Psychological Correlates of Interoceptive Perception in Healthy Population

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Abstract. Investigating awareness of internal state of the body (i.e. interoception) is a promising field in the neuroscience domain. Evidence indicated interoceptive alterations in a wide variety of conditions. However, among literature, there is a consistent lack of information regarding the psychological correlates of interoceptive awareness (IA) in healthy population.

Methods: 54 subjects performed a complete interoceptive assessment for accuracy (IAc), metacognitive awareness (IAw), and sensibility (IAs) measured through M.A.I.A questionnaire. Subjects also performed psychological assessment for depression (BDI), anxiety (BAI), state and trait anxiety (STAI), and eating disorders (EDI-3) risks. **Results**: IAc and IAw positively correlated across the whole sample and IAw strongly positively correlated with several MAIA subscales. Significant negative correlations were also found with state anxiety and depressive symptoms. Female subjects exhibited a different interoceptive pattern with a negative relationship between IAc and BMI, and IAw and state anxiety. Conversely, male subjects exhibited a positive relationship between IAw and BMI, and IAc and Age, while IAw showed a negative relationship with state anxiety and depression. **Conclusions**: Perception of internal state of the body and relative metacognitive awareness appeared only partially connected. Different interoceptive patterns between male and female subjects appeared primarily related to specific body perceptions rather than gender differences. Considering the relationship between interoception and wellbeing, knowledge regarding how interoceptive processes work could help develop tailored technological interventions that utilize interoceptive treatments and multisensory stimulation to enhance human well-been through technology.

Keywords: Interoception · Interoceptive awareness · Emotions · Interoceptive technology · Interoceptive stimulation · Interoceptive treatments

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1 Introduction

Our body represents the focal lens that allows us to perceive the world. We live, explore, and relate to others through our body and its perceptions. Furthermore, the way we process and integrate perceptions coming from the body defines who we are, our self, and – ultimately – our wellbeing [1–4]. Several authors explored the relationship between the perception of the body and the human well-being, and these efforts resonated with different scientific solutions aimed at enhancing healthy bodily processing through the new field of embodied technology. From this perspective, embodied technology represents a new outlook focused upon the possibility to use technology to stimulate bodily perceptions with the ultimate goal of promoting a balanced autonomic functioning both in healthy both in clinical populations [2, 5, 6].

Traditionally, the study of body perception has always been related to proprioceptive signals, nonetheless in the last two decades neuro-scientific evidence brought light to a brand new concept of interoceptive perceptions. Interoception, defined as the psychological sense of the entire organism [7], reshaped several domains of science bringing a new perspective to several fields from psychology to cognitive sciences to neuroscience. Nonetheless, to properly explore technological solutions applied to the interoceptive domain, more data need to be collected especially regarding behavioural interoceptive functioning in healthy population.

Interoception can be explored on different axes. The most accepted framework has been proposed by Garfinkel, Seth, Barrett, Suzuki and Critchley [8] and described three interoceptive axes: interoceptive accuracy (IAc) i.e. subject's ability to correctly perceive his own body, metacognitive awareness (IAw) i.e. subject's confidence in the accuracy evaluation, and sensibility (IAs) i.e. subject's cognitive evaluation of his bodily perceptions. These axes have been explored in different contexts, with a main focus upon accuracy alterations in different clinical [9] and non-clinical conditions, nonetheless across literature there is a consistent lack of information regarding psychological correlates (e.g. mood both in trait both in state conditions, body-related psychological processes and beliefs) of interoception in healthy samples. This gap not only creates an area of unidentified knowledge but it also interferes with the ability to correctly elaborate interoceptive information in other contexts. Beginning to address this issue and moving toward a more complex knowledge about interoceptive processes, the study explored psychological correlates of interoception in healthy population.

In healthy subjects, we hypothesize a positive correlation between IAc and IAw. According to literature [10], we also hypothesize a positive relationship between anxiety and IAc and a negative relationship between depressive symptoms and IAc [11]. Considering evidence related to eating disorder [12] we also hypothesize a negative relationship between interoceptive accuracy and EDI-3 risk subscales.

2 Methods

2.1 Participants

Sample size calculation based on previous studies [8, 10, 13] indicate a total sample size of fifty-six subjects [$\rho^2 = 0.3$, α err prob. = 0.05, power = .95]. Fifty-six subjects were recruited at the Catholic University of the Sacred Heart of Milan, campus of Psychology. Data for two subjects were not collected due to ECG technical issues. Fifty-four subjects [18.5% male] were included into the study. Exclusion criteria were the presence of current psychological or physical diagnoses. Subjects received instruction to avoid medications in the 12 h before the meeting. Similar instruction was given for nicotine and caffeine, and subjects were asked to avoid them in the 2 h before the experiment. All subjects gave written informed consent in accordance with the Declaration of Helsinki (2008). The protocol was approved by the Ethics Committee of Catholic University of Sacred Heart of Milan.

2.2 Procedure

Subjects were accommodated in a comfortable room and received information about the experiment. After information was given, they proceeded to sign written consent and took part to a brief anamnestic interview with a psychologist specialized in psychopathological and personality assessment. Following the interview they proceeded to compile a series of psychological questionnaires. After the questionnaires, subjects were connected to a portable ECG device with Ag/AgCl electrodes to perform the interoceptive tasks. At the end of the tasks, electrodes were removed and subjects were debriefed.

2.3 Psychological Assessment

Depressive mood alterations were assessed through the Beck Depression Inventory (BDI-II) [14] that is a 21 self-reported questionnaire able to discriminate different levels of depression. The instrument is among the most diffused and well validated whereas scores under 13 indicate normal mood variations, while scores above 14 are able to differentiate from mild, to moderate, to severe depressive status [15, 16].

Anxiety was assessed both in state and trait dimensions through the 40-items State Trait Anxiety Inventory (STAI) [17], whereas scores above 40 indicate clinical anxiety both in trait and status conditions. Due to known correlations between STAI and BDI [18] measures, anxiety was also assessed through the BAI [19], a specific scale that provides a trait-like measure of anxiety without overlapping constructs with the BDI. Risks for eating disorders were assessed through EDI-3 [20] risk subscales [21]. The EDI-3 questionnaire [20–22] is a specific instrument able to assess different eating related subclinical risks, through three specific subscales: Drive for Thinness (DT) is a

subscale connected to behavioural and cognitive drives linked to anorexia nervosa tendencies. Bulimia (B) is a subscale that assess for bulimic tendencies, and Body Dissatisfaction (BD) is a scale that explores a generalized construct related to a diffuse dissatisfaction towards the body. The sum of the scores from these subscales composes a Global Risk Index (EDRC).

2.4 Interoceptive Measures

Interoception has been recently operationalized in three separate constructs: interoceptive accuracy, interoceptive metacognitive awareness, interoceptive sensibility [8]. Interoceptive Accuracy (IAc) was assessed through a well validated and wide utilized heart beat perception task, originally designed by Schandry [23]. Subjects were connected to a portable ECG unit sampling at 250 Hz [24–28] with Ag/AgCl electrodes and they were instructed to count their own heartbeats in specific intervals time intervals (25, 35, 45, and 100 s). Accuracy index was calculated according to: $1/4\sum(1 - (|\text{recorded heartbeats} - \text{counted heartbeats}|)/\text{recorded heartbeats})$.

Interoceptive metacognitive awareness (IAw) is a response of confidence that assesses how much subjects considered their answers to the accuracy tasks correct. IAw is evaluated with a Visual Analogue Scale that ranges from "not confident at all" to "fully confident" according to Garfinkel, Seth, Barrett, Suzuki and Critchley [8].

Interoceptive sensibility was assessed through The Multidimensional Assessment of Interoceptive Awareness (MAIA) questionnaire [29]. The M.A.I.A. is a multidimensional 32 items questionnaire with 8 subscales. The M.A.I.A. is a multidimensional 32 items questionnaire with 8 subscales. The Noticing (NO) subscale expresses subject's awareness of uncomfortable, comfortable, and neutral body sensations. The Not-Distracting (ND) subscale expresses subject's tendency not to ignore or distract oneself from sensations of pain or discomfort. The Not-Worrying (NW) subscale expresses subject's tendency not to worry or experience emotional distress with sensations of pain or discomfort. The Attention Regulation (AR) subscale expresses subject's ability to sustain and control attention to body sensations. The Emotional Awareness (EA) subscale expresses subject's awareness of the connection between body sensations and emotional states. The Self-Regulation (SR) subscale expresses subject's ability to regulate distress by attention to body sensations. The Body Listening (BL) subscale expresses subject's ability to active listening to the body for insight. The Trusting (TR) subscale expresses subject's experience of one's body as safe and trustworthy. Responses are given on a 6 points likert scale, from 0 to 5. Each subscale score ranges from 0 to 5.

2.5 Statistical Analyses

Linear and non-linear correlational analyses were run for variables of main interest in the whole sample and across the different gender subsamples. Following literature suggestions [18] and results from previous studies [13] we also implemented different factors structures for BDI [15, 16], to identify cognitive and somatic (body related) depressive symptoms.

3 Results

3.1 Sample Psychological Characteristics and Psychological Measures

Total sample of N = 54 was comparable for age [mean = 25.74 years; SD = 6.38] and BMI [mean = 21.01; SD = 2.24] with other healthy sample in literature [8]. Sample showed moderate levels of anxiety [STAI_T mean = 42.63, SD = 9.81; STAI_S mean = 34.18, SD = 7.77; BAI mean = 10.88, SD = 7.55] and depressive symptoms [mean = 8.72; SD = 6.72]. EDI-3 subscales indicated a generalized high Global risk index [EDRC mean = 22.5; SD = 7.9] and Body Dissatisfaction [BD mean = 11.70; SD = 8.84], a moderate Drive for thinness [DT mean = 7.66; SD = 7.89] and a low Bulimia risks [B mean = 3.09; SD = 3.37]. Results are summarized in Table 1.

Table 1. Psychological assessment scores

	N	Min	Max	Mean	SD
Age	54	19.0	48.0	25.74	6.38
BMI	54	17.26	28.71	21.012	2.24
BDI_tot	54	.0	37.0	8.72	6.72
BDI_cogn	54	.0	25.0	5.25	4.91
BDI_som	54	.0	12.0	3.46	2.42
STAI_T	54	25.0	64.0	42.63	9.81
STAI_S	54	21.0	62.0	34.18	7.77
BAI	54	.0	34.0	10.88	7.55
EDI_DT	54	.0	27.0	7.66	7.89
EDI_B	54	.0	13.0	3.09	3.37
EDI_BD	54	.0	32.0	11.70	8.84
EDI_EDRC	54	.0	67.0	22.46	17.13

BMI: body mass index, BDI_tot: BDI total score, BDI_cogn: BDI cognitive factors, BDI_som: BDI somatic factors, STAI_T: STAI trait anxiety, STAI_s: STAI state anxiety, BAI: Beck Anxiety Inventory, EDI_DT: EDI Drive for thinness subscale, EDI_B: Bulimia subscale, EDI_BD: Body Dissatisfaction subscale. EDI_EDRC: EDI Global Risk Index (EDRC).

Several significant correlations were found between psychometric variables. Results are summarized in Table 2.

Table 2. Correlation analyses for psychometric variables

	Age	BMI	BDI_tot	BDI_cogn	BDI_som	STAI_T	STAI_S	BAI	EDI_DT	EDI_B	EDI_BD
Age	1										
BMI	.463**	1									
BDI_tot	−.013	.083	1								
BDI_cogn	−.027	.074	.961**	1							
BDI_som	.019	.079	.828**	.641**	1						
STAI_T	−.167	.137	.495**	.486**	.390**	1					
STAI_S	.185	.303*	.375**	.385**	.260	.337*	1				
BAI	−.312*	−.032	.360**	.343*	.306*	.361**	.084	1			
EDI_DT	−.122	.141	.165	.172	.109	.295*	−.037	.193	1		
EDI_B	.057	.353**	.497**	.435**	.497**	.553**	.339*	.249	.387**	1	
EDI_BD	−.069	.164	.341*	.347*	.244	.483**	.214	.289*	.615**	.589**	1
EDI_EDRC	−.081	.219	.350**	.344*	.274*	.494**	.160	.287*	.855**	.680**	.916**

**Correlation is significant at level 0.01 (two tails). *Correlation is significant at level 0.05 (two tails). BMI: body mass index, BDI_tot: BDI total score, BDI_cogn: BDI cognitive factors, BDI_som: BDI somatic factors, STAI_T: STAI trait anxiety, STAI_s: STAI state anxiety, BAI: Beck Anxiety Inventory, EDI_DT: EDI Drive for thinness subscale, EDI_B: Bulimia subscale, EDI_BD: Body Dissatisfaction subscale. EDI_EDRC: EDI Global Risk Index (EDRC).

3.2 Interoceptive Accuracy, Metacognitive Awareness, Sensibility

Total sample interoceptive accuracy mean score was 0.54 [SD = 0.22] while interoceptive metacognitive awareness mean score was 43.68 [SD = 20.88]. M.A.I.A. scores are reported in Table 3 and correlations in Table 4.

Table 3. MAIA subscales scores

Scale	Min	Max	Mean	SD
NO	1.00	4.75	3.07	.91
ND	1.33	4.00	2.39	.66
NW	.00	5.0	2.50	1.25
AR	.43	4.57	2.69	.97
EA	1.0	4.8	3.17	.88
SR	.00	5.00	2.37	1.18
BL	.00	4.66	2.49	1.17
TR	.33	5.00	3.16	1.16

NO: Noticing subscale, ND: Not Distracting subscale, NW: Not Worrying subscale, AR: Attention Regulation subscale, EA: Emotional Awareness subscale, SR: Self-Regulation subscale, BL: Body Listening subscale, TR: Trusting subscale.

Table 4. Correlation analyses for interoceptive variables

	IAc	IAw	MAIA_NO	MAIA_ND	MAIA_NW	MAIA_AR	MAIA_EA	MAIA_SR	MAIA_BL
IAc	1								
IAw	.406**	1							
MAIA_NO	.152	.371**	1						
MAIA_ND	.202	.272*	.186	1					
MAIA_NW	−.137	.176	.154	−.240	1				
MAIA_AR	.248	.453**	.579**	.137	.348**	1			
MAIA_EA	.165	.591**	.534**	.252	.280*	.426**	1		
MAIA_SR	.225	.463**	.550**	.086	.382**	.580**	.583**	1	
MAIA_BL	.134	.563**	.501**	.133	.214	.674**	.575**	.641**	1
MAIA_TR	.244	.372**	.419**	.163	.385**	.527**	.500**	.600**	.555**

**Correlation is significant at level 0.01 (two tails). *Correlation is significant at level 0.05 (two tails). IAc: interoceptive accuracy, IAw: interoceptive metacognitive awareness, MAIA_NO: Noticing subscale, MAIA_ND: Not Distracting subscale, MAIA_NW: Not Worrying subscale, MAIA_AR: Attention Regulation subscale, MAIA_EA: Emotional Awareness subscale, MAIA_SR: Self-Regulation subscale, MAIA_BL: Body Listening subscale, MAIA_TR: Trusting subscale.

IAc positively correlated with IAw [r = .406; p = .002], and IAw positively correlated with several MAIA subscales including Noticing [r = .371; p = .006], Not Distracting [r = .272; p = .046], Attention Regulation [r = .453; p = .001], Emotional Awareness [r = .591; p < .001], Self-Regulation [r = .463; p < .001], Body Listening [r = .563; p < .001], and Trusting [r = .372; p = .006].

3.3 Relationship Between Measures and Gender

Several significant correlations were found between MAIA subscales and different psychometric variables [Table 5].

Table 5. Correlation analyses between MAIA subscales and psychometric variables

	BDI_tot	BDI_cogn	BDI_som	STAI_T	STAI_S	BAI	EDI_DT	EDI_B	EDI_BD	EDI_EDRC
MAIA_NO	−.077	−.082	−.049	−.106	−.236	.257	−.170	−.237	−.292*	−.276*
MAIA_ND	−.237	−.218	−.216	−.228	−.167	−.098	−.009	−.195	−.095	−.092
MAIA_NW	−.086	−.125	.016	−.187	−.116	−.173	−.139	.011	−.182	−.156
MAIA_AR	−.015	−.049	.058	−.123	−.267	.095	−.191	−.173	−.492**	−.376**
MAIA_EA	−.058	−.030	−.100	−.241	−.281*	.149	.053	−.231	−.255	−.153
MAIA_SR	−.290*	−.302*	−.193	−.496**	−.447**	−.072	−.161	−.448**	−.421**	−.380**
MAIA_BL	−.075	−.047	−.114	−.278*	−.312*	.054	−.155	−.188	−.368**	−.298*
MAIA_TR	−.050	−.076	.016	−.550**	−.230	−.019	−.405**	−.279*	−.603**	−.552**

**Correlation is significant at level 0.01 (two tails). *Correlation is significant at level 0.05 (two tails). MAIA_NO: Noticing subscale, MAIA_ND: Not Distracting subscale, MAIA_NW: Not Worrying subscale, MAIA_AR: Attention Regulation subscale, MAIA_EA: Emotional Awareness subscale, MAIA_SR: Self-Regulation subscale, MAIA_BL: Body Listening subscale, MAIA_TR: Trusting subscale. BMI: body mass index, BDI_tot: BDI total score, BDI_cogn: BDI cognitive factors, BDI_som: BDI somatic factors, STAI_T: STAI trait anxiety, STAI_s: STAI state anxiety, BAI: Beck Anxiety Inventory, EDI_DT: EDI Drive for thinness subscale, EDI_B: Bulimia subscale, EDI_BD: Body Dissatisfaction subscale. EDI_EDRC: EDI Global Risk Index (EDRC).

Correlations between interoceptive variables remained significant when splitting for gender, nonetheless some interesting results emerged in the female group [Fig. 1] that showed a negative correlation between IAw and BMI [r = −.297; p = .050] and a negative correlation between IAc and state anxiety (STAI) [r = −.319; p = .035].

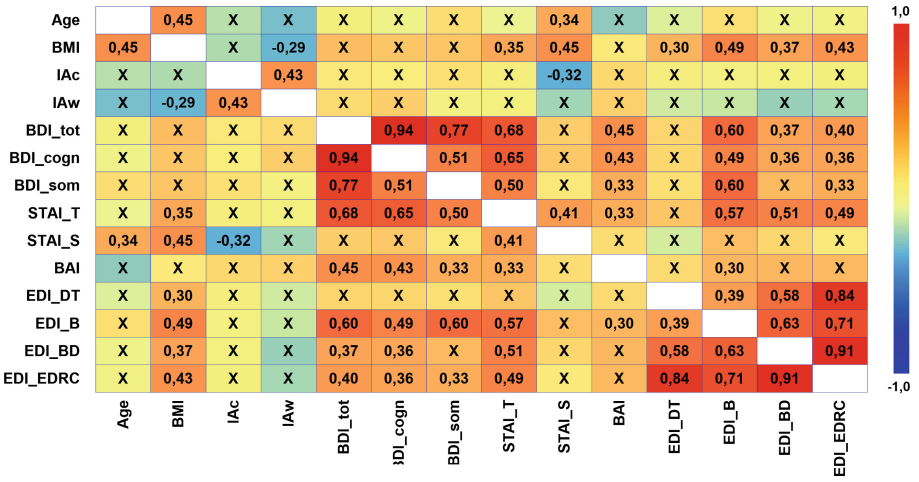

Fig. 1. Correlation table for the female subsample. If r value is present, correlation is significant at level 0.05 (two tails). BMI: body mass index, IAc: interoceptive accuracy, IAw: interoceptive metacognitive awareness, BDI_tot: BDI total score, BDI_cogn: BDI cognitive factors, BDI_som: BDI somatic factors, STAI_T: STAI trait anxiety, STAI_s: STAI state anxiety, BAI: Beck Anxiety Inventory, EDI_DT: EDI Drive for thinness subscale, EDI_B: Bulimia subscale, EDI_BD: Body Dissatisfaction subscale. EDI_EDRC: EDI Global Risk Index (EDRC).

Correlation between IAc and IAw remained strong [r = .433; p = .003]. Conversely, male subjects exhibited different interoceptive patterns whereas strong significant positive correlations were found between IAw and BMI [r = .680; p = .030] and IAw and Age [r = .712; p = .021] in an opposite direction than female subjects. Moreover, in male sample no significant correlation was found between IAc and IAw [r = .478; p = .162] while significant negative correlations were found for IAw and somatic symptoms of depression [r = −.678; p = .031] and IAw and trait anxiety on both STAI [r = −.739; p = .015] and BAI [r = −.716; p = .020] (Fig. 2).

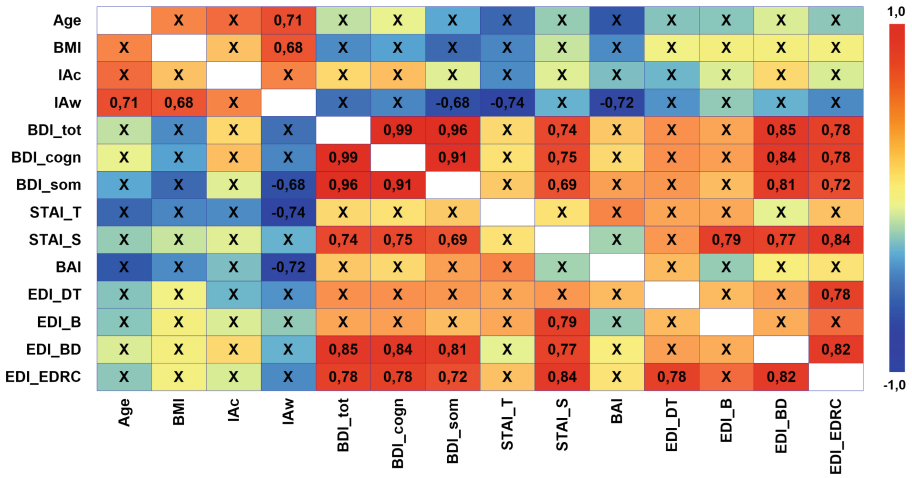

Fig. 2. Correlation table for the male subsample. If r value is present, correlation is significant at level 0.05 (two tails). BMI: body mass index, IAc: interoceptive accuracy, IAw: interoceptive metacognitive awareness, BDI_tot: BDI total score, BDI_cogn: BDI cognitive factors, BDI_som: BDI somatic factors, STAI_T: STAI trait anxiety, STAI_s: STAI state anxiety, BAI: Beck Anxiety Inventory, EDI_DT: EDI Drive for thinness subscale, EDI_B: Bulimia subscale, EDI_BD: Body Dissatisfaction subscale. EDI_EDRC: EDI Global Risk Index (EDRC).

4 Discussion

The study analyzed psychological correlates of interoceptive perception in healthy sample population. As hypothesized a significant positive relationship was found between interoceptive accuracy and metacognitive awareness. Nonetheless, it is worth noticing that this relationship was weak, suggesting that the two constructs have a high degree of separation. Across the whole sample, interoceptive accuracy acted as a partially independent factor with weak connections with psychological correlates measured through self-reported instruments.

Albeit interoceptive accuracy showed weak connections with psychological correlates, metacognitive awareness appeared to be strongly related to psychological factors and to MAIA subscales. As a matter of fact, interoceptive sensibility subscales showed strong positive relationships with metacognitive awareness, suggesting a possible congruency of constructs, especially for MAIA Emotional Awareness subscale. From this perspective, metacognitive awareness showed a high sensitivity to psychological correlates of emotions. Negative relationships were found with anxiety and depressive symptoms, confirming respectively previous results for accuracy and supporting previous evidence from literature [10, 11, 18].

Interoceptive sensitivity measured via MAIA subscales appeared strongly connected to psychological correlates of emotions. Specifically, Self-Regulation (SR) scale, whose score indicates subject's ability to regulate distress by attention to body sensations, was the most sensitive to emotion and mood alterations due to strong negative relationships with all anxiety and depression measures.

Male and female subjects exhibited different interoceptive patterns and, quite interesting, these patterns appeared related to body perception cognitive processes, rather than gender specificity. Age and BMI acted in an opposite way related to gender, with a positive relationship in males regarding interoceptive metacognitive processing, and a negative relationship in females. A possible explanation for such radical difference can be found analyzing in detail the relationships between interoceptive variables, BMI, and EDI-3 risk subscales within the female subgroup. In female subjects, the BMI was positive related with all the EDI risk subscales and negatively related with metacognitive awareness, indicating that female subjects experience negative perceptions in response to positive variations of their weight. This pattern was not present in male subjects whereas BMI did not correlate with EDI-3 risk subscales and – moreover – it had a positive relationship with awareness. It therefore possible that differences in interoceptive patterns within the female subsample were due to mechanisms connected to body dissatisfaction and body perception alterations, related to eating disorder risks as assessed by EDI subscales.

5 Conclusion and Technological Applications

Interoception represents an emerging field of study in the consciousness domain and understand how perception of bodily inputs works can lead to a brand new perspective regarding several pathological and non-pathological conditions. From this point of view, interoceptive technological devices able to stimulate and manipulate the perception of inner bodily sensations may provide new innovative solutions with several applications in clinical and non-clinical fields. Such interoceptive technological devices have already been developed [30, 31] and used for assessment purposes [13, 32]; nonetheless they can also be used to achieve different goals beyond psychological and psychopathological assessment. This kind of technology can be used in non-pathological contests to improve embodiment and body ownership [33], and it also can be used to enhance human well-being through manipulation of the parasympathetic and sympathetic autonomic system [30, 31]. Merging interoceptive stimulation devices with other technologies such as virtual reality (VR), vibration multisensory systems, and "positive technologies" [2, 3, 34, 35] can therefore offer new forms of treatment for clinical and subclinical conditions [9, 36, 37]. As a matter of fact,, considering the relation between interoceptive perception and well-being [2], the understanding of interoceptive integration processes can lead to new form of interventions that can show effectiveness in a broad range of clinical and non-clinical alterations.

6 Conflict of Interest Statement

The authors had no conflict of interest.

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