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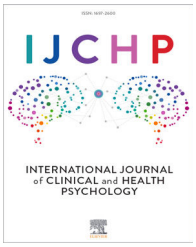

ORIGINAL ARTICLE

Interoceptive attention facilitates emotion regulation strategy use

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Abstract
Background: Perception of bodily signals—or interoception—has been suggested to facilitate individuals' habitual use of emotion regulation (ER) strategies and to guide the flexible deployment of specific ER strategies. Previous research has shown that the emotional intensity of stimuli modulates regulatory choice between disengagement (i.e., distraction) and engagement strategies (i.e., reappraisal). *Method:* This study used experience-sampling methods to investigate the role of interoceptive attention in dynamic changes in ER strategies. Healthy participants first completed one-time measurements of ER strategies, emotional awareness and interoceptive attention in the lab and then reported on negative events and use of strategies including reappraisal and distraction, throughout daily life. *Results:* Results showed that interoceptive attention was positively associated with habitual use of several ER strategies, and emotional awareness mediated the relations between interoceptive attention and these ER strategies. Results also suggested an interaction between interoceptive attention and intensity of negative events; individuals with higher interoceptive attention used distraction rather than reappraisal only during high intensity negative life events, but those with lower interoceptive attention used more distraction than reappraisal, regardless of event intensity. *Conclusions:* Overall, these findings suggest interoceptive attention may increase emotional awareness, which in turn facilitates application of certain ER strategies but also the flexible deployment of appropriate strategies tailored to a given situation. Training interoceptive attention may provide a promising way to improve ER and promote mental health.

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Introduction

Emotions involve complex sets of physiological, behavioral and experiential responses and play an essential role in our lives. In many cases, emotions may play an adaptive role in survival and development, but emotions can also hinder mental functioning or environmental adaptation when they are too intense or not suitable in a given context (Smith & Lazarus, 1990). It is therefore appropriate to adjust the type, intensity, duration and expression of emotions depending on one's particular regulatory goals—a group of processes known as emotion regulation (ER; Gross, 1998). Individual differences in the regulation of negative emotions have been explored, including their potential impact on mental health (John & Gross, 2007). Assessing how individuals vary in their habitual use of certain ER strategies can at least partially explain why individuals react differently and experience different emotions, when faced with similar situations and environments (Joormann & Gotlib, 2010; Wang et al., 2021). The ability to implement suitable strategies based on context has increasingly been suggested as a primary indicator of emotion regulation ability (Bonanno & Burton, 2013; Cheng et al., 2014). Using strategies flexibly, in ways that are matched to specific situations and contexts, may be more beneficial for successful emotion regulation versus rigidly utilizing the same strategies regardless of contextual demands (Aldao & Nolen-Hoeksema, 2013; Bonanno & Burton, 2013).

Previous studies have suggested that various factors—spanning demographics, personality and cognition—can predict or influence individual differences in emotion regulation (John & Gross, 2007). Recent research suggests that the perception of bodily signals, referred to as interoception, underlies individual differences in emotional awareness and thus influences the process of emotion regulation (Gross, 2015; Herbert et al., 2007). Interoception is not a single process but rather forms a broader taxonomy with several dimensions, including interoceptive accuracy, attention, and sensibility (Garfinkel et al., 2015; Khalsa et al., 2018). For instance, Murphy et al. (2019) distinguish between interoceptive accuracy and attention-, each of which can be assessed using either self-reported or more objective methods. More specifically, objective measures of interoceptive accuracy would involve behavioural tests of participants' ability to monitor bodily signals precisely (e.g., reporting how many times their heartbeats within a given time period, which is then compared to actual heart-rate-monitor data), but participants can also be asked to subjectively report on the accuracy of their interoceptive abilities. Interoceptive attention more specifically refers to how much space in one's attention interoceptive signals take up and is typically measured using either experience sampling metrics or self-reported attention to bodily signals (Murphy et al., 2019). Still others have used the term interoceptive sensibility to refer to the combination of subjective beliefs about one's interoceptive accuracy and attention, but the rest of this paper will focus on subjectively reported interoceptive attention.

Several prominent theories propose a close relationship between interoception and processing of emotions (Craig, 2002; Damasio, 1996; James, 1884), which is in line with studies demonstrating that individuals reporting highly differentiated bodily and emotional experiences were more efficient in regulating their emotions (Barrett et al., 2001; Barrett et al., 2004). Trainings for interoception, such as those using mindfulness approaches, are now being adopted as interventions to help individuals better process and cope with emotions (e.g., Aaron et al., 2020; Remmers et al., 2016). Additionally, an emerging body of empirical studies has observed modulation of ER by interoception (Füstös et al., 2013; Kever et al., 2015; Lischke et al., 2020; Pollatos et al., 2015; Schuette et al., 2021; Zamariola et al., 2019a; Zamariola et al., 2019b). For instance, measured by the Heartbeat Counting Task (Schandry, 1981), higher objective interoceptive accuracy has been shown to help successful downregulation of negative emotions (Füstös et al., 2013; Kever et al., 2015; Pollatos et al., 2015; Weiss et al., 2014). However, this advantage of high interoceptive accuracy has not always been consistently documented, when using large samples or different measures of ER (Schuette et al., 2021; Zamariola et al., 2019a). Instead, they found positive correlations between ER and self-reported interoceptive attention measured by the Noticing subscale of Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012; Schuette et al., 2021; Zamariola et al., 2019b). Previous research has shown that interoceptive accuracy was relatively difficult to improve by training (Borneman & Singer, 2017), while interoceptive attention, like mindfully attending to the breath, can be trained more easily (Roemer et al., 2015). Although interoceptive attention is likely a useful target for interventions aiming to improve ER ability and mental health, it has been less examined in this context compared to interoceptive accuracy. Additionally, the measurement of ER in these above empirical studies mostly involved reappraisal and suppression strategies (Füstös et al., 2013; Kever et al., 2015; Lischke et al., 2020; Pollatos et al., 2015). In the present study, we further explore the relations between interoceptive attention and diverse ER strategies.

In addition to potential direct effects, researchers have proposed that interoception may influence ER through emotional awareness, the ability to actively attend to one's emotions (Füstös et al., 2013; Schuette et al., 2021). Indeed, a large body of studies have found that individuals with higher interoceptive accuracy report increased emotional awareness (Pollatos et al., 2005). Further, emotional awareness and recognition are involved in all three stages of ER proposed by Gross (2015)—namely identification, selection, and implementation. When developing the Difficulties in Emotion Regulation Scale (DERS), Gratz and Roemer (2004) identified emotional awareness as one of the essential factors for successful ER, and theories indicate emotional awareness as a fundamental aspect of ER (Barrett et al., 2001). Thus, the current study aims to test for a potential mediating role of emotional awareness in the relation

between interoceptive attention and habitual use of various ER strategies.

In addition to influencing ER strategy use broadly, it has been suggested that interoceptive information can be important in facilitating the flexible use of specific ER strategies to meet specific contextual demands (Ardi et al; 2021; Bonanno & Burton, 2013). For instance, Birk and Bonanno (2016) demonstrated that internal feedback including bodily information and emotional awareness guided participants to switch to an optimal ER strategy when emotional stimuli changed and predicted a higher level of well-being. However, there is still a lack of research that directly tests modulation of flexible ER strategy use by interoceptive attention in real-life settings.

Emotion regulation in daily life is a dynamic process that requires multiple strategies adopted together or in succession (Aldao et al., 2014). It is likely that people choose, abandon, and update ER strategies dynamically in response to their ever-changing environment (Aldao et al., 2015). When a strategy fits a given situation, it is adaptive, and can be considered to have good strategy-situation fit (Cheng et al., 2014; Haines et al., 2016; Troy et al., 2013). This strategy-situation fit requires both evaluating contextual demands and flexibly matching strategies to meet these demands (Goodman et al., 2021). For example, emotional intensity is one particular contextual demand that has been frequently examined in relation to ER strategy choice (Matthews et al., 2021). Studies have consistently demonstrated that healthy participants prefer to use strategies that involve engagement with and re-interpretation of emotional information (i.e., reappraisal) in response to situations with relatively low emotional intensity, whereas they choose to use strategies that involve disengagement of attention from emotional stimuli (i.e., distraction) in high-intensity negative emotional situations (Feldman & Freitas, 2021; Hay et al., 2015; Sheppes et al., 2011, 2014). Furthermore, this flexible regulatory pattern has been found to be more adaptive compared to rigid regulatory styles, which are characterized by indistinguishably adopting a single strategy (Birk & Bonanno, 2016; Levy-Gigi et al., 2016; Murphy & Young, 2020). One possible reason for these findings is that strategies such as reappraisal are engaged to serve long-term goals, leading to adaptive consequences in low-intensity situations (Sheppes & Meiran, 2007; 2008). However, in high intensity contexts, simply disengaging attention via distraction can be less effortful and thus more effective in more quickly blocking potent, strong emotions (Sheppes et al., 2014; Webb et al., 2012). In line with this assumption, neural evidence has shown that distraction reduces activity of the amygdala more than reappraisal (McRae et al., 2010), especially for high-intensity emotions (Shafir et al., 2015). Using distraction versus reappraisal for events of varying emotional intensities is also consistent with leading therapy models such as dialectical behavior therapy (Linehan, 1987; 2014). Based on research and theory suggesting the importance of matches between emotional intensity and choice of ER strategy (Sheppes, 2020), in the present study we investigated strategy-situation fit by comparing participants' ER strategy choices (i.e., reappraisal vs. distraction), in the contexts of differing emotional intensity levels. Specifically, we considered that people with a high level of strategy-situation fit would distract themselves rather than reappraise in high-intensity emotional contexts but would use more reappraisal than distraction in situations with low emotional intensity. People with low strategy-situation fit would have difficulty matching strategies to meet situations differing in emotional intensity, instead indiscriminately choosing less adaptive regulation strategies (e.g., distraction).

Considering the close relationship between strategy-situation fit and mental health (e.g., Goodman et al., 2021; Haines et al., 2016), we believe it is necessary to examine whether higher interoceptive attention may facilitate more successful matching of ER strategies to contextual demands; this might eventually help reveal novel pathways for effective ER-related intervention for those with mental health problems. To this end, in the current study we utilized the experience-sampling method (ESM) to investigate how individuals employ ER strategies in response to negative events that occur in daily life, and how these ER-use patterns might relate to interoceptive attention. ESM uses structured diary techniques to measure individual experiences of mood, behavior and context as they occur in daily life (Dimotakis et al., 2013). ESM is designed to reduce recall bias and to collect valid intensive longitudinal data for measuring individual differences in intraindividual variability. Thus, it is highly suitable for exploring when and how people use ER strategies in real-life settings and is often viewed as an optimal way to accurately measure ER ability (Aldao et al., 2015; Haines et al., 2016).

In sum, the present study aimed to test two hypotheses: 1) higher interoceptive attention may increase habitual use of ER strategies through augmented emotional awareness; and 2) higher interoceptive attention may increase strategy-situation fit in real life settings. To test the first hypothesis of a potential mediating role of emotional awareness in the relation between interoceptive attention and habitual ER use, we measured trait-level interoceptive attention, ER strategy use and emotional awareness. The Noticing scale of the MAIA (Mehling et al., 2012) was applied to measure self-reported levels of interoceptive attention. The Regulation of Emotion Systems Survey (RESS) (De France & Hollenstein, 2017) was used to assess individual habitual use of ER strategies including reappraisal, suppression, rumination, distraction, engagement and arousal control. We expected that reappraisal, rumination and arousal control would be positively correlated with interoceptive attention because they relate to increased bodily and emotional awareness. Conversely, we expected the strategies of distraction, suppression, and engagement may not have this association with interoceptive attention because they likely involve external attentional control or inhibitory systems (McRae & Gross, 2020), thus diverting attention from internal signals (James, 1884; Pollatos et al., 2005). For the second hypothesis, we fitted the co-variance between the use of two ER strategies (reappraisal and distraction) and the reported intensity of life events in multilevel models to quantify strategy-situation fit. Cross-level moderation effects were estimated to examine how interoceptive attention might modulate the effects of emotional intensity on regulatory strategy use. We expected that only individuals with high levels of interoceptive attention would use more distraction when regulating highly negative life events, while they would use more reappraisal when facing low-intensity negative situations.

Methods

Participants and procedures

This study was approved by the scientific and ethical review board at Southwest University, China. Participants were part of an ongoing project examining associations among brain imaging, creativity, and mental health (Wei et al., 2018). Therefore, exclusion criteria were a history of head injury, neurological or psychiatric disorders, exposure to psychotropic medications and pregnancy. The procedures and sample of current manuscript were the same as those in a published paper using the same dataset (Wang et al. 2021). As suggested in previous studies (Blanke et al., 2020, study 3 and study 4), we initially planned to recruit around 200 undergraduate students via online advertising. To balance the gender ratio, we recruited 230 healthy university students (125 females; mean age = 19.97 years, SD = 2.27). They completed demographic information and several one-time questionnaires. A total of 223 participants started the ESM procedures. In ESM study, twelve participants were excluded from data analyses after data collection because of equipment malfunction (n = 3), poor compliance (n = 7, $>$ 35% missing data), and fewer than 7 negative life events reported (n = 2), resulting in a final sample of 211 participants (117 females; mean age = 19.81 years, SD = 1.36) for the multilevel analyses. The standards of poor compliance with 30∼20% missing data was commonly used in previous studies according to a Meta-analysis (Vachon et al. 2019).

After giving written informed consent, participants completed demographic information and several one-time questionnaires. Then, they were given instructions to complete the experience sampling portion of the study, using the Wenjuanxing platform (https://www.wjx.cn/). Before leaving the lab, participants underwent a practice trial on their own smart phones. In the following 10 days, participants answered questions on the Wenjuanxing platform 5 times per day, whenever they received a notification. Notifications happened between 10 a.m. and 10 p.m., with a minimum interval of 120 minutes. Participants had to complete each questionnaire within 20 minutes. The questions that participants answered each time were identical, including (1) name and ID, (2) negative events experienced since the previous notification, as well as a rating of their intensity, and (3) use of seven ER strategies since the previous notification. Finally, participants were compensated with money if they completed more than 75% of notifications throughout the entire ESM procedure.

One-time measurements

Self-reported interoceptive attention

The Multidimensional Assessment of Interoceptive Awareness (MAIA) includes eight subscales (Mehling et al., 2012), but our focus for this study was the Noticing subscale. The Noticing subscale captures self-reported beliefs regarding one's attention to interoceptive signals (Mehling et al., 2012). The MAIA_Noticing subscale contains 4 items (e.g., "I notice changes in my breathing, such as whether it slows down or speeds up"). Participants indicated their awareness of body sensations on a 5-point rating scale from 0 (*never*) to 4 (*always*). The average score of the 4 items indexes the level of interoceptive attention for each participant. Cronbach's α for the Noticing subscale was .71 in this study.

Habitual use of emotion regulation strategies

We assessed habitual use of emotion regulation strategies using the Regulation of Emotion Systems Survey (RESS), which is designed to measure an individual's tendency to use six specific ER strategies to downregulate negative feelings (De France & Hollenstein, 2017). The RESS is composed of six subscales: distraction (e.g., "Engaging in something else to keep busy"), rumination (e.g., "Thinking repeatedly about what was bothering me"), reappraisal (e.g., "Looking at the emotional event from a different perspective"), suppression (e.g., "Pretending I was not upset"), engagement (e.g., "Using facial expressions to show that I was upset"), and arousal control (e.g., "Trying to slow my heart rate and breathing"). Items are answered on a five-point Likert scale from 1 (*never*) to 5 (always). Cronbach's alpha for each subscale ranged from .71 to .92, which showed good internal reliability of the RESS in the current study.

Emotional awareness

The emotional awareness was assessed using the Awareness subscale of the Difficulties in Emotion Regulation Scale (DERS_Awareness; Gratz & Roemer, 2004). The Awareness subscale including 6 items was used to assess individuals' attention to their emotions. Sample items include "I am attentive to my feelings; I care about what I am feeling." Participants were asked to rate items with a five-point Likert scale ranging from 1 (almost never) to 5 (almost always). Higher scores indicate lower emotional awareness. Cronbach's α for the Awareness subscale was .78 in this study.

Real-time experience sampling measurements

Negative events

We asked participants if they had had a negative event since the previous notification (or since waking up if it was the first notification of the day). If the answer was yes, they had to describe these events and rate the intensity of the negative event from 0 (*not at all*) to 100 (*very strong*).

Emotion regulation strategies

At each ESM prompt, participants reported their use of seven ER strategies since waking up / the last notification, using seven single items rated on a scale from 0 (*did not apply at all*) to 100 (*applied strongly*), which has been widely adopted in previous ESM studies (Blanke et al., 2020; Brans et al., 2013). Examples of the items included "I saw the things that happened or my feelings from a different perspective" (reappraisal) and "I distracted my attention away from the things happened or my feelings" (distraction). Besides reappraisal and distraction, other possible ER strategies included rumination, acceptance, emotional expression, expressive suppression, and social sharing, considering that participants would take different ER strategies to cope with negative life events in real-life situations (English et al., 2017; Kalokerinos et al., 2017). The specific items are presented in supplemental materials (Table S1).

Data analysis

Interoceptive attention and habitual use of emotion regulation strategies

To investigate the associations between interoceptive attention and habitual use of each ER strategy measured by the RESS, we conducted partial correlation analyses including the other ER strategies of the RESS as covariates; the false discovery rate (FDR) was used to correct for multiple comparisons. To investigate whether the effect of interoceptive attention on habitual use of ER strategies was mediated by emotional awareness, we estimated mediation models to test the indirect effects of interoceptive attention on the use of each ER strategy, respectively. We had hypothesized positive associations between interocpetive attention and the strategies related to increased bodily and emotional awareness. Therefore, only ER strategies that positively related to interoceptive attention and survived in FDR correction were considered in our mediation analyses. Bootstrapping with 5,000 bootstrap resamples was used to estimate bias-corrected 95% confidence intervals (CIs) of indirect effects for each model. All analyses were controlled for age and gender. Mediation models (model 4) were conducted in SPSS 22 using the PROCESS extension (3.0 Version) (Hayes, 2018).

Interoceptive attention and strategy-situation fit

To compute the individuals' level of strategy-situation fit, we assessed the co-variation between the use of two types of strategies (distraction and reappraisal) and the emotional intensity level of life events at the same time point (Goodman et al., 2021; Haines et al., 2016). Considering the nested structure of experience-sampling data, we built a multilevel model using the "lme4" package in R and corrected the model with maximum likelihood methods by using "REML" function (Bates, 2010). Before model fitting, we examined the normal distribution and outliers and heteroscedasticity for variables of interest. According to the principles of centering, we group-mean centered level-1 predictors, including the intensity of events and strategy category, and grand-mean centered the level-2 predictors, including interoceptive attention, age and gender. Additionally, the between-individual averages of event intensities were included as covariates in the level-2 model. We used the "bruceR" package in R (Bao, 2022) to center these above-mentioned variables.

At the within-person level (level-1) of multilevel models, ER strategy use was regressed onto the intensity level of life events and strategy category. To compare the use level of two ER strategies when responding to the same life events, we created a dummy within-person variable "Strategy category" by coding reappraisal and distraction as 1 and 2, respectively. The model for the within-person level is shown in the Equation (1):

$$\begin{aligned}\mathbf{Strategy\ use}_{ti} = {} & \beta_{0i} + \beta_{1i}\,(\mathbf{Intensity\ of\ events}_{ti}) \\ & + \beta_{2i}\,(\mathbf{Strategy\ category}_{ti}) + r_{ti}\end{aligned} \tag{1}$$

The dependent variable (Strategy use $_{ti}$) reflects each person's (i's) use of either reappraisal or distraction at time t. The intercept (β_{0i}) represents each person's mean reported emotional intensity level for life events. The slope (β_{1i}) reflects the within-person associations between strategy use and emotional intensity of life events at time t. A positive Strategy use-Intensity of events slope indicates greater levels of overall ER strategy use in the context of higher intensity events. The slope (β_{2i}) reflects the within-person associations between strategy category and strategy use at time t. A positive Strategy use- Strategy category slope indicates greater use level of distraction, as we used dummy codes for distraction and reappraisal strategy categories (2 and 1, respectively). We were primarily interested in the interaction effects between intensity of events and strategy category (i.e., strategy-situation fit). A positive estimated value for Strategy category × Intensity of events indicated greater use of distraction over reappraisal during negative life events with high emotional intensity, whereas negative estimated values indicated greater use level of reappraisal over distraction during negative life events with high emotional intensity; thus, higher values of this interaction term, represent a higher level of strategy-situation fit. The within-person residual (r_{ti}) reflects the unexplained component of each person's strategy use at time t. All parameters in Equation 1 were allowed to vary randomly across people.

At the between-person level (level-2), the associations between the variables at within-person level and MAIA_Noticing were modelled as shown in Equations (2-4). Considering specific demographic variables (e.g. age and gender) have been suggested to play a critical role in ER use, we controlled for effects of gender and age in our current model (Sanchis-Sanchis et al., 2020; Thomsen et al., 2005).

$$\begin{aligned}\beta_{0i} = {} & \gamma_{00} + \gamma_{01}(\mathbf{MAIA\_Noticing}_i) + \gamma_{02}(\mathbf{gender}) \\ & + \gamma_{03}(\mathbf{age}) + u_{0i}\end{aligned} \tag{2}$$

$$\begin{aligned}\beta_{1i} = {} & \gamma_{10} + \gamma_{11}(\mathbf{MAIA\_Noticing}_i) + \gamma_{12}(\mathbf{gender}) \\ & + \gamma_{13}(\mathbf{age}) + u_{1i}\end{aligned} \tag{3}$$

$$\begin{aligned}\beta_{2i} = {} & \gamma_{20} + \gamma_{21}(\mathbf{MAIA\_Noticing}_i) + \gamma_{22}(\mathbf{gender}) \\ & + \gamma_{23}(\mathbf{age}) + u_{2i}\end{aligned} \tag{4}$$

In the Equations (2) and (3), the intercepts γ_{00}, γ_{10} and γ_{20} reflect estimates of within-person parameters in the Equation (1) for a person with an average MAIA_Noticing score. The slopes γ_{01}, γ_{11} and γ_{21} represent between-person associations between strategy category and each within-person parameter modelled in Equation (1). Specifically, the γ_{01} slopes are estimates of the association between interoceptive attention and strategy use. The γ_{11} and γ_{21} slopes are estimates of the association between a) MAIA_Noticing and b) within-person Strategy use-Intensity of events and Strategy use-Strategy category slopes. Of particular interest, the three-way interaction (Intensity of life events × MAIA_Noticing × Strategy category) represents the association between interoceptive attention and strategy-situation fit. We hypothesized that interoceptive attention would facilitate strategy-situation fit, which means the estimated values of the two-way interaction (Intensity of life events × Strategy category) should be more positive in participants with higher MAIA_Noticing scores than in

participants with lower MAIA_Noticing scores. The between-person residuals u_{0i}, u_{1i} and u_{2i} reflect person-specific variance in each within-person parameter that is unexplained by all variables at the between-person level. We used the "effectsize" package in R (Long, 2020) to estimate the effect size of our parameters of interest.

Results

Interoceptive attention and habitual use of emotion regulation strategies

Descriptive statistics and correlation coefficients for interoceptive attention, habitual use of ER strategies and DERS_Awareness are displayed in Table 1. Interoceptive attention was positively correlated with habitual use of reappraisal (r = .17, p_{FDR} = .020), arousal control (r = .30, p_{FDR} < .001, rumination (r = .17, p_{FDR} = .020) and negatively correlated with distraction (r = -.15, p_{FDR} = .037). As expected, interoceptive attention was significantly negatively related to DERS_Awareness (r = -.27, p_{FDR} < .001). To then test our mediation hypotheses, we included only ER strategies significantly positively related with interoceptive attention. Therefore, we included three ER strategies for the mediation analyses.

As Fig. 1 illustrates, the standardized regression coefficient between interoceptive attention and DERS_Awareness was statistically significant, as were the standardized regression coefficients between DERS_Awareness and all three ER strategies (i.e., reappraisal, arousal control, and rumination). We tested the significance of the indirect effects of interoceptive attention on ER strategies, using bootstrapping procedures with 5,000 samples. The bootstrapped standardized indirect effect of interoceptive attention on reappraisal through DERS_Awareness was 0.11 (95% CI [0.05, 0.17], Fig. 1a). We also observed a significant indirect effect of interoceptive attention on arousal control through DERS_Awareness, with a bootstrapped standardized indirect effect was 0.05 (95% CI [0.01, 0.09], Fig. 1b). Finally, there was also a significant indirect effect of interoceptive attention on rumination, through DERS_Awareness, with a bootstrapped standardized indirect effect of 0.10 (95% CI [0.04, 0.16], Fig. 1c). For reappraisal and arousal control, direct effects of interoceptive attention remained significant, suggesting partial mediation, whereas the direct effect on rumination was nonsignificant and approached zero (though this may be accounted for by a lower total effect of interoceptive attention on rumination vs. the other strategies).

Interoceptive attention and strategy-situation fit

Two hundred eleven subjects did the real-time experiential sampling measurements, reporting on negative events and their corresponding intensity ratings, as well as ER use in daily life. A total of 2,860 negative events were reported from 211 participants, which accounted for 24.77% of total timepoints measured. Responses at time points without negative events reported accounted for 75.23% of the total time points measured, and these responses were excluded from analyses explicitly examining effects of negative event intensity. The average number of reported negative events was 13.55 (SD = 4.58, range: 7-33). The negative events participants reported were diverse, relating to topics such as academics, relationships, and weather. The average intensity of negative events was 42.90 (SD = 16.90, range: 0-100). All the given ER strategies were used by participants (see Fig. S1), but we focus our analyses on the two strategies of reappraisal and distraction. We compared the mean use of these two ER strategies (reappraisal and distraction) in the situations with vs. without negative events. As expected, the results from paired-samples T test showed that mean use of both reappraisal and distraction in situations without negative life events were significantly lower than with negative events (reappraisal: $t_{(210)}$ = -8.79, p < 0.001, d = 0.61; distraction $t_{(210)}$ = -9.67, p < 0.001, d = 0.67). These findings further suggest that negative event is a major reason to engage in ER.

In preliminary analyses, we ran two null models to estimate means, SDs and Intraclass Correlation Coefficients (ICCs) for intensity of negative life events and use of reappraisal and distraction strategies. The mean level of intensity of negative life events was 42.90 (SE = 1.21, 95% CI [40.51, 45.27]), with SDs of 23.77 and 16.90 at the within- and between-person levels, respectively. The ICC for

Table 1 Descriptive statistics and correlations between interoceptive attention, emotional awareness and emotion regulation strategies.

	M	*SD*	*Cronbach's a*	*Related to MAIA_Noticing (r)*	*Related to DERS_Awareness (r)*
1. MAIA_Noticing	2.15	0.78	.71	–	−.27***
2. DERS_Awareness	16.00	4.06	.78	−.27***	–
3. Distraction	3.83	0.90	.79	−.15*	−.07
4. Reappraisal	3.17	0.69	.89	.17*	−.28***
5. Rumination	2.72	0.71	.89	.17*	−.22**
6. Arousal Control	2.53	0.80	.79	.30***	−.09
7. Suppression	2.50	0.86	.92	−.13	−.03
8. Engagement	2.75	0.76	.90	−.12	−.17**

N = 230; * p < .05, ** p < .01, *** p < .001; MAIA: Multidimensional Assessment of Interoceptive Awareness; DERS: Difficulties in Emotion Regulation Scale.

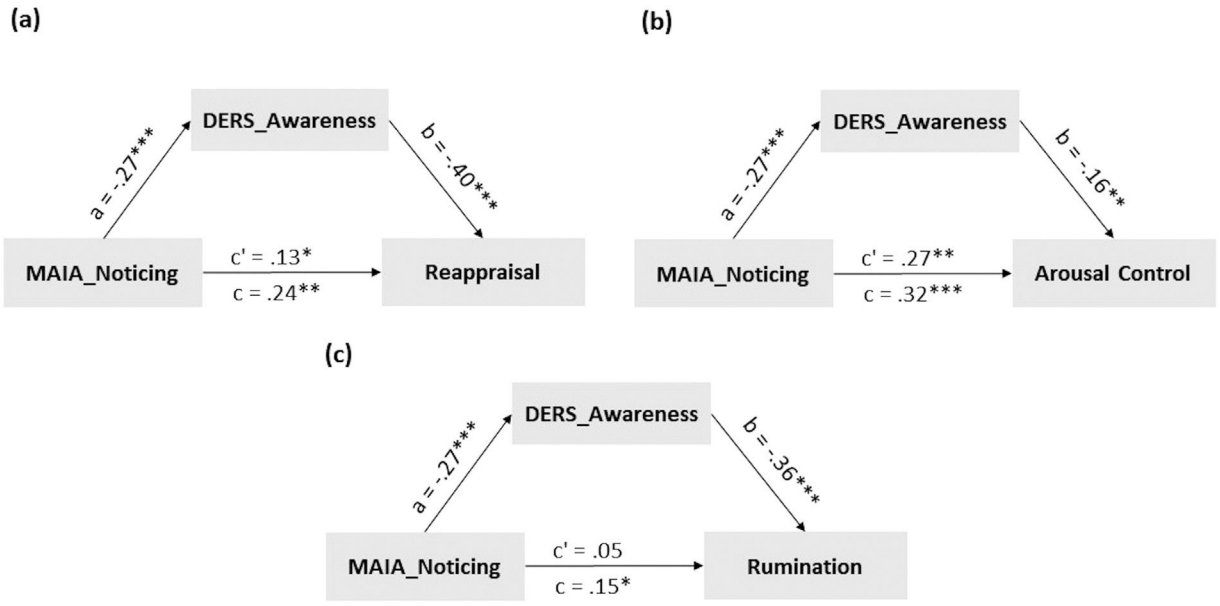

Figure 1 Mediation results. * $p < .05$, ** $p < .01$, *** $p < .001$; MAIA: Multidimensional Assessment of Interoceptive Awareness; DERS: Difficulties in Emotion Regulation Scale.

emotional intensity of events was 0.34, indicating that 34% of the total variability in emotional intensity of events was between-persons and 66% was within-persons. Regarding the use of reappraisal and distraction strategies, the mean level was 40.99 (*SE* = 1.17, 95% CI [38.68, 43.29]), with SDs of 22.45 and 16.41 at the within- and between-person levels, respectively. The ICC for strategy use was 0.35, indicating that 35% of the total variability in strategy use was between-persons and 65% was within-persons. The values of ICCs for variables were greater than 0.06, suggesting multilevel analysis might be the best way to account for this substantial within-person variance (Cohen, 1988). As shown in Fig. S2, all variables of interest (level-1 residuals, interoceptive attention, strategy use, and intensity of events) were normally distributed and there were no outliers for these variables. As shown in the Fig. S3, residuals showed a seemingly chaotic mass of scatter along the X axis. Additionally, the Breusch-Pagan test rejected the null hypothesis that the residual variance is non-constant ($\chi 2$ = .39, p = .533).

Results of our main model including parameter estimates, t values, p values and 95% CIs are presented in Table 2. The main effect of intensity of negative life events was significant (B = .06, p = .006, f^2 = .48), suggesting that most individuals tended to use a higher level of ER strategies when coping with higher intensity negative events. The interaction of Strategy category × Intensity of events was significant (B = .06, p = .003, f^2 = .04), which reflected that individuals used more reappraisal and less distraction when coping with less intensity life events, and showed the opposite tendency when coping with high intensity life events (high strategy-situation fit). Moreover, the interaction of

Table 2 Results of multilevel regression analyses predicting level of strategy use from emotional intensity of events, strategy category and interoceptive attention.

	Est (S.E)	*t*	*p*	*95% CI*
Gender	1.06 (2.55)	.42	.678	[−3.64, 4.83]
Age	.64 (.97)	.66	.513	[−.94, 2.31]
MAIA_Noticing	2.74 (2.61)	1.05	.298	[−1.24 6.38]
Strategy category	−.82 (1.05)	−.78	.436	[−2.89,1.26]
Event_Int	.06 (.02)	2.78	.006	[.02, .10]
Event_Int_mean	.25(0.07)	3.36	.001	[.15, .39]
MAIA_Noticing × Strategy category	−4.88 (1.29)	−3.70	< .001	[−7.43, -2.32]
MAIA_Noticing × Event_Int	.01 (.03)	.39	.701	[−.04, .06]
Strategy category × Event_Int	.06 (.02)	2.93	.003	[.02, .10]
MAIA_Noticing × Strategy category × Event_Int	.05 (.03)	2.08	.034	[.00, .10]

N = 211; MAIA: Multidimensional Assessment of Interoceptive Awareness (grand-mean centered); Event_Int: Intensity of Event (group-mean centered).

Table 3 Simple slope estimates of the association between intensity level of adverse events and ER strategy use at low and high levels of interoceptive attention.

	MAIA_Noticing (-1 SD)				MAIA_Noticing (+1 SD)			
	Est (S.E)	*t*	*p*	*95 %CI*	Est (S.E)	*t*	*p*	*95 %CI*
Strategy category × Event_Int	-.01 (.02)	-.19	.851	[-.05, .04]	.12 (.06)	1.90	.052	[.03, .25]

N = 211; ER:Emotion regulation; MAIA: Multidimensional Assessment of Interoceptive Awareness (grand-mean centered); Event_Int: Intensity of Event (group-mean centered).

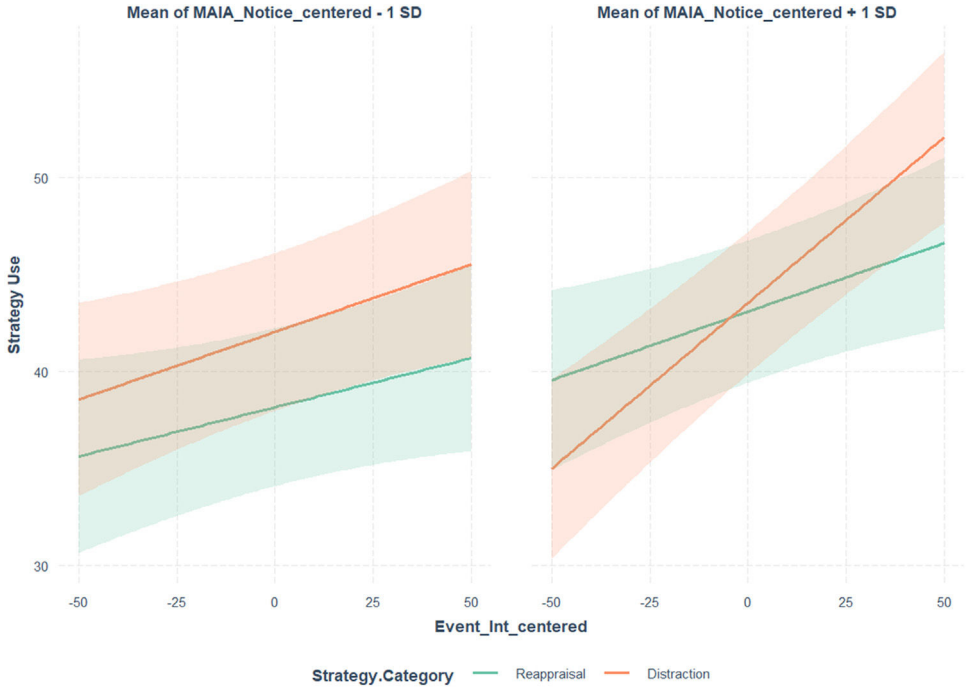

Figure 2 Simple slopes reflecting use of reappraisal and distraction in situations with different levels of emotional intensity among individuals scoring low (−1 SD below the mean) and high (+1 SD above the mean) on interoceptive attention. The shadowed areas represent 95% CIs. MAIA: Multidimensional Assessment of Interoceptive Awareness (grand-mean centered); Event_Int: Intensity of Event (group-mean centered).

MAIA_Noticing × Strategy category was significant (B = -4.88, $p < .001$, f^2 = .16), which reflected that individuals with higher interoceptive attention would use less distraction than reappraisal when coping with negative events in daily life. Of particular interest, the interaction effect of MAIA_Noticing × Strategy category × Intensity of events was significant (B = .05, p = .034, f^2 = .03), indicating that interoceptive attention is positively related to flexible use of ER strategies measured by situation-strategy fit. We also excluded data from subjects who reported less than 10 negative events and built a supplemental model (sample size = 187). The main results from this model remained mostly the same (Table S2). In addition, we did not find any effects of demographic variables on the ER strategy use in our models. As shown in Table S3, the results remained similar even though we did not control the effects of demographic variables.

We used the "interactions" package in R (Long, 2020) to do follow-up simple slope tests. As displayed in Table 3, the simple slope was positive (B = .12, p = .052, f^2 = .10) in the subsample with +1SD MAIA_Noticing, reflecting that people with high interoceptive attention used more distraction than reappraisal when dealing with high intensity negative life events. However, the simple slope was nonsignificant negative (B = -.01, p = .851, $f^2 < .01$) in the subsample with -1SD MAIA_Noticing, indicating that people with low interoceptive attention indistinguishably used more distraction than reappraisal when dealing with all negative life events (see Fig. 2).

Discussion

Despite ongoing research and dialogue concerning the important role of interoception in emotion regulation (Füstös et al., 2013; Kever et al., 2015; Lischke et al., 2020; Pollatos et al., 2015; Schuette et al., 2021), there is limited quantitative research exploring the potential mechanisms behind their association, as well as how the dynamics of interoception and ER manifest in daily life. The present study confirmed that interoceptive attention may facilitate

habitual use of ER strategies at least in part through increased emotional awareness. Furthermore, using ESM, we found that higher interoceptive attention was associated with increased strategy-situation fit in daily life. Specifically, individuals with higher interoceptive attention adopted more distraction than reappraisal, only during negative events of high intensity, whereas individuals with lower interoceptive attention indistinguishably used more distraction than reappraisal when dealing with negative life events—regardless of an event's intensity—likely reflecting a rigid regulatory style. Keeping in line with prominent theories, these findings taken together support the notion that interoceptive signals help application of ER strategies and selection of appropriate strategies tailored to a given situation (Craig, 2002; Damasio, 1996; James, 1884).

Higher interoceptive attention was associated with increased habitual use of several specific ER strategies including arousal control, reappraisal, and rumination. It is plausible that increased interoceptive attention would facilitate arousal control; attention to bodily signals shapes cognitive emotion regulation strategies including reappraisal and rumination, which is in accordance with several influential theories including embodied cognition and the somatic marker hypothesis (Barsalou, 2008; Damasio, 1996). In other words, higher bodily awareness may increase habitual application of ER strategies, both for strategies that are relatively adaptive (e.g., arousal control and reappraisal) and less adaptive (e.g., rumination). Findings are also consistent with other recent work examining the relationship between self-report interoceptive attention and habitual ER use (Schuette et al., 2021; Zamariola et al., 2019b). In contrast to the aforementioned ER strategies, higher interoceptive attention was also linked to decreased habitual use of distraction, suggesting that more attention to bodily signals related to emotions might make it difficult (or, alternatively, less necessary) to distract from emotions. The distraction strategy involves external attentional control systems (Kanske et al., 2011; McRae et al., 2010) and thus diverts attention away from internal visceral signals related to emotions (James, 1884; Pollatos et al., 2005), which may account for the negative associations between distraction and interoceptive attention. Although previous studies found interoceptive accuracy was positively correlated with suppression (Kever et al., 2015; Lischke et al., 2020; Pollatos et al., 2015), we did not find a significant association between interoceptive attention and suppression. The divergence between the findings in present and previous studies may reflect differing effects of various interoception sub-dimensions on ER strategy use (Calì et al., 2015; Garfinkel et al., 2016). The potential multidimensional nature of these interoception-ER associations, still need to be further clarified, as do potential underlying mechanisms of these associations. For example, the relations between different interoception sub-dimensions and various ER strategies need to be examined more thoroughly.

Our mediation models revealed that emotional awareness, in part, mediates the associations between interoceptive attention and habitual use of reappraisal, rumination, and arousal control. As expected, interoceptive attention is related to increased awareness of emotional states, which may in turn initiate use of reappraisal, rumination, and arousal control. This is in line with previous studies showing that individuals with higher interoceptive attention are better at emotion recognition, which is related to ER (Brewer et al., 2016; Murphy et al., 2017; Murphy et al., 2018). Despite these promising mediation model results, we should note that mediational and correlational analyses in cross-sectional data cannot fully capture causal mechanisms and the directionality of effects among variables, but merely provide evidence consistent with proposed causal models. For instance, it could still be that increased use of certain ER strategies improve emotional awareness and interoceptive attention, or that these relations are bidirectional; likewise, habitual use of ER strategies such as distraction or suppression might actively inhibit interoceptive attention and emotional awareness. Thus, further research should be done to investigate the direction and precise mechanisms of causation, when it comes to interoception, emotional awareness, and ER strategy use.

Perhaps most interestingly, we found an interaction between interoceptive attention and negative event intensity, in predicting ER strategy use. Namely, individuals who reported higher interoceptive attention used more distraction than reappraisal when the contexts were more negative due to negative life events, whereas individuals with lower interoceptive attention indistinguishably used more distraction than reappraisal, regardless of the negative intensity of the contexts. Previous studies have revealed that a preference for distraction rather than reappraisal is an optimal way for regulating strong negative emotion, so the tendency to modulate ER strategies as a function of contextual demands like event intensity may reflect a high level of ER flexibility and adaptive functioning (Sheppes et al., 2011). Therefore, our results demonstrate that individual differences in interoceptive attention could be an important factor in influencing individuals' abilities to flexibly deploy ER strategies that meet specific situational demands. This result could be explained in the framework of ER flexibility proposed by Bonanno and Burton (2013). They propose three sequential components of flexibility: context sensitivity, repertoire of regulatory strategies, and response to feedback. The feedback consists of internal feedback such as bodily and emotional signals, as well as social feedback (Bonanno & Burton, 2013). The present study sheds light on one important form of internal feedback facilitating adaptive ER, namely increased bodily awareness. This is also consistent with previous empirical studies showing that increased interoceptive signals are associated with improved sensitivity of ER strategy selection to emotional intensity (Ardi et al; 2021; Birk & Bonanno, 2016). Our study extends this relation between interceptive attention and flexible use of ER strategies into actual daily life. Future work should examine the potential role of interoceptive attention and of strategy-situation matching, in the ER deficits documented among those with psychopathology (Sheppes et al., 2014; Wilson & Gilbert, 2008).

With the emergence of body-oriented interventions, the benefits of interoceptive attention are beginning to be explored. Our findings—which underscore the importance of interoception in emotion regulation—imply that training interoceptive attention may provide a promising way to improve individuals' use of flexible and adaptive ER, in turn, leading to improvements in well-being and resilience (Bonanno, 2005; Kashdan & Rottenberg, 2010; Opitz et al.,

2012). However, it should be noted that being overly focused on bodily sensations may result in somatization and anxiety (Dunn et al., 2010; Palser et al., 2018; Pollatos et al., 2007; Tan et al., 2018; Wang et al., 2020). Indeed, interoceptive attention was not only associated with greater use of reappraisal and arousal control in our current study, but was also positively associated with rumination, a key marker of depression and anxiety. When developing the MAIA, Mehling (2016) distinguished between hypervigilant attention to bodily sensations and mindful attention, with the latter being beneficial for emotional health; this highlights the importance of quality rather than just quantity, when determining the adaptiveness of interoception. Future studies are needed to investigate whether anxious attention to physiological signals may hamper flexible regulation of emotion and how mindfulness training might influence choice of ER strategies, considering that mindfulness promotes focused attention rather than distraction (Ardi et al; 2021; Mehling et al., 2013; Villemure et al., 2014).

Despite its strengths, the present study had several potential limitations worth noting. The sample consisted of university students and thus findings may not be applied to the broader general population or specific clinical groups. Future studies are needed to examine whether interoceptive ability may help regulate emotions in other populations such as teenagers or patients with mental health problems. Additionally, we only used trait questionnaire measures of interoceptive attention and emotional awareness, but it may be worthwhile to measure state interoceptive attention and emotional awareness and then examine the relationship between them and ER flexibility, as these processes may all three differ across various situations and life contexts. Third, future studies would benefit by incorporating physiological measurements related to emotions to complement self-reported data, which can provide more insights into the biological underpinnings of individual differences in emotion regulation. Fourth, this study did not include assessments of well-being or mental health/illness, which could help provide further support for an adaptive, functional role of interoceptive attention; future studies could examine whether interoceptive attention predicts daily well-being and resilience, which might be mediated through an impact on strategy-situation fit. Fifth, in the EMS procedure used for our sample, we measured ER use by participants during each set interval rather than in specific response to reported negative events, more follow-up work is needed. Finally, the concept of the strategy-situation fit needs to be extended to take into account the compatibility of ER strategies and additional specific situational characteristics, such as social contexts and regulatory goals (Benson et al., 2019; Eldesouky & English, 2019). More specifically, there may be a great discrepancy in the fit between ER preferences and contextual characteristics shaped by different cultural contexts. For example, contrary to the findings regarding ER choice within American samples, Indian people have shown a relative preference for reappraisal in processing high-intensity negative stimuli, which some have proposed may be related to common Indian religious beliefs (Mehta et al., 2017). Therefore, it is necessary to further investigate how the adaptive values of various strategy-situation combinations may vary across specific cultural and social contexts.

Conclusions

In summary, we investigated whether interoceptive attention might facilitate habitual use of ER strategies and flexible use of strategies to match contextual demands. Combining trait-level assessments with questionnaires and state-level measures with ESM, our findings indicated that interoceptive feedback may facilitate application of specific ER strategies and guide how one matches specific strategies to differing situations. Training interoceptive attention may provide a useful way to improve emotion regulation and poses a promising avenue for future work.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.ijchp.2022.100336.

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