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## The associations between levels of the neuroscientific self and borderline personality traits

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### A B S T R A C T

Processes contributing to forming and maintaining the self are matters of longstanding debate and significance, for example regarding disorders manifesting aberrant self-processing, such as borderline personality disorder. One theory proposes a hierarchy of self-referential processes including interoceptive-, exteroceptive-, and mental-self-processing levels. No systematic examination of these levels in relation to borderline personality traits has been conducted. Understanding this relationship may highlight underlying mechanisms contributing to observable borderline personality pathology. The sample of 118 healthy adults (mean age = 36.4 years, SD = 14.6, 80 females) completed an online survey, using instruments indexing self-processing at interoceptive, exteroceptive and mental levels. More atypical embodied sense of self (an exteroceptive index) and lower self-insight (a mental index) were associated with higher self-relevant borderline personality trait levels. There was no evidence of a relationship between interoceptive and self-relevant borderline personality trait measures. These findings support exteroceptive- and mental-self-processing atypicalities in the manifestation of self-relevant borderline personality traits. Specifically targeting these domains behaviourally and narratively may augment existing evidence-based borderline personality disorder interventions.

### 1. Introduction

Modern scientific attempts at understanding the self, developmentally and dynamically, have yielded theories grounding the self in bodily processes (Damasio, 2003; Qin et al., 2020). One prominent model is the hierarchical structure of self-referential processing posited by Qin et al. (2020; Fig. 1). The foundational level is interoceptive self-processing (ISP), involving perception and integration of internal sensory systems, such as gastrointestinal functions (Craig, 2002). Sub-dimensions include interoceptive accuracy (of interoceptive detection); sensibility (self-reported interoceptive abilities); and awareness (metacognitive awareness regarding accuracy) (Garfinkel et al., 2015). Exteroceptive self-processing (ESP) integrates exteroceptive self-relevant signals (e.g. vision, touch) and proprioceptive signals (sense of body in space), with interoceptive information, linking body and environment. Finally, mental self-processing (MSP), synthesises ISP/ESP with 'mental' representations and processes, producing sub-domains like self-awareness and autobiographical memory (Qin et al., 2020).

This model grounds the present study, potentially providing a translatable framework for the examination of disorders where sense of

self is affected. This may inform understanding and intervention regarding these conditions (Kerr et al., 2015; Qin et al., 2020). While atypical self-processing occurs in numerous disorders, identity disturbance is a central feature of personality disorders, in particular borderline personality disorder (BPD; De Meulemeester et al., 2021). BPD is a pervasive disorder characterised in part by emotion dysregulation and identity disturbance. Identity disturbances in BPD include identity diffusion (confusion/uncertainty regarding identity; Jørgensen & Bøye, 2022), poor self-concept (negative or distorted self-evaluations of one's identity; Wright et al., 2021), and atypical self-other distinction (SOD; processes distinguishing self from others; De Meulemeester et al., 2021).

While the model of Qin et al. (2020) provides a foundation for the exploration of self-processing within clinical cohorts by delineating *where* self-processing types are occurring, it does not aim to provide a cognitive processing theory regarding *how* this processing is occurring. One augmentative theory in this regard is predictive processing. This proposes that brains seek error minimisation when predicting sensory input, by comparing predictions of incoming 'bottom up' sensory input (pertaining more to ISP/ESP) and making dynamic adjustments to

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internal 'top down' predictive models (pertaining more to MSP) accordingly (De Meulemeester et al., 2021; Fineberg et al., 2014; Hohwy, 2020; Scalabrini et al., 2022). The BPD predictive processing account posits that developmental maltreatment/ produces inconsistent (or unreliable/volatile) social-sensory input, making it difficult to form accurate or adaptive models of self and other/social behaviour (Herzog et al., 2022). The resulting predictive capacity of the system may thereby become inconsistently accurate, causing an overreliance on sensory and environmental feedback, leading to difficulties integrating consistent (or positive or adaptive) information about the self into one's self-concept, along with a decrease in attention to internal physiological sensations (Herzog et al., 2022). When applying this theoretical approach to the Qin et al. (2020) model, it would suggest that MSP in childhood was impacted due to inconsistent or problematic exteroceptive information, producing hyper-focus on external sensory input to improve predictive processing models of social feedback (and thereby minimise social problems or danger). This may also result in the underdevelopment (or under-integration) of ISP, as well as being conducive to MSP that relies disproportionately on (inconsistent/problematic) external information to construct identity. It should also be acknowledged that this is just one possible interpretation within the synthesis of two prominent frameworks: this is neither exhaustive nor certain, nor does it imply that one self-processing domain (for example exteroception) is predominantly causative, or that there is sufficient evidence to suggest that this is the case.

Atypical self-processing may occur across ISP, ESP and MSP levels in BPD (Back & Bertsch, 2020; De Meulemeester et al., 2021; Neustadter et al., 2019; Wright et al., 2021). Regarding interoception, findings vary with ISP sub-domain (Back & Bertsch, 2020). *Interoceptive accuracy* appears intact or reduced, depending on intentional attention (Back & Bertsch, 2020; D'Andrea et al., 2022). Heightened stress responses in BPD may disrupt interoceptive accuracy, which may remain intact during low-arousal states, contributing to mixed findings (Bourvis et al., 2021). Regarding *interoceptive sensibility*, more research is needed (Back & Bertsch, 2020). *Interoceptive awareness* may be affected by attentional bias toward exteroceptive - and away from interoceptive - input, echoing predictive processing theory. By this account, interoceptive accuracy may be intact but unattended/mistrusted diminishing interoceptive awareness (Back & Bertsch, 2020; Garfinkel et al., 2015).

This may contribute to bodily illusion susceptibility, suggesting challenges in ISP/ESP integration (Palmer & Tsakiris, 2018). Regarding ESP, this difficulty in BPD has been identified using the rubber hand illusion (RHI) (De Meulemeester et al., 2021). Individuals with BPD appear to have increased RHI susceptibility, experiencing a prolonged sense of rubber hand ownership, interpreted as indicating difficulties with perceptual self-other distinction (SOD; De Meulemeester et al., 2021; Neustadter et al., 2019). This results in a 'blurring' and/or rigid egocentric/altercentric SOD biases (De Meulemeester et al., 2021). This may add to difficulties constructing a stable sense of self over time,

increasing fragility of sense of self and emotional lability (De Meulemeester et al., 2021; Hohwy, 2020).

This could partially explain findings relating to MSP in BPD, including aspects of identity disturbance such as dissociation and negative self-concept (Winter et al., 2017; Wright et al., 2021). Individuals with BPD exhibit emotional negativity bias toward themselves (Winter et al., 2017), while also experiencing atypicalities in Theory of Mind (ToM; De Meulemeester et al., 2021). ToM refers to the ability to infer and interpret the mental and emotional states of others, which are reportedly impaired in BPD. However, this may be limited to, or exaggerated in, stressful social and attachment-related situations (De Meulemeester et al., 2021; Luyten et al., 2021).

Overall, while findings generally identify atypical self-processing in BPD, the ways in which self-processing levels proposed by Qin et al. (2020) are affected remains unclear. Most studies exploring components of self-processing in BPD have also primarily focused on clinical populations, despite BPD and personality disorders more generally moving toward a dimensional model of pathology, whereby BPD-relevant traits are distributed continuously across clinical and non-clinical boundaries (McLaughlin & Sheridan, 2016). Researching non-clinical populations not only allows the capture of BPD traits with reference to self-processing abilities regardless of diagnostic threshold, it also increases the relevance of the study with potential impact for a larger portion of the population.

This study therefore aims to use the three-level model of Qin et al. (2020) as a basis for exploring self-processing relationships with self-relevant BPD (SR-BPD) traits. We expect higher SR-BPD trait levels to be associated with reduced interoceptive sensibility (ISP); more atypical ESP (higher embodied sense of self scores and reduced exteroceptive awareness scores); and reduced self-reflection and insight scores (MSP).

## 2. Method

### 2.1. Participants

Participants were 118 healthy adults (mean age = 36.4 years, SD = 14.6, 80 females). 83 were recruited via social media and poster advertisements at Deakin university campuses, with the option to go into a draw to win a \$100 Visa gift card. The majority of these were therefore sourced in Australia and tended to be older (mean age = 40.8 years, SD = 14.9, 60 females). A further 35 were recruited via Prolific ([www.prolific.co](http://www.prolific.co)) and were paid £4.02 (data on nationality not collected; mean age = 25.9 years, SD = 6.0, 20 females). Overall, male and female participants were similarly aged – for further details on samples see Supplemental Materials A. Participants were 18 or older without current or historical psychiatric or neurological conditions. Participants read and acknowledged the plain language statement and provided informed consent. Procedures were approved by the Human Ethics Advisory Group Health at Deakin University (HEAG-H 50\_2022).

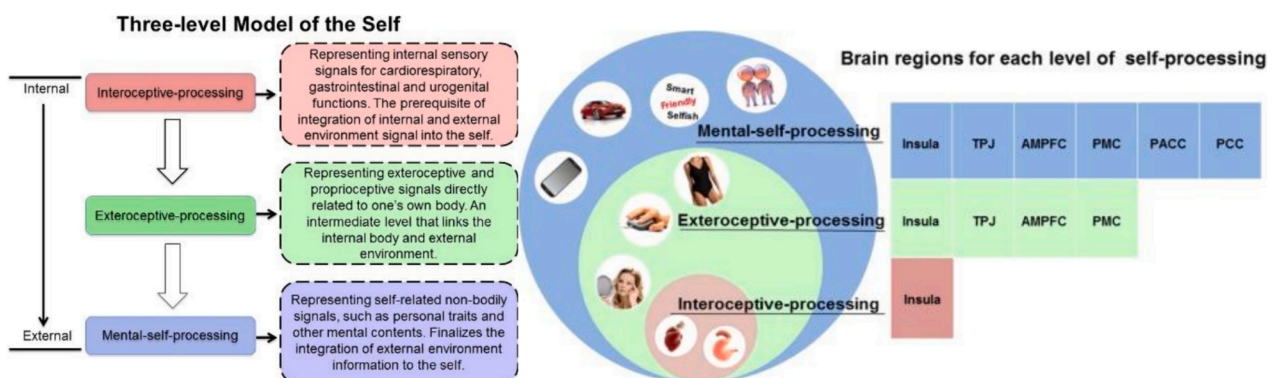


Fig. 1. Three-level model of self. Reproduced and adapted with permission from Qin et al. (2020).

## 2.2. Measures

### 2.2.1. Interoceptive self-processing

The Three-domain Interoceptive Sensations Questionnaire (THISQ; Vleminx et al., 2021), contains 18 items indexing interoceptive sensitivity on a 5-point scale (e.g., “I notice when I pant”) over three subscales (Cardiorespiratory Activation, Cardiorespiratory Deactivation, and Gastroesophageal Sensations). Total score reliability is good ( $\alpha = 0.84$ ; present sample  $\alpha = 0.85$ ).

### 2.2.2. Exteroceptive self-processing

The Embodied Sense of Self Scale (ESSS; Asai et al., 2016) indexes three factors relevant to exteroception (Ownership, Narrative, and Agency). There are 25 items on a 5-point scale such as “Sometimes the clothes I am wearing feel heavy”. Total score reliability is good ( $\alpha = 0.84$ ; present sample  $\alpha = 0.85$ ). Although this instrument was developed partly with psychotic features in mind, it was validated largely with non-clinical samples and is underpinned by universal neuroscientific self-processing constructs relevant to BPD and non-clinical populations also.

The Five Facets Mindfulness Questionnaire - Observing subscale (FFMQ-Observing; de Bruin et al., 2012) indexes aspects of exteroceptive awareness unaccounted for in the ESSS. It has 8 items scored on a 5-point scale, such as “When I take a shower or bath, I stay alert to the sensations of water on my body”. Reliability of FFMQ subscales are adequate-good ( $\alpha = 0.72$ – $0.92$ , herein  $\alpha = 0.79$ ).

### 2.2.3. Mental self-processing

The Self-Reflection and Insight Scale (SRIS; Grant et al., 2002) consists of two factors - Self-Reflection (SRIS-SR) and Insight (SRIS-IN) - with the former comprised of two further subscales; Need for Self-Reflection and Engagement in Self-Reflection. 20 items are scored on a 6-point scale, such as “I rarely spend time on self-reflection”. Reliability is good-excellent ( $\alpha = 0.87$ – $0.91$ ; herein  $\alpha = 0.83$ – $0.88$ ).

### 2.2.4. Self-processing-relevant BPD (SR-BPD) traits

The Self-Concept and Identity Measure (SCIM; Kaufman et al., 2015a, 2015b) indexes identity-related pathological and non-pathological traits relevant to BPD via 27 items across three factors (Consolidated Identity, Disturbed Identity, Lack of Identity). Scale options 1–7 range from “strongly disagree” to “strongly agree”. Option 8 is “I don't know” (scored 0). A sample item is “I feel empty inside, like a person without a soul”. Reliability is good ( $\alpha = 0.89$ ; present sample  $\alpha = 0.90$ ). Total SCIM score shows strong associations with BPD ( $r = 0.56$ – $0.59$ ) and emotion dysregulation ( $r = 0.62$ – $0.66$ ) measure scores, associations that are stronger than, for example, associations with other conditions such as substance use or PTSD ( $r = 0.23$ – $0.29$ ), a pattern that holds across SCIM subscales and in nations where English is not the first language (Bogaerts et al., 2018; James et al., 2023; Kaufman et al., 2015a, 2015b; Kaufman et al., 2019). While it is identity-related distress can be associated with several disorders, identity disturbance is particularly associated with personality disorders, is an explicit criterion for BPD alone, and distinguishes BPD from other disorders (Wilkinson-Ryan & Westen, 2000). Furthermore, developmental identity disturbance is increasing considered central to, and associated with, broader BPD etiology and is strongly correlated with other BPD-specific symptom domains such as chronic emptiness, suicidality and dissociation (Kaufman & Crowell, 2014; Rivnyák et al., 2021). Additionally and for example, in a recent non-clinical network analysis examining BPD traits, identity diffusion was both the least redundant and most central symptom domain (Rivnyák et al., 2021). Finally, the SCIM has also been validated among clinical and non-clinical populations (Kaufman et al., 2019). Given all these considerations, the SCIM was deemed an appropriate index of general population BPD traits most relevant to self-processing, both directly (via the criterion of identity disturbance and its centrality to BPD symptoms more broadly) and indirectly (via the known strong associations of identity disturbance with other BPD traits as noted

above).

## 2.3. Procedure

The survey was constructed using Qualtrics ([www.qualtrics.com](http://www.qualtrics.com)), with an approximate duration of 15–30 min (median = 21.59 min, range = 10.9–205.8 min). Participants sourced the survey via digital link or QR code on advertising material or Prolific website ([www.prolific.co](http://www.prolific.co)). To manage bot interference, reCAPTCHA was added, along with a question requesting a description of an image. Two ‘trap question’ attention checks were incorporated (e.g. “Please select ‘Agree’”). Respondents were excluded if they failed both attention checks ( $n = 4$ ), or for sub-10-min completion time ( $n = 1$ ). The survey sequence consisted of demographic information collection (age, biological sex, gender identity, and highest education level achieved), self-processing questionnaires (presented in a randomised order for each participant), followed by the SCIM.

## 2.4. Data pre-screening

For inclusion, participants needed to have successfully completed bot checks, one attention check, all self-processing questionnaires and the SCIM. Three researchers (CW, KY, PD) independently screened data for repetitive response patterns to confirm genuine responses.

## 3. Results

A hierarchical multiple linear regression tested hypotheses, entering THISQ total, ESSS total, FFMQ-Obs, and SRIS-SR/SRIS-IN scores as predictors, with SCIM total the outcome variable (Table 2). Covariates included relevant demographic variables such as age and sex. An additional post-hoc multiple regression was conducted to explore which ESSS subscales were accounting for SCIM variance (Table 3). Linear regression assumptions were met for all analyses. The dataset is available at figshare (<https://figshare.com/s/db2a8de00fdc13f4e16d>). Table 1 displays bivariate correlations. Coded variables were as follows: sex (1 = male, 2 = female); education (1 = did not complete high school, to 7 = doctoral degree or above). As 8 % of respondents identified as non-binary, a further hierarchical regression was conducted with gender as a covariate also (see Supplemental Materials B).

No significant relationship between the interoceptive processing measure (THISQ) and BPD self-related traits (SCIM) was observed. Likewise, no relationship was indicated between the exteroceptive processing measure of observation (FFMQ-Obs), nor the mental self-processing measure of self-reflection (SRIS-SR) and the measure of BPD self-related traits (Table 2). A significant positive relationship was observed between exteroceptive measures of self-narrative and body-ownership (ESSS Narrative and Ownership subscales), indicating a partial validation of our initial hypotheses (Table 3; Fig. 2). Similarly, higher levels of our mental self-processing measure of insight (SRIS-IN) predicted lower BPD self-related traits (SCIM), again partially confirming our hypotheses (Table 2; Fig. 3).

## 4. Discussion

This study examined relationships between three self-processing levels delineated by Qin et al. (2020; ISP, ESP, and MSP) and SR-BPD traits in a non-clinical sample. Results indicated that more atypical embodied sense of self (ESP) predicted higher SR-BPD trait scores. Additionally, greater self-insight (an MSP index) predicted lower SCIM scores.

### 4.1. Mental self-processing

Self-insight was the strongest predictor of SR-BPD traits. This dovetails with identity diffusion findings in BPD, where difficulty connecting

**Table 1**  
Correlations between demographic and total score variables.

Variables	1. SCIM total	2. Age	3. Biological sex	4. Education level	5. THISQ total	6. ESSS total	7. FFMQ observing	8. SRIS-SR	9. SRIS insight
1. SCIM total	1.00								
2. Age	-0.23**	1.00							
3. Biological sex	-0.13	0.03	1.00						
4. Education level	-0.22**	0.37***	0.11	1.00					
5. THISQ total	-0.01	-0.04	0.10	-0.06	1.00				
6. ESSS total	0.60***	-0.17*	0.17	-0.07	0.26**	1.00			
7. FFMQ observing	0.02	-0.10	0.06*	-0.08	0.51***	0.36***	1.00		
8. SRIS-SR	0.05	-0.22**	0.10	0.14	0.18*	0.27**	0.32***	1.00	
9. SRIS insight	-0.66***	0.26	-0.11	0.15	-0.06	-0.62***	-0.08	0.04	1.00

Note.  
\*  $p < .05$ .  
\*\*  $p < .01$ .  
\*\*\*  $p < .001$ .

**Table 2**  
Primary ISP, ESP, and MSP measures predicting SCIM total score.

Variables	95 % CI			SE B	$\beta$	$R^2$	$R^2_{adj}$	$R^2$ change	F	F Change
	B	LL	UL							
Step 1: demographics						0.09	0.06	0.09	(3, 114) 3.57*	
Age	-0.28	-0.58	0.03	0.15	-0.18					
Biological Sex	-5.21	-14.03	3.60	4.45	-0.11					
Education level	-1.92	-4.46	0.63	1.28	-0.16					
Step 2: Self-Processing						0.59	0.56	0.50	(8, 109) 19.25***	(5, 109) 26.27***
Age	-0.09	-0.24	0.22	0.16	-0.01					
Biological Sex	-10.96	-17.17	-4.75	3.13	-0.22**					
Education level	-1.61	-3.44	0.21	0.92	-0.12					
ISP										
THISQ total	-0.16	-0.47	0.16	0.16	-0.07					
ESP										
ESSS total	0.66	0.37	0.95	0.14	0.41**					
FFMQ observing subscale	-0.60	-1.29	0.09	0.35	-0.13					
MSP										
SRIS-SR: self-reflection	0.14	-0.31	0.59	0.23	0.05					
SRIS-IN: insight	-1.75	-2.44	-1.06	0.35	-0.43***					

N = 118.

ISP = Interoceptive Self-Processing; ESP = Exteroceptive Self-Processing; MSP = Mental Self-Processing; SCIM = Self-Concept and Identity Measure; THISQ = Three-domain Interoceptive Sensations Questionnaire; ESSS = Embodied Sense of Self Scale; FFMQ = Five Factor Mindfulness Questionnaire; SRIS = Self-Reflection and Insight Scale.

\*  $p < .05$ .  
\*\*  $p < .01$ .  
\*\*\*  $p < .001$ .

**Table 3**  
ESSS subscales predicting SCIM total score.

Variables	95 % CI			SE B	$\beta$
	B	LL	UL		
Age	-0.15	-0.38	0.09	0.12	-0.09
Biological Sex	-9.29	-16.02	-2.55	3.40	-0.19**
Education Level	-1.61	-3.53	0.30	0.96	-0.12
Narrative Subscale	1.92	1.13	2.71	0.40	0.45***
Ownership Subscale	1.22	0.54	1.90	0.34	0.32***
Agency Subscale	-0.31	-1.08	0.46	0.39	-0.07

ESSS = Embodied Sense of Self Scale.

\*\*  $p < .01$ .  
\*\*\*  $p < .001$ .

with one's identity relates to impaired self-insight, in addition to research indicating reduced insight in adolescents with BPD (Bourvis et al., 2021; Jørgensen & Bøye, 2022). Considering predictive processing theory and developmental factors contributing to BPD, reduced insight may relate to difficulties building consistent models of oneself-in-the-world due to ESP-related prediction errors (Fineberg et al., 2014). In

contrast, self-reflection did not predict SR-BPD traits, which aligns with research indicating self-reflection in BPD is not inhibited, but rather has a negativity bias (Grant et al., 2002; Winter et al., 2017). SRIS authors also observe that insight and self-reflection scores can diverge, noting engagement in self-reflection may be ruminative, or reflect insight-building difficulty (Grant et al., 2002). The need for engagement with self-reflection may therefore not be impacted in BPD. Impaired insight may better reflect MSP difficulties in BPD, where aberrant ESP input and integration into MSP (including working and predictive models) reduce insight irrespective of self-reflection frequency. This may partially explain difficulties those with higher SR-BPD trait levels have developing positive self-concept and self-esteem, as information used to construct self is inconsistent, negatively distorted, or questioned (Perryckad & Hohwy, 2022; Qin et al., 2020).

#### 4.2. Exteroceptive self-processing

Higher SR-BPD traits were predicted by more atypical embodied sense of self scores, in particular regarding Ownership and Narrative subscales. Aberrant sense of body ownership echoes RHI findings, in which participants with BPD are generally more susceptible to the

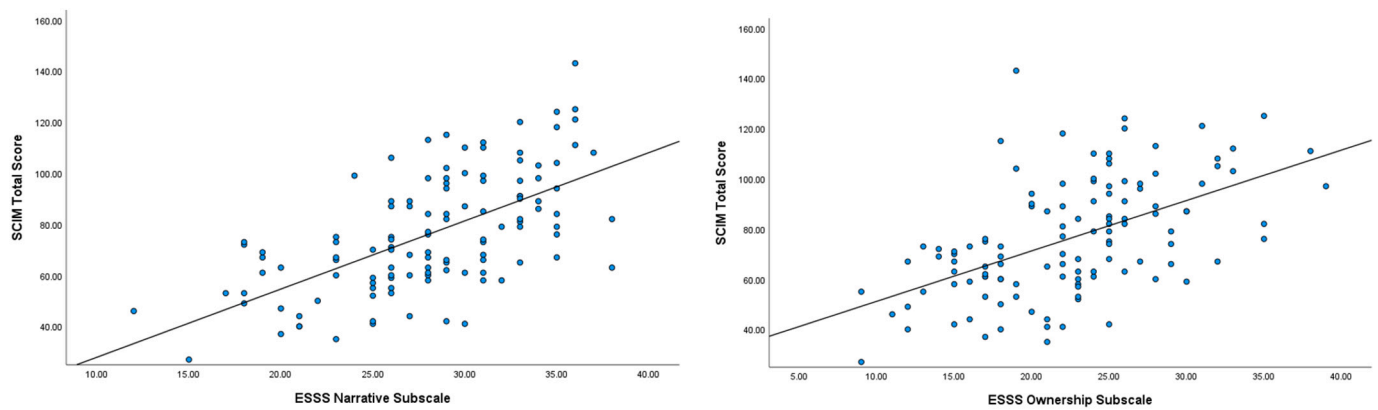


Fig. 3. SRIS Insight and SCIM total relationship.

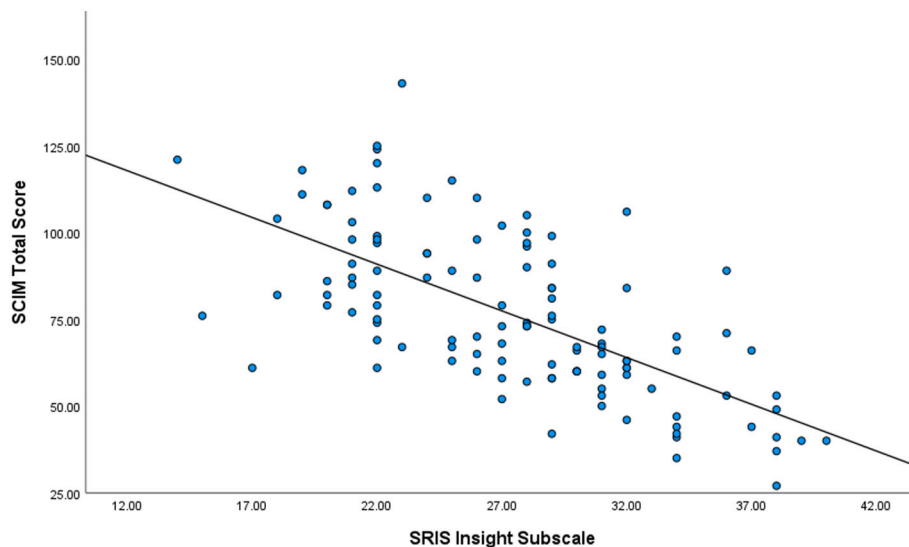


Fig. 2. Relationship between ESSS Narrative (left) and ESSS Ownership (right) and SCIM total.

illusion, indicating relative abnormalities with sense of body ownership and increased blurring across regular SOD boundaries (De Meulemeester et al., 2021; Neustadter et al., 2019). If the integration of exteroceptive information into the self is disrupted, as is suggested in predictive processing accounts of BPD, this would partially explain atypical sense of body ownership, which would in turn link to MSP findings regarding lower insight in those with higher BPD traits (Fineberg et al., 2014). Likewise, a disruption in continuity of self-over-time, as observed with the Narrative subscale, would additionally make insight difficult. Disruptions to narrative sense of self in BPD have been previously noted (Kaufman & Crowell, 2014).

Our measure of exteroceptive awareness, FFMQ-Observing, did not predict SR-BPD trait levels. This may reflect insufficient power, ceiling effects in a non-clinical population, or a genuine null finding. Power may also have been impacted via certain items within this subscale tapping into general exteroception (rather than self-relevant exteroception).

#### 4.3. Interoceptive self-processing

ISP associations with SR-BPD traits were not observed. As above, this could relate to insufficient power in the context of self-report methodology. ISP differences may have been detectable with behavioural/physiological paradigms (tapping into interoceptive accuracy, for example). The use of a self-report ISP index also implies heavy reliance on insight regarding interoceptive processes, which was notably affected

for those with higher levels of SR-BPD traits. Some prior findings indicate that interoceptive sensibility, assessed specifically via self-report, may be less affected in BPD than other ISP sub-domains (Back & Bertsch, 2020; Garfinkel et al., 2015).

#### 4.4. Limitations and future directions

As noted, certain null findings may reflect insufficient power to detect weak effects in the context of self-report methodology. Future studies should aim to incorporate behavioural and physiological measures of self-processing to supplement self-report measures, particularly in relation to ISP and ESP (De Meulemeester et al., 2021; Garfinkel et al., 2015). Such measures would aid in further elucidating the validity and utility of the hierarchical model of self-processing and predictive processing with respect to conditions such as BPD. This could also contribute to comparison with other relevant models, such as the basis model of self-specificity, which proposes that processing relevant to self is not a higher order cognitive function (for example a manifestation of metacognition) as is often assumed or implied, but rather a much broader basic function grounded in spontaneous (resting state or default mode) brain activity (Northoff, 2016; Scalabrini et al., 2022). Applied to personality, a multilayered model of self is proposed, including relational alignment, self-constitution, self-manifestation, and self-expansion, whereby in a borderline organisation self-manifestation level impairments are emphasised (present moment experience

including self-other processing, oscillation between disordered self-states) (Scalabrini et al., 2018). Broadly speaking, our findings regarding aspects of atypical MSP (insight and narrative) and ESP (body ownership) are not inconsistent with such a model, but again, a more cross-model study design would be required to drill down into the core tenets of the basis model with respect to BPD traits.

In future, other-report measures may also be a useful cross-reference. Furthermore, the inclusion of a broader measure of BPD traits, and an instrument indexing trauma exposure and/or attachment style may provide additional insight into the development of identity issues in BPD, as both trauma/maltreatment exposure and insecure attachment are key contributors to identity disturbance in BPD, and could provide additional insight into the nature of this disruption (MacIntosh et al., 2015; Scalabrini et al., 2022). This raises a final future direction: longitudinal data. While this cross-sectional study assesses current self-processing features, it is presumed that ISP, ESP and MSP levels are shaped atypically in BPD by erratic, invalidating and/or abusive interpersonal environments. Learning more regarding these aberrant self-processing trajectories will augment cross-sectional knowledge and inform both understanding and interventions relevant to BPD.

## 5. Conclusion

The present study explored the relationship between SR-BPD traits and ISP, ESP and MSP levels. Our findings provide some support for the notion that difficulties with aspects of ESP and MSP are related to higher SR-BPD trait levels in the general population and are interpretable and consistent with predictive processing accounts of BPD (Fineberg et al., 2014; Hohwy, 2020). It is noted, however, that a need for more sensitive and specific self- and other-report measures of self-processing levels exists (Back & Bertsch, 2020). Future research would benefit from further exploration into the mechanisms of ESP in BPD, and the inclusion of additional physiological and behavioural measures to target specific areas of self-processing. Overall, these findings suggest disruption of ESP and MSP in relation to higher SR-BPD traits, representing a possible target for future BPD treatment-integration. While evidence-based BPD treatments exist, they tend to focus on addressing symptoms (e.g. dialectical behaviour therapy) and/or underlying maladaptive beliefs/behaviours (e.g. schema therapy). Whilst excellent treatments, they may benefit from integration with a more central model of self-processing and self-development that could aid individualisation of formulation and treatment planning, as per the suggestions of Kerr et al. (2015). For example, a hierarchical self-processing approach might focus more explicitly on linking interoceptive and exteroceptive signals with MSP in a more adaptive way, or incorporating this with a predictive processing informed approach might focus specifically on building insight into these categories in order to challenge and adjust different types of over- or under-integration of sensory information into predictive models in order to improve their accuracy and adaptability.

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## Ethics approval statement

Procedures approved by the Deakin University Human Ethics Advisory Group Health (HEAG-H 50\_2022). Procedures conducted in accordance with standards of HEAG-H and 1964 Helsinki declaration and later amendments.

## CRedit authorship contribution statement

**Charlotte Wardell:** Writing – original draft, Project administration, Investigation, Formal analysis, Data curation. **Michael Do:** Supervision,

Software, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Talitha C. Ford:** Writing – review & editing, Conceptualization. **Aron T. Hill:** Writing – review & editing, Conceptualization. **Soukayna Bekkali:** Writing – review & editing, Conceptualization. **Melissa Kirkovski:** Writing – review & editing, Conceptualization. **David Skvarc:** Writing – review & editing, Formal analysis, Data curation. **Kimberly Jones:** Writing – review & editing, Project administration, Investigation, Formal analysis, Data curation. **Luke McInerney:** Writing – review & editing, Project administration, Investigation, Formal analysis, Data curation. **Peter G. Enticott:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Peter H. Donaldson:** Writing – review & editing, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

## Declaration of competing interest

The authors report no conflicts of interest.

## Data availability

The dataset is available at figshare (<https://figshare.com/s/db2a8de00fdc13f4e16d>).

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.paid.2024.112748>.

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