02 [-0.03, 0.07]	0.000 / 0.223
Breathing	0.08*** [0.04, 0.13]	0.003 / 0.221
Temperature of the body	< 0.01 [-0.05, 0.05]	0.000 / 0.226
Sensations from the stomach/gut	0.06** [0.02, 0.10]	0.002 / 0.221
Hunger/satiation	0.06*** [0.02, 0.09]	0.002 / 0.222
Tiredness/alertness	0.09*** [0.04, 0.13]	0.004 / 0.227
Skin moisture	0.06* [0.01, 0.10]	0.001 / 0.222
Tightness/looseness of muscles	0.10*** [0.06, 0.14]	0.005 / 0.223

Table 6. Associations between self-reported awareness of individual body sensations and self-reported first-person thought. Note: Cells report unstandardized coefficient estimates with 95% Confidence Intervals reported in square brackets; intercept and random effect estimates not shown; *$p < .05$; **$p < .01$; ***$p < .001$.

Discussion

Results from Study 2 replicated our main findings from Study 1: in moments of greater awareness of sensations from their body, participants reported experiencing greater first-person thought. This positive association was fairly consistent across awareness ratings of most of the eight individual body sensations measured (e.g., sensations from the gut, breathing), though failed to reach significance for two (i.e., heartbeat, body temperature). This pattern of associations suggests that heightened awareness of body sensations may be related to greater first-person thought regardless of the specific sensation(s) a person is aware of in the moment. However, future work should probe the non-significant relationship between first-person thought and awareness of both body temperature and heartbeat in more detail. The non-significant association between awareness of one's heartbeat and first-person thought is of particular interest as much of the prior literature has shown that sensitivity to or processing of cardiac activity specifically is associated with first-person experience[23–25]. It may be that first-person experiences are more closely associated with subconscious awareness of one's heartbeat or the neural processing of this information, but less closely associated with subjective awareness of sensations related to cardiac activity.

Of note, the range and variability of body awareness ratings was lower in Study 2 than in Study 1, despite sample and participant mean ratings being fairly comparable across studies. This difference in variability is evident when comparing Figs. 1 and 2 (see also Tables 1 and 4). This is interesting to consider in light of the use of a single, global rating of body awareness in Study 1 but an index variable calculated by combining awareness ratings of individual body sensations in Study 2. On the one hand, the difference in variability may simply reflect the fact that single-item measures are inherently more noisy and less reliable than multi-item measures[79,80]. However, it is also possible that broad awareness of sensations from the body in general tends to vary more markedly from moment to moment than does awareness of specific sensations, such that individuals might exhibit selectively high or low awareness of specific interoceptive channels that does not vary much from moment-to-moment (e.g., someone who is never aware of their heartbeat but is aware of other bodily sensations more broadly). Future work should continue to examine individual differences in variability in body awareness across specific sensory channels.

Importantly, the relationship between momentary body awareness and first-person thought was also evident when using our NLP-derived indices of both first-person thought and body awareness. As the thought descriptions were collected prior to participant's subjective ratings of first-person thought and body awareness, this suggests that these associations may be present throughout daily life without explicit prompting to attend to or report on these experiences.

General discussion

Across two studies we found convergent evidence for a relationship between momentary body awareness and momentary first-person thought. Specifically, in line with predictions, people reported experiencing greater first-person thought in moments when they also reported heightened awareness of sensations from their body. This relationship held: when using self-report measures of both momentary body awareness and first-person thought (Studies 1 and 2); when using NLP-derived measures of both constructs taken from participants' descriptions of their current thoughts (Study 2); for self-reported awareness of many individual body sensations (Study 2) as well as awareness of the body more generally (Study 1); and over time, even as mean levels of body awareness and first-person thought were increasing within individuals (Study 1).

Our findings are consistent with past research suggesting that the processing of sensory input from the body plays an important role in first-person experience[18,23–25,81]. However, our studies also build on the current literature in a number of critical ways. Previous research on first-person thought and the body has primarily focused on how "I" centered thoughts relate to activity in different brain regions posited to be involved in interoceptive processing[23–25] or how it relates to the ability to objectively detect internal sensations (i.e. heartbeat[81]). Here, we looked at one's *subjective awareness* of body sensations and how that is related to first-person thought, and our findings suggest that these constructs appear to be associated even at the level of subjective experience. In addition, our studies explored the relationship between body awareness and first-person thought in real-world settings. By expanding beyond a traditional cross-sectional lab-based research paradigm, we were able to capture the nature of this relationship within-participants across multiple contexts throughout their everyday lives. This furthers the previous literature, which has been conducted almost exclusively in lab-based settings and highlights the generalizability of findings to ecologically valid contexts at the within-subject level.

These findings also highlight several potentially fruitful avenues for future research. For instance, in our studies, we only asked about awareness of body sensations and not about the quality of these sensations (e.g., we asked about the awareness of one's heartbeat, but did not ask whether their heart was beating fast or slow). Future studies could include ambulatory physiological measures to provide an objective measure of actual body activity as well as qualitative questions about body sensations. This would allow for an examination of if or how awareness of body sensations and first-person thought fluctuate with actual changes in autonomic activity.

Another future avenue is to examine differences in more general self-focus. While we specifically assessed first-person thought, it is possible that thinking about or attending to the self at all is associated with heightened body awareness, regardless of whether one is thinking of themselves as the actor/agent or object of thought. It is also possible that heightened body awareness could be considered a facet or indicator of self-focus, in which case other measures related to self-focus, such as emotional awareness, may also predict first-person thought. Interestingly, although not a measure of emotional awareness per se, a recent study found that momentary body awareness was associated with the intensity of concurrent self-reported emotional experience (MacVittie, A., Petagna, K., Wormwood, J. B., under review), suggesting a potential relationship between body awareness and other self-focused experiential constructs. Future studies should attempt to disentangle these possibilities.

In addition, future studies should look to replicate these findings in samples that are more diverse (e.g., older participants or participants from different racial and ethnic groups). Although we recruited participants for our studies through Prolific and were able to acquire a relatively diverse sample in terms of country of origin, our sample was primarily white and of young/middle age, which leaves questions about how first-person thought and body experience may be related among participants of demographic groups that are underrepresented in our sample. This represents a particularly interesting avenue for future studies as there is evidence that body awareness may differ for certain demographic groups. For instance, there is evidence that body awareness changes from early to late adulthood (Murphy et al., 2018; Cabrera et al., 2018; Nusser et al., 2021), however these studies have yielded mixed results. On one hand, some studies suggest that awareness of body sensations decreases in old age[82,83], whereas some studies show that this awareness does not change from early to late adulthood[84–86]. In addition, there is some evidence that body awareness may vary across gender such that women reported greater body awareness on a "Noticing" subscale of interoceptive awareness[87], though a prior experience sampling study did not find a difference in self-reported body awareness among men and women[88]. Indeed, we observed heightened body awareness among women relative to men in our sample in Study 2, though not in Study 1. It would be interesting for future studies with more diverse participant samples to examine whether instances of first-person thought also differ across the lifespan or are greater among women (though we did not observe either in our studies). We also note that the association between first-person thought and body awareness held in our studies when controlling for age and gender and mean body awareness, suggesting that this association may hold across various demographic groups even if they differ in mean levels of body awareness or first-person thought.

There is also some evidence that body awareness differs across cultures, such that body awareness appears to be heightened in non-Western cultures relative to European Americans[89,90]. For example, West Africans tend to report greater awareness than European Americans[89]. Given our results, we'd anticipate greater first-person thought among cultures with higher body awareness, but this is at odds with findings that many non-Western cultures tend to have a more "other-focused" view of the self, such that social aspects of the self (i.e., roles, relationships) are more central to the concept of the self[91]. Future studies should examine whether the observed association between body awareness and first-person thought is unique to more individualistic cultures that tend to place emphasis on the individual self or whether it holds in other cultures that tend to have a more socially inclusive conceptualization of the self in community.

Our findings may also have implications for understanding the etiology and maintenance, of psychiatric disorders involving distortions in body awareness (e.g., body dysmorphic disorder[92], disordered eating[93]), and/or first-person experience (e.g., dissociation disorders[94]). For example, there is much evidence that points to differences in interoceptive abilities in those with disordered eating, such that interoceptive ability tends to be lower in those with eating disorders[95,96] (for a review, see[97]). Dissociative experiences, experiences involving disruptions in the sense of self, also appear to be more prevalent among those with disordered eating[98], particularly those engaging in binging/purging behaviors[99,100]. Conversely, compared to individuals with no history of disordered eating, individuals with current anorexia nervosa scored lower on self-focused attention and those with a history of anorexia who were weight-restored scored higher on self-focused attention[101]. These findings suggest that associations between first-person thought and body awareness may be disrupted among those with disordered eating and may fluctuate as a function of current symptomology and recovery. Of note, we observed significant variability in the association between momentary body awareness and first-person thought in our studies such that, while there was a positive association on average, some participants evidenced no association or even a negative association between these constructs (see Figs. 1 and 2). Future studies should assess whether such differences across individuals in the association between body awareness and first-person thought are associated with psychopathology.

Critically, we attempted to measure naturally occurring body awareness in the present set of studies, but interrupting participants' daily lives by prompting them to report on their awareness of body sensations may have encouraged participants to scan their body for sensations in ways they would not normally do. Participants in our studies may have been reporting on their ability to be aware of sensations from their body at the time of prompting rather than how aware they were of their body naturally at the time of the prompt. Future work should look to disentangle unprompted or naturally occurring body awareness from perceived ability to be aware of body sensations when asked. We attempted to account for this in Study 2 by using an NLP-derived measure of body awareness taken from participants' thought descriptions that were collected prior to self-reported body awareness. However, it is likely that participants thoughts were already primed to be aware of their body sensations at the time of the prompt (i.e., when they were writing out their current thoughts), especially later in the EMA protocol, as the prompts were all identical and always included questions about body awareness. However, our novel NLP-derived measure of body-related thoughts could be used in future work to study body awareness without explicitly prompting participants to attend to or report on their experience of sensations from their body. To our knowledge, this is the first such measure of body-related thoughts derived from natural language, and we provide preliminary evidence of its validity; it was associated with subjective ratings of momentary body awareness and replicated the observed relationship with first-person thought. This would be a major advantage for researchers interested in studying body awareness 'in the wild' in the future, as naturally occurring fluctuations in body awareness might be very different when participants are not being prompted to potentially stop what they are doing and scan for any sensations from their bodies.

Data availability

The study and primary analyses were not pre-registered, though some supplemental analyses were, and all data and materials related to the present investigation are publicly available on OSF (https://osf.io/4ft37/).

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Author contributions
J.K., L.A., C.M., A.M., and J.W. created and ran the first study. E.K., C.M., and J.W. created and ran the second study. A.M. analyzed the data from both studies pertaining to this manuscript under the supervision from J.W., and A.M. and J.W. wrote the main manuscript text. All authors reviewed and edited the manuscript.

Declarations

Competing interests
The authors declare no competing interests.

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Correspondence and requests for materials should be addressed to A.M.