Non-Suicidal Self-injury is associated with Multidimensional Deficits in Interoception: Evidence from Three Studies

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ABSTRACT

Non-suicidal self-injury (NSSI) is the deliberate and direct injury of one's own body tissue without suicidal intent. As the known risk factors for NSSI predispose to a range of psychiatric disorders, there is a limited understanding of the specific individual differences that result in NSSI. Therefore, in three studies, a multidimensional approach examined the novel proposition that deficiencies in aspects of interoceptive processing represent one such individual difference. Study 1 and study 2 used principal component analysis to explore the underlying structure of the sub-scales from a variety of body awareness questionnaires. Three components emerged that were replicated across both studies; 'interoceptive and emotional ambivalence'; 'interoceptive awareness'; 'interoceptive appreciation'. Study 3 extended the model examining the link between NSSI and the objective interoceptive index; 'interoceptive accuracy'. Those with a history of NSSI were characterised by a difficulty in distinguishing and interpreting interoceptive signals and this effect was mediated by a low appreciation of these sensations. These effects were reliable across all three studies. In study 3, NSSI was also associated with lower interoceptive accuracy. These data suggest that a failure to accurately detect and conceptualise interoceptive signals may lead to a depreciation of the body, predisposing to NSSI. NSSI may serve to resolve the resulting state of emotional and interoceptive uncertainty associated with the body's function in emotional experience. These findings offer new insight into the interoceptive processes that underlie NSSI and suggest specific pathways that could be addressed during clinical interventions.

Keywords: Interoceptive accuracy, Alexithymia, Body appreciation, awareness, NSSI.

General Scientific Summary

There is limited understanding of the individual risk factors for non-suicidal self-injury (NSSI). This study suggests that those with an inability to detect or identify emotions and a depreciation of interoceptive sensations may predispose towards NSSI.

Non-suicidal self-injury (NSSI) is the deliberate and direct injury of one's own body tissue without suicidal intent (Claes & Vandereycken, 2007). Although it is estimated that as many as 17.2% of the general population have engaged in self-injurious behaviour (Swannell, Martin, Page, Hasking, & St John, 2014), many precipitating factors have been subject to limited investigation. Recent findings that interoception (the perception and interpretation of signals from the body) contributes significantly to an individual's emotional experience has shed light on the mechanisms surrounding emotional disorders (Bechara, Damasio, Damasio, & Anderson, 1994; A. Craig, 2003; Critchley, Wiens, Rotshtein, Öhman, & Dolan, 2004; Pezzulo, Rigoli, & Friston, 2015; Seth, 2013), and has the potential to enhance our understanding of NSSI. Indeed, there are reports that how an individual experiences their body influences the capacity for NSSI (Forrest, Smith, White, & Joiner, 2015; Muehlenkamp, Peat, Claes, & Smits, 2012). However, these studies have confounded a general awareness of bodily signals with an inability to accurately identify and interpret what is felt (Forrest et al., 2015). In addition, how the interpretation of bodily signals relates to more attitudinal components of body perception (i.e. body image or body appreciation) is unclear. Thus, a more complete understanding of the inter-relations between the different components of interoception and NSSI is required. The present study represents the first attempt to develop a multidimensional framework to relate interoception to self-injury.

To date emotional dysregulation has been found to be one of the best predictors of NSSI (Adrian, Zeman, Erdley, Lisa, & Sim, 2011). For instance, those who endorse NSSI displayed elevated physiological arousal (skin conductance), and lower distress tolerance, in response to a laboratory-based stressor (Nock & Mendes, 2008). However, there are numerous non-injurious strategies for regulating emotion and it is unclear why some individuals use NSSI whilst others do not. In this respect understanding individual differences in interoception and how it relates to NSSI may help.

Interoception refers to 'the sense of the physiological condition of the body' (A. Craig, 2003). Within the insula cortex of the brain, interoceptive representations give rise to feelings of pain, sensual touch, temperature, vasomotor activity, visceral sensation (such as the heartbeat), hunger and thirst (A. Craig, 2003). It is thought that these sensations provide the foundation for the phenomenological experience of emotion and self-awareness (A. D. Craig,

2002). Studies that have directly assessed interoceptive deficits in those with a history of NSSI have done most often as it relates to eating disorders (ED). For example, studies using the Interoceptive awareness subscale (EDI-IA) of the Eating Disorder Inventory (Garner, 2002), found that interoceptive deficits were associated with NSSI in people with ED (Dodd et al., 2017; Favaro & Santonastaso, 1997; Forrest et al., 2015; Fujimori et al., 2011; Muehlenkamp et al., 2012; Ross, Heath, & Toste, 2009). Importantly, these interoceptive deficits remained after co-morbid ED pathology was controlled statistically (Forrest et al., 2015; Muehlenkamp et al., 2012). However, the EDI-IA items focus on ambivalence regarding internal states (e.g., "When I am upset, I don't know if I am sad, frightened, or angry") rather than awareness of bodily signals per se. Thus the EDI-IA scale bears more resemblance to the concept of alexithymia (an inability to identify and describe feelings); a concept which itself has been linked to an increased vulnerability to self-injury (Norman & Borrill, 2015). One possible explanation for this relationship is that individuals with alexithymia lack the cognitive structure required to adequately conceptualise interoceptive signals and thus their feelings (Preece, Becerra, Allan, Robinson, & Dandy, 2017). As such they tend to focus on the physiological aspects of emotion and somaticize their emotional experiences (De Gucht & Heiser, 2003). This increased bodily focus may also precipitate NSSI, although this hypothesis has not been tested formally.

Importantly, an 'awareness' of the physiological aspects of emotion per se may not by itself define the behavioural outcome. That is, although you may be able to accurately detect changes in the body, it is the ability to interpret and appreciate these sensations which defines how they are utilised (Burg, Probst, Heidenreich, & Michalak, 2017; W. Mehling, 2016). For example, in the context of 'trust' or 'appreciation' body awareness may help an individual to accept and respond positively to physiological sensations. Conversely, angst driven hyper-vigilance may result in dissatisfaction, ambivalence and indecision. Interestingly, body regard or appreciation has been shown to protect against NSSI. For example, Muehlenkamp (2012) found that emotion dysregulation was associated with NSSI, but only in those with low levels of body regard (Muehlenkamp, Bagge, Tull, & Gratz, 2013). With this in mind, in relation to NSSI it is important to differentiate between the different facets of body awareness.

A further explanation for the observed association between NSSI and alexithymia is that in contrast to self-report data showing increased attention to body signals, individuals high in alexithymia have been shown to have impaired interoceptive abilities when measured objectively (most often using a heartbeat counting as an indication of interoceptive accuracy) (Shah, Hall, Catmur, & Bird, 2016). Interestingly, qualitative data has revealed that individuals who use NSSI report feeling both overwhelmed by emotions they can't identify and emotionally detached or 'numb' (Horne & Csipke, 2009). Self-injury may help to resolve these problems by increasing the extent to which the body contributes to emotional experience (Horne & Csipke, 2009). Thus it is plausible that precisely and correctly monitoring changes in internal body state is diminished in those who use NSSI, although this hypothesis has not yet been examined.

Taken together, what is evident is that attempts have been made to begin to investigate links between NSSI and interoception; however these are hampered by a lack of a clear conceptual framework, and a limited understanding of the possible inter-relationships between key concepts. There is a need to disentangle the components of interoception and clarify how they relate to NSSI. Thus the aim of the present studies was to determine the link between aspects of interoception and NSSI.

Study 1

Whereas previous research has taken a top down approach to the categorisation of different aspects of body awareness (Hielscher, Whitford, Scott, & Zopf, 2019), the first study was designed to use a bottom up approach to disentangle the components of interoception and determine their unique ability to predict NSSI.

METHODS

Participants

Adult males and females were recruited to participate in this study (N = 100). Data were collected through the Qualtrics web-based software. Thirty-five participants endorsed a history of NSSI, and sixty-five participants endorsed no history of NSSI and served as non-

NSSI controls. There were sixty-three females and thirty-seven males. Participants had an average age of 24.9(5.7).

Procedure

Participants were recruited via popular social media websites and online forums. They completed a variety of widely used questionnaires (see below) via their own computers using a link to the secure online survey platform. They were taken to a page containing the study information and informed consent was signalled by the decision to proceed after reading this page. No monetary or other credit was offered as payment for participation. Questionnaires were presented to the participants in random order, with the exception of the demographics questionnaire, which all participants completed first. Ethical approval was gained from Swansea University Psychology ethics committee. Participants were informed that participation was voluntary and that they were free to withdraw their data up to the point of clicking submit at the end of the questionnaire. All participant responses were anonymous. Participants completed the entire questionnaire at one-time point taking approximately 15–20 min to complete.

Measures

Demographics

Data regarding age and gender were collected by self-report at the beginning of the survey.

Multidimensional Assessment of Interoceptive awareness (MAIA)

The MAIA (W. E. Mehling et al., 2012), which has 32 items, was used to assess eight concepts related to interoception: (1) *Noticing* (awareness of uncomfortable, comfortable, or neutral body sensations), (2) *Not Distracting* (tendency not to use distraction to cope with discomfort), (3) *Not Worrying* scale (tendency not to experience emotional distress with physical discomfort) (4) *Attention Regulation* (ability to sustain and control attention to body sensations) (5) *Emotional awareness* (ability to attribute specific physical sensations to physiological manifestations of emotions) (6) *Self-Regulation* scale, (ability to regulate distress by attention to body sensations) (7) *Body Listening* scale, (tendency to actively listen to the body for insight) (8) *Trusting* (the experience of one's body as safe and trustworthy). With all scales a higher score indicated greater interoceptive abilities. In the present sample

Cronbach's alpha's were 0.69, 0.56, 0.41, 0.85, 0.82, 0.76, 0.81 and 0.86 respectively. Due to their low reliability the 'Not worrying' scale and the 'Not distracting' scale were not analysed.

Body Appreciation Scale (BAS)

Attitude towards the body was assessed using the BAS (Avalos, Tylka, & Wood-Barcalow, 2005), which measures aspects of positive body image. This questionnaire is a 13-item scale that has been shown to have a one dimensional structure (Avalos et al., 2005); therefore all 13 items were averaged to obtain an overall BAS score (higher scores reflected greater body appreciation). The internal consistency in the present sample was $\alpha = 0.95$.

Toronto Alexithymia Scale (TAS-20)

Individual differences in identifying and describing feelings were measured using the TAS-20 (Bagby, Parker, & Taylor, 1994). This 20 item scale is composed of three factors: (1) difficulty modulating and identifying feelings (DIF); (2) difficulty describing one's feelings to others (DDF); and (3) externally oriented thinking (EOT). Higher scores indicate more alexithymia. In the present sample Cronbach's alpha's were 0.88, 0.87, 0.42 respectively. Due to its low alpha the EOT scale was excluded from subsequent analysis.

Eating disorder inventory 3 (EDI-3)

The Interoceptive awareness subscale of the EDI (Garner, 2002) is a 9-item assessment of interoceptive deficits, specifically in recognizing emotional and gastrointestinal sensations. Higher scores represent more disturbed interoceptive abilities. Reliability in the current sample was $\alpha = 0.81$. This scale was included because it has been used to examine interoception and NSSI in the context of eating disorders.

Inventory of Statements about Self-Injury (ISAS)

The frequency and functions of NSSI were measured using the ISAS (Klonsky & Glenn, 2009). The first section of the ISAS was used. This measures the lifetime frequency of 12 NSSI (e.g. cutting, burning, biting) behaviours performed "intentionally (i.e., on purpose) and without suicidal intent". Participants who endorsed one of these behaviours were considered to have a lifetime history of NSSI. Of those who reported using self-injury the frequencies of each NSSI behaviour were: 51.4% cutting, 45.7% biting, 34.3% burning, 28.6% carving, 48.6%

pinching, 42.9% pulling hair, 68.6% severe scratching, 65.7% banging or hitting self, 68.0% interfering with wound healing, 22.9% grazing skin, 11.4% sticking self with needles, 42.9% swallowing dangerous substances. Nearly all (86.0%) reported more than one type of NSSI behaviour.

RESULTS

Sample characteristics and the use of NSSI

Gender was not related to the incidence of self-injury ($X^2(1) = 0.170$, $p = 0.680$). However, those with a history of NSSI were significantly younger ($F(1,98) = 4.582$, $p < 0.035$) (NSSI 22.57(0.89), No NSSI 24.93(0.65).

Principal component analysis

Questionnaire subscales were entered into a principal components analysis to establish a higher order factor structure. Promax (oblique) rotation was applied as the orthogonality of interoceptive indices has not been established. The analysis yielded three factors with eigenvalues greater than 1 which were saved as standardised individual components to be used for subsequent analysis (Table 1). The first factor, which explained 32.3% of the variance, encompassed the two TAS sub-scales (DIF and DDF) and the EDI_IA scale: a higher score on this factor indicates interoceptive and emotional ambivalence (IAb). The second factor explained a further 29.4% of the variance and included the MAIA subscales 'Emotional awareness', 'Noticing', 'Body Listening' and 'Attention regulation'. This factor represented an awareness of, and ability to attend to, interoceptive signals; a higher score indicates a greater awareness (IAw). The third component, which explained 10.3% of the variance, encompassed the MAIA subscales 'Trusting' and 'Self-regulation' and the BAS; higher scores indicate more trust in and appreciation of the body (IAp). In total the three components accounted for 72.1% of the variance.

Sub-scale	Interoceptive Ambivalence	Interoceptive Awareness	Interoceptive Appreciation
TAS-DIF	0.964	-0.183	0.067
TAS-DDF	0.951	-0.059	0.028
EDI-IA	0.767	0.186	-0.165
MAIA-Emotional awareness	-0.214	0.923	-0.084
MAIA-Noticing	0.086	0.827	-0.184
MAIA-Body listening	0.056	0.630	0.217
MAIA-Attention regulation	-0.022	0.566	0.412
MAIA-Trusting	-0.087	-0.086	0.882
MAIA-Self regulation	0.283	0.228	0.745
BAS	-0.279	-0.083	0.703

Table 1. Component matrix for body awareness questionnaire sub-scales in study 1.

N= 100. MAIA – Multidimensional Assessment of Interoceptive awareness, BAS – Body Appreciation Scale, EDI-IA – Eating Disorder Inventory – Interoceptive awareness, DIF – Difficulty Identifying Feelings, DDF – Difficulty Describing Feelings.

The association between the three interoceptive components and NSSI

To determine the association between the resulting interoceptive dimensions and NSSI, correlational analysis (Pearsons r) was used (NSSI was dummy coded). IAb correlated positively with IAw ($r = 0.328, p < 0.001$) and negatively with IAp ($r = -0.335, p < 0.001$). IAw was also related to IAp ($r = 0.299, p < 0.003$) (Table 2). Positive associations were observed between NSSI and all three interoceptive indices: IAb ($r = 0.378, p < 0.001$), IAw ($r = 0.322, p < 0.001$) and IAp ($r = -0.276, p < 0.007$); those endorsing NSSI were characterised by higher IAb and IAw but lower IAp (Figure 1).

	Interoceptive Awareness	Interoceptive Appreciation	NSSI
Interoceptive Ambivalence	0.328**	-0.335**	0.378**
Interoceptive Awareness		0.299*	0.322**
Interoceptive Appreciation			-0.276*

Table 2. Zero order correlations (Pearson's r) between interoceptive dimensions in study 1. $N = 100$. ** $p < 0.001$ * $p < 0.01$.

Figure 1. Mean differences between NSSI groups on each of the interoceptive dimensions in study 1 (Top: N=100), study 2 (Middle: N=138), and study 3 (Bottom: N=85). In all three studies those with a history of NSSI had higher interoceptive ambivalence and lower body interoceptive appreciation.

Mediation analysis

As the resulting interoceptive dimensions were not orthogonal, possible mediation effects were considered. Based on the previous literature, a priori it was hypothesised that IAb effects NSSI through IAw and/ or IAp. A logistic mediation analysis was carried out using Hayes PROCESS model 4 (Figure. 2) (Hayes, 2013). The PROCESS macro uses bootstrapped sampling to estimate the indirect mediation effect. In the present analysis 5000 bootstrapped samples were drawn with replacement to estimate a sampling distribution for the indirect mediation pathway. The total effect of X on Y (denoted by c in Figure. 2), can be expressed as the sum of the direct effect (denoted by c') and indirect effect, which is the product of the a and b paths (denoted by ab), such that $c = c' + ab$. Indirect effects (B) and 95% confidence intervals are reported. IAb was entered as the independent variable (X), NSSI was the dependent variable (Y), IAw (M_1) and IAp (M_2) were parallel mediators. Age and gender were entered as covariates of both M and Y.

Figure 2. The statistical model which tested the direct and indirect effects of interoceptive ambivalence on NSSI.

In the first stage of the analysis the influence of IAb on IAw was considered. There was a positive association between IAb and IAw ($B=0.328$, 95% CI LL 0.124, UL 0.532). There was no effect of age ($B= -0.022$, 95% CI LL -0.058, UL 0.014) or gender ($B= 0.039$, 95% CI LL -0.378, UL 0.457). The model accounted for 12% of the variance in IAw and was significant ($R^2 = 0.12$, $F(3,96)=4.191$, $p<0.007$).

In the second stage of the analysis the influence of IAb on IAp was examined. The model accounted for 18% of the variance in IAp and was again significant ($R^2 = 0.18$, $F(3,96)=6.732$, $p<0.0004$). IAb negatively predicted IAp ($B=-0.363$, 95% CI LL -0.551, UL -0.176). Again there were no effects of age ($B= -0.033$, 95% CI LL -0.067, UL -0.001) or gender ($B= -0.325$, 95% CI LL -0.708, UL 0.058).

In the third stage IAw predicted NSSI ($B= 1.324$, 95% CI LL 0.491, UL 2.157), as did IAp ($B= -1.414$, 95% CI LL -2.316, UL -0.512) although IAb did not ($B= 0.239$, 95% CI LL -0.422, UL 0.901). Age was a significant predictor of NSSI ($B= -0.167$, 95% CI LL -0.305, UL -0.028); younger participants were more likely to endorse self-injury. However, the effect of gender was not significant ($B= 0.737$, 95% CI LL -0.479, UL 1.955). Nagelkerke's R^2 of 0.455 indicated that approximately 45% of the variance in NSSI was explained by the model.

The indirect effect of IAb on NSSI through IAw the effect was significant ($B= 0.434$, 95% CI LL 0.167, UL 0.994) as was the indirect effect of IAb on NSSI through IAp ($B= 0.514$, 95% CI LL 0.207, UL 1.269).

Overall the results from study 1 suggest a three factor model of interoception in NSSI whereby those high in interoceptive ambivalence (factor 1) tend to both notice or pay more attention to the body (factor 2) and have low bodily interoceptive appreciation (factor 3). The combination of these two processes may explain the link between interoceptive and emotional ambivalence and NSSI.

Study 2

Study 2 sought to replicate the factor structure and mediation effects observed in study 1. Given previous links between alexithymia and the tendency to somaticize emotional

experiences (De Gucht & Heiser, 2003) an additional scale, the 'Somatization' subscale of the Symptom Checklist-90 (SCL-90) was included (Derogatis, Rickels, & Rock, 1976). In addition, this study controlled for key confounders, specifically comorbid anxiety and depression.

METHODS

In an identical fashion to study 1, adult males and females were recruited to participate in this study (N = 138). Sixty participants endorsed a history of NSSI, and seventy-eight participants endorsed no history of NSSI. The frequency of each NSSI behaviour was: 63.3% cutting, 40.0% biting, 26.7% burning, 23.3% carving, 48.3% pinching, 41.7% pulling hair, 73.3% severe scratching, 55.0% banging or hitting self, 51.7% interfering with wound healing, 33.3% grazing skin, 11.7% sticking self with needles, 18.3% swallowing dangerous substances. 95.0% reported more than one type of NSSI behaviour. There were twenty males and one hundred and eighteen females with a mean age of 26.0(11.9). The inclusion criteria, procedure and methods were the same as in study one with the addition of the 'Somatization' subscale of the Symptom Checklist-90 (SCL-90), Beck's Depression Inventory (BDI) and Beck's Anxiety Inventory (BAI).

In the present sample Cronbach's alpha's were 0.70 (noticing), 0.87 (attention regulation), 0.84 (emotional awareness), 0.83 (self-regulation), 0.88 (body listening), 0.92 (trusting), 0.89 (DDF), 0.89 (DIF), 0.74 (EDI-AI), and 0.96 (BAS).

'Somatization' subscale of the Symptom Checklist-90 (SCL-90).

Twelve items of somatisation were taken from SCL-90 (Derogatis et al., 1976) to measure distress arising from perceptions of bodily dysfunction. The severity of these somatic symptoms were evaluated from 0 = not at all to 4 = extremely disturbing during. The reliability for SCL - 90 - Somatisation subscale was $\alpha = 0.83$.

Beck's Depression Inventory (BDI)

The level of depression was assessed by using BDI (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961). Twenty-one items regarding main depressive symptoms were scored from 0 to 3. Higher scores indicate more intensive symptoms of depression. In the present study, the reliability for this scale was $\alpha = 0.94$.

Beck's Anxiety Inventory (BAI)

BAI (Beck, Epstein, Brown, & Steer, 1988) was used to measure the severity of anxiety in participants. Twenty-one common symptoms of anxiety were self-assessed from 1 to 4 when higher scores reflect more severe anxiety. The Cronbach's alpha for this scale was 0.93.

RESULTS

Sample characteristics and the use of NSSI

Females were more likely to report a history of NSSI than males ($\chi^2(1) = 7.719, p = 0.005$). In addition, those with a history of NSSI were significantly younger ($F(1,136) = 13.911, p < 0.0001$) (No NSSI 29.24(1.28), NSSI 21.95(1.47)).

Principal component analysis

As in study 1, questionnaire subscales were subject to principal components analysis with a Promax (oblique) rotation. The analysis yielded three factors with eigenvalues greater than 1 which were saved as standardised individual components to be used for subsequent analysis (Table 3). The first factor, which explained 38.8% of the variance, encompassed the MAIA subscales 'Emotional awareness', 'Noticing', 'Body Listening', 'Self-regulation' and 'Attention regulation'. Again this factor represented an awareness of, and ability to attend to, interoceptive signals; a higher score indicates a greater awareness (IAw). The second factor explained a further 22.0% of the variance and included the two TAS sub-scales (DIF and DDF) and the EDI_IA scale: a higher score on this factor indicates interoceptive and emotional ambivalence (IAb). Finally, the third component explained 9.4% of the variance and encompassed the MAIA subscale 'Trusting', the BAS and the SCL-90 somatization subscale; higher scores indicate more trust in and appreciation of the body and a tendency not to somaticize (IAp). In total the three components accounted for 70.2% of the variance.

Sub-scale	Interoceptive Ambivalence	Interoceptive Awareness	Interoceptive Appreciation
TAS-DIF	-0.141	0.961	0.218
TAS-DDF	0.083	0.918	-0.023
EDI-IA	0.016	0.742	-0.254
MAIA-Emotional awareness	0.863	0.178	-0.017
MAIA-Noticing	0.851	-0.061	-0.307
MAIA-Body listening	0.816	-0.110	-0.120
MAIA-Attention regulation	0.681	-0.023	0.223
MAIA-Self regulation	0.635	-0.022	0.386
MAIA-Trusting	0.407	-0.080	0.570
BAS	-0.038	0.145	0.929
SCL-90S	0.306	0.244	-0.573

Table 3. Component matrix for body awareness questionnaire sub-scales in study 2.

N= 138. MAIA – Multidimensional Assessment of Interoceptive awareness, BAS – Body Appreciation Scale, EDI-IA – Eating Disorder Inventory – Interoceptive awareness, DIF – Difficulty Identifying Feelings, DDF – Difficulty Describing Feelings, SCL-90S – SCL-90 somatization subscale.

Independent association between interoceptive components and NSSI

Correlational analysis (Pearsons r) was used (NSSI was dummy coded) to determine the association between interoceptive components and NSSI. As expected, NSSI was positively correlated with both anxiety ($r = 0.393, p < 0.001$) and depression ($r = 0.498, p < 0.001$). A higher anxiety also predicted higher IAb ($r = 0.598, p < 0.001$) and lower IAp ($r = -0.523, p < 0.001$), although no association was observed between anxiety and IAw ($r = -0.076, p = 0.375$). Depression was associated with all three interoceptive indices: IAb ($r = 0.626, p < 0.001$), IAw ($r = -0.210, p < 0.014$), and IAp ($r = -0.474, p < 0.001$).

NSSI was positively associated with IAb ($r = 0.478, p < 0.001$) and negatively associated with IAp ($r = -0.522, p < 0.001$). However, in contrast to study 1, IAw was unrelated to NSSI ($r = -0.133, p = 0.119$). Mean differences between NSSI groups on each of the interoceptive dimensions are shown in Figure 1. All three interoceptive indices were again related (Table 4).

	Interoceptive Awareness	Interoceptive Appreciation	NSSI	DEP	ANX
Interoceptive Ambivalence	-0.177*	-0.484***	0.478***	0.626***	0.598***
Interoceptive Awareness		0.318***	-0.133	-0.210*	-0.076
Interoceptive Appreciation			-0.522***	-0.474***	-0.523***
NSSI				0.498***	0.393***
DEP					0.601***

Table 4. Zero order correlations (Pearson's r) between interoceptive dimensions in study 2. N= 100. *** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$.

Mediation analysis

Based on the findings from study 1 it was hypothesised that IAb effects NSSI through IAw and/ or IAp. The analysis was identical to study 1 with the exception that anxiety and depression rating were entered as additional covariates of both M and Y.

In the first stage of the analysis the influence of IAb on IAw was considered. No association between IAb and IAw was observed ($B = -0.129$, 95% CI LL -0.365, UL 0.106). There was no effect of age ($B = -0.001$, 95% CI LL -0.015, UL 0.013) or gender ($B = -0.146$, 95% CI LL -0.629,

UL 0.337), anxiety ($B = 0.075$, 95% CI LL -0.053, UL 0.203) nor depression ($B = -0.116$, 95% CI LL -0.245, UL 0.012). The model was not significant ($R^2 = 0.05$, $F(5, 132) = 1.628$, $p = 0.156$).

When the effects of IAb on IAp was examined. The model accounted for 38% of the variance in IAp and was significant ($R^2 = 0.38$, $F(5, 132) = 16.799$, $p < 0.0001$). IAb negatively predicted IAp ($B = -0.208$, 95% CI LL -0.398, UL -0.018). Again there were no effects of age ($B = 0.005$, 95% CI LL -0.006, UL 0.016), however, females had lower IAp than males ($B = -0.665$, 95% CI LL -1.054, UL -0.275). The influence of depression just missed significance ($B = -0.098$, 95% CI LL -0.202, UL -0.005), although those who were most anxious had significantly lower IAp ($B = -0.136$, 95% CI LL -0.240, UL -0.033).

In the third stage IAp predicted NSSI ($B = -0.972$, 95% CI LL -1.603, UL -0.340), although IAw ($B = 0.149$, 95% CI LL -0.354, UL 0.653) and IAb ($B = 0.524$, 95% CI LL -0.101, UL 1.150) did not. Younger participants were more likely to endorse NSSI ($B = -0.075$, 95% CI LL -0.133, UL -0.018), as were females ($B = 1.662$, 95% CI LL 0.081, UL 3.244). Although anxiety had no influence ($B = -0.050$, 95% CI LL -0.418, UL 0.318), those who were more depressed were more likely to engage in NSSI ($B = 0.452$, 95% CI LL 0.106, UL 0.798). Nagelkerke's R^2 of 0.561 indicated that approximately 56% of the variance in NSSI was explained by the model.

The indirect effect of IAb on NSSI through IAw the effect was not significant ($B = -0.019$, 95% CI LL -0.155, UL 0.057). However, the indirect effect of IAb on NSSI through IAp was significant ($B = 0.202$, 95% CI LL 0.019, UL 0.528).

Overall the results of study 2 supported the three factor interoception model of NSSI with principal component analysis replicating the factor structure observed in study 1. Interestingly, the SCL-90 somatization subscale loaded onto factor 3 alongside the MAIA subscale 'Trusting' and the BAS, rather than factor 1 which represented a tendency to become aware/ to attend to interoceptive signals. Although the associations between IAb, IAp and NSSI were confirmed, and remained significant after controlling for anxiety and depression, this was not true for IA.

Study 3

A limitation of previous research that has examined the link between body awareness and NSSI is its reliance on self-report measures. Therefore, study 3 sought to extend the model by examining the link between NSSI and objective interoceptive accuracy. In addition, it was considered whether this objective index explained additional variance in NSSI, over and above that associated with self-report interoceptive indices.

METHODS

Eighty-five females were recruited to participate in this study, of which twenty-nine had a history of NSSI. The frequency of each NSSI behaviour was: 55.2% cutting, 51.7% biting, 27.6% burning, 24.1% carving, 58.6% pinching, 41.4% pulling hair, 72.4% severe scratching, 65.5% banging or hitting self, 55.2% interfering with wound healing, 41.4% grazing skin, 10.3% sticking self with needles, 24.1% swallowing dangerous substances. 96.2% reported more than one type of NSSI behaviour. The average age was 24.5(9.45) – age did not predict the use of NSSI ($F(1,83) = 0.480, p=0.490$). To limit the time associated with completing questionnaires one scale from each factor was chosen to represent each self-report interoceptive dimension. These included the MAIA subscales 'Trusting' and 'Noticing' and the EDI-3 'interoceptive deficits' scale which previously loaded onto the IAp, IAw and IAb factors respectively. In the present sample Cronbach's alpha's were 0.73 (noticing), 0.73 (trusting), and 0.85 (EDI-AI).

Procedure

After providing their written informed consent, participants rated their general levels of anxiety and depression and then completed the questionnaires. After which they were fitted with Ag/AgCl electrodes, transducers were applied to the subjects and connected to a BIOPAC MP150 and ECG100C amplifier module (BIOPAC, USA). Participants then completed the interoception task as outlined below. Interbeat interval data were monitored throughout the interoception with a sampling rate of 2000Hz. The procedure was approved by Swansea University department of Psychology ethics committee and was conducted in accordance with the principles laid down by the declaration of Helsinki 2013.

Interoceptive accuracy (IAc)

The heartbeat perception Task was performed using the mental tracking method (Schandry, 1981) with intervals of 30, 35, 40, 45 and 50 s that were separated by 30 s resting periods. During each trial R-R intervals were recorded and participants were asked to silently count their heartbeats without the use of an exteroceptive aid (such as taking one's pulse). At the end of each period participants reported the number of counted heartbeats. The participants were not informed about the length of the counting phases or about the quality of their performance. The transformation $1 - (\text{abs}(n\text{beats}_{\text{real}} - n\text{beats}_{\text{reported}}) / (n\text{beats}_{\text{real}}))$ was used to calculate heartbeat tracking scores. These scores were then averaged to form a mean heartbeat tracking score (IAc). The interoception score varied between 0 and 1 with a higher score indicating better accuracy. The internal consistency of this measure was good: Cronbach's alpha 0.82. This heartbeat detection Task is a standard measure used to assess the accuracy of the ability to detect interoceptive signals.

Mood

Participants were asked to describe their general predisposition using visual analogue scales (VAS) with pairs of adjectives at the ends of 100 mm lines; Composed/Anxious and Elated/Depressed (Lorr, McNair, & Fisher, 1982).

RESULTS

Independent association between interoceptive components and NSSI

As before, correlational analysis (Pearsons r) was used (NSSI was dummy coded) to determine the association between interoceptive components and NSSI. NSSI was positively correlated with depression ($r = 0.218, p < 0.045$) but not anxiety ($r = 0.032, p = 0.770$). Similarly, NSSI was positively associated with IAb ($r = 0.397, p < 0.001$) and negatively associated with IAp ($r = -0.450, p < 0.001$). However, no relationship was observed between IAw and NSSI ($r = 0.111, p = 0.314$). Mean differences between NSSI groups on each of the interoceptive dimensions are shown in Figure 1. IAb was negatively correlated with IAp ($r = -0.274, p < 0.011$), and positively with IAw ($r = 0.251, p < 0.030$) (Table 5). Interestingly, those who reported NSSI had lower heartbeat perception (IAc) than those who did not report NSSI ($r = -0.252, p < 0.020$). A higher IAc was related to higher IAp ($r = 0.242, p < 0.026$) but not to the other self-report interoceptive indices (Table 5; Figure 3).

	Noticing	Trusting	IAC	NSSI
EDI_IA	0.251 [*]	-0.274 ^{**}	-0.063	0.397 ^{***}
Noticing		0.174	-0.021	0.111
Trusting			0.242 [*]	-0.450 ^{***}
IAC				-0.252 ^{**}

Table 5. Zero order correlations (Pearson's *r*) between interoceptive dimensions in study 3. N= 100. *** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$. IAC – interoceptive accuracy. EDI-AI – Eating disorder inventory interoceptive awareness scale.

Figure 3. Mean differences between NSSI groups on interoceptive accuracy (N=85). Those with a history of NSSI had significantly lower interoceptive accuracy.

Mediation analysis

Cooks distance, with a threshold of $N/4$, was used to detect possible outliers (Cook, 1977). This resulted in one case, which had a score of 0.086, being removed. Analysis parameters were identical to those in studies 1 and 2 with anxiety and depression ratings entered as covariates. Based on the findings from the previous two studies it was hypothesised that IAb would influence NSSI through its effects on IAp. The effects of IAc and IAw were examined by entering them as additional parallel mediators which allowed the unique effects of each interoceptive indices on NSSI to be considered.

The direct effect of IAb on NSSI remained significant when considered as part of the model ($B = 0.936$, 95% CI LL 0.235, UL 1.637). In addition, those who endorsed NSSI had lower IAc ($B = -7.385$, 95% CI LL -13.333, UL -1.437), lower IAp ($B = -1.148$, 95% CI LL -1.853, UL -0.442), and higher IAw ($B = 0.803$, 95% CI LL 0.116, UL 1.489). Thus each interoceptive index contributed independently to the model. The latter effect of IAw was only significant in the context of the multivariate model. Nagelkerke's R^2 of 0.586 indicated that approximately 58% of the variance in NSSI was explained by the model.

The indirect effect IAb on NSSI through IAp was again significant for a third time ($B = 0.310$, 95% CI LL 0.005, UL 0.954) suggesting that this is a robust effect. However, the other indirect pathways were not significant: IAb $\rightarrow$ IAc $\rightarrow$ NSSI ($B = 0.058$, 95% CI LL -0.191, UL 0.441), IAb $\rightarrow$ IAw $\rightarrow$ NSSI ($B = 0.056$, 95% CI LL -0.164, UL 0.411). Thus, although those who have a history of NSSI showed, across a number of dimensions, aberrant interoceptive processing, only the evaluative component appears to explain the link between IAb and NSSI.

DISCUSSION

For the first time a range of aspects of body awareness was examined in those who self-injure. Given the previous lack of conceptual clarity in this area three studies took an empirical driven approach to the categorisation of different aspects of body awareness and their relationship to NSSI. A principal component analysis in study 1 revealed three higher order dimensions: 'interoceptive and emotional ambivalence' (an inability to differentiate interoceptive signals and feelings), 'interoceptive awareness' (the subjective tendency to

notice or attend to bodily sensations), and an evaluative component 'Body interoceptive appreciation' (Table 1). This factor structure was then replicated in an independent sample (Study 2; Table 3). In three studies, those with a history of NSSI were characterised by greater interoceptive and emotional ambivalence (IAb), and lower bodily interoceptive appreciation (IAp) (Figure 1). Further, the effect IAb on NSSI was mediated by IAp highlighting a novel pathway through which IAb may predispose to NSSI (Figure 2). Findings from study 3 revealed that although individuals with a history of NSSI self-reported greater subjective interoceptive awareness (IAw) when measured objectively they lacked the ability to precisely and correctly monitor changes in internal body state (Interoceptive accuracy - IAc) (Figures 1 and 3). This multidimensional approach offers a novel insight into the pathology that underlies NSSI, providing a biologically plausible explanation for the apparent paradox that individuals who self-injure often report feeling 'emotionally overwhelmed', and at the same time being 'emotionally numb' (Horne & Csipke, 2009).

The existing 'body awareness' literature has utilised a variety of psychometric assessments based on different definitions (W. E. Mehling et al., 2009). This has led to a varied operationalization of specific terms and a lack of clarity regarding dimensions of clinical importance: the scant literature concerning body awareness in those who endorse NSSI is a prime example. To date, studies considering interoceptive deficits in those who self-injure have primarily utilised the Eating Disorder Inventory 'Interoceptive awareness' subscale (EDI-AI) (Garner, 2002) (e.g. Dodd et al., 2017; Favaro & Santonastaso, 1997; Forrest et al., 2015; Fujimori et al., 2011; Muehlenkamp et al., 2012; Ross et al., 2009). However, rather than measuring 'body awareness' per se, this instrument assesses ambivalence regarding internal states (Merwin, Zucker, Lacy, & Elliott, 2010). As such the first aim of the present studies was to establish a higher order factor structure of a variety of commonly used body awareness questionnaires and relate these to NSSI. Components were identified that represented three distinct facets of interoception: (1) interoceptive and emotional ambivalence (IAb); (2) a subjective tendency to notice and attend to bodily signals (IAw), (3) interoceptive appreciation of the body (IAp).

Predictably, the EDI-IA scale combined with the TAS sub-scales (DIF and DDF) to produce the component representing 'interoceptive and emotional ambivalence' (Tables 1 and 3). Thus

previous research purporting to examine the role of 'interoceptive awareness' in NSSI has inadvertently added to the literature associating NSSI with alexithymia (see Norman & Borrill, 2015 for a review). The present findings also support this contention; those who endorse NSSI were characterised by greater 'interoceptive and emotional ambivalence' (Figure 1).

Individuals with alexithymia (characterised by an inability to identify and describe feelings and an externally orientated thinking style) are widely considered to lack interoceptive abilities. For example, Herbert, Herbert, and Pollatos (2011) found that the objective ability to detect the heartbeat is negatively associated with all aspects of alexithymia (DIF, DDF and EOT). Conversely, alexithymia related positively with a self-report measure of interoceptive awareness (The Self-awareness Questionnaire) (Longarzo et al., 2015). Whilst these reports appear contradictory they may be explained by evidence that interoceptive accuracy (objective heartbeat detection performance) and interoceptive sensibility (self-evaluated interoceptive *belief*, gauged using interviews/questionnaires) measure different aspects of interoceptive processing (Garfinkel, Seth, Barrett, Suzuki, & Critchley, 2015). Indeed, study 3 confirmed this dissociation; the self-reported tendency to notice bodily sensations was unrelated to interoceptive accuracy (Table 5). Thus, it is plausible that individuals with alexithymia may lack an objective ability to detect bodily signals while simultaneously self-reporting a higher awareness of the body.

In relation to NSSI a similar pattern emerged - those with a history of NSSI were subjectively more aware of their bodily sensations (Study 1 and Study 3) but lacked objective interoceptive accuracy (IAc) (Study 3). This is an important finding as low IAc may be the biological basis for reports of 'absent affect' and 'detachment' and 'disembodiment' in those who use NSSI (Horne & Csipke, 2009). However, although IAc and the EDI-IA (which correlated highly with standard measures of alexithymia: Tables 1 and 3) were both associated with NSSI, the two interoceptive components were not related implying that they are independent risk factors for NSSI. This is in line with findings of (Pollatos et al., 2008) who reported that although those with anorexia nervosa had deficits of both measures, the measures themselves were not related.

Interestingly, it has been proposed that alexithymia may result not only from an inability to detect physiological sensations but also underdeveloped cognitive structures that provide the qualitative conceptual aspects of emotion (Preece et al., 2017). This is supported by neuroimaging research which showed reduced activation in brain regions associated with emotions, while also showing increased activation in regions involved in physiological sensation (Kano & Fukudo, 2013). Thus alexithymia can be understood as an inability to adequately conceptualise and integrate interoceptive signals to form a phenomenological representation of the emotion that is being felt. Instead unstructured or uncategorised bodily signals are perceived. Therefore, those with alexithymia may pay more attention to physiological aspects of emotion and describe emotional experiences in terms of bodily states rather than elaborating feelings. This might explain why those high in IAb consistently self-reported greater body awareness (Tables 2, 4 and 5); a process that may not necessarily lead to increased objective interoceptive accuracy. Importantly, an increased subjective awareness of the body in those high in IAb might explain their increased use of NSSI. Indeed, in the present study the influence of IAb on NSSI was mediated by increased self-reported IAw (Figure 2), although a caveat is that this indirect effect was only significant in the first study. Therefore, increased bodily attention alone is not sufficient to explain the use of NSSI.

With this in mind, it has recently been argued that 'interoceptive awareness' should encompass a broader range of cognitive and behavioural phenomena than simply an awareness of interoceptive sensations (W. Mehling, 2016). From this perspective *how* one attends to and appraises bodily signals is of critical importance. For example, in the context of 'trust' and 'appreciation', mindful body awareness may help one accept and respond intuitively to bodily sensations. Conversely, angst driven hyper-vigilance may result in ambivalence, hesitation and indecision. The pattern of results derived from the principal component analysis in study 1 and study 2 supported this view. Specifically, 'interoceptive awareness' comprised of the MAIA subscales 'emotional awareness', 'noticing', 'body listening' and 'attention regulation' that statistically loaded onto a single component, while 'trusting' combined with 'body appreciation' to produce a separate dimension. This suggests that 'body awareness' (whether this results from passively 'noticing' bodily signals or actively 'listening' and directing 'attention' to them) and 'interoceptive appreciation' (which will also impinge upon how one *uses* the body to 'self-regulate') may represent discrete interoceptive

dimensions. In this context it is important to consider that one function of NSSI may be to manipulate the *way* in which the body contributes to the experience of emotion (Horne & Csipke, 2009). As such NSSI may be more closely associated with 'interoceptive appreciation' or the trust that one has in their bodily sensations. That is, if an individual does not trust their sensations, they are unlikely to utilise them to guide what they are feeling. Therefore, NSSI may become an alternative way to embody an emotional experience without the need to acknowledge unpleasant or untrustworthy interoceptive signals. In addition, if one evaluates their body negatively it may become easier to deliberately self-injure (Hooley & Franklin, 2018). Indeed, a robust finding across three studies was that individuals with a history of NSSI were characterised by a distrust and depreciation of the body (Figure 1). This might explain why body awareness alone is not sufficient to precipitate NSSI (Tables 4 and 5), rather it is *how* one attends to and appraises bodily signals that is important. Similar findings have been noted in relation to emotional dysregulation. Muehlenkamp et al. (2013) examined a related construct, 'body regard', in relation to NSSI. In their study emotional dysregulation was associated with NSSI but only in individuals low in 'body regard' (Muehlenkamp et al., 2013). Thus it appears that diminished body 'interoceptive appreciation' alters the way the body is used for self-regulatory purposes, precipitating NSSI.

A further finding, consistent across all three studies, was that diminished 'interoceptive appreciation' (IAp) mediated the association between 'interoceptive ambivalence' (IAb) and NSSI. These findings suggest that an inability to identify and conceptualise interoceptive and emotional signals may lead to difficulties in trusting what is being felt in the body. Interestingly, in studies 1 and 2 this was full mediation (the direct effect IAb was diminished when IAp was included in the model), however, in study 3 only partial mediation was observed (the direct effect IAb remained significant when IAp was included in the model). As a result, a further function of NSSI may be to resolve a state of interoceptive and emotional uncertainty - NSSI may serve to disambiguate the body's role in emotional experience and provide clarity about what is being felt. It is plausible that this may be exacerbated when there is low objective interoceptive accuracy – in this context NSSI may serve to both enhance and clarify the role of the body.

This framework might also explain the heightened subjective interoceptive awareness in those who use NSSI. That is, if one is unable to conceptualise or trust what is being felt, a consequence might be that in search for understanding, there might be an uneasy hyper-vigilance directed to the body. In this way heightened subjective interoceptive awareness becomes a by-product of a dysfunctional interoceptive system, increasing scrutiny of the body. However, as subjective interoceptive awareness is usually unrelated to objective interoceptive accuracy the search for understanding is in vain, and the increased focus on the body serves only to exacerbate the use of NSSI. Although further research is needed to confirm this framework there are potentially important clinical considerations. In particular, interventions aimed at ameliorating NSSI might benefit from fostering affectionate and trusting attention to bodily experiences. In addition, the development of interventions that improve objective interoceptive accuracy may help the use of bodily experiences for affect regulation.

The limitations of the present study should be considered. Although the present results provide novel information related to NSSI, as with all cross-sectional designs causality cannot be established. For instance, it is equally plausible that a mistrust of bodily sensations may lead to confusion about what is being felt – as such these associations are likely to be bidirectional resulting in a self-perpetuating cycle that becomes to break. In order to understand the temporal order in which these variables relate to each other, longitudinal investigations of community and clinical samples are needed to examine whether aspects of body awareness are indeed a causal factor for NSSI, rather than a consequence of the behaviour. Using the heartbeat counting task has been questioned, as it may be possible that participants base their counts on beliefs about HR (Brener & Ring, 2016). Therefore, future research should seek to replicate these findings using a more robust heartbeat discrimination task based on the method of constant stimuli (Young et al., 2017). In addition, it has previously been considered that only those above 0.85 on this heartbeat counting test be considered to have high IAc (H. A. Young, Gaylor, de Kerckhove, Watkins, & Benton, 2019). However, using this criterion we were able to replicate the result; those with an IAc score > 0.85 were significantly less likely to have a history of NSSI males ($\chi^2(1) = 4.333$, $p = 0.037$).

CONCLUSION

The present results indicated that a complex pattern of body awareness underlies NSSI. The results of three studies suggest that those with a history of NSSI have difficulty distinguishing interoceptive signals and emotions; a finding that may be interpreted as a failure to integrate and conceptualise interoceptive signals to form a coherent representation of the emotion being felt. This phenomenon in turn may hinder the ability to interoceptively appreciate the body's role in emotional experience. Despite a diminished ability to precisely and correctly monitor changes in internal body state when measured objectively (lower interoceptive accuracy), an angst driven hyper-vigilance directed at the body in search of understanding may lead to a heightened subjective interoceptive awareness. NSSI may serve to resolve the resulting state of emotional and interoceptive uncertainty associated with the body's function in emotional experience.

These clinically relevant findings highlight specific targets for NSSI intervention, for example, a focus on improving compassionate self-focus may be beneficial. In addition, they emphasise that if one is to reveal new and important mechanistic insights into the link between interoception and NSSI, a multifaceted approach will be required.

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