

Connected minds in disconnected bodies: Exploring the role of interoceptive sensibility and alexithymia in problematic use of the internet

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ABSTRACT

Introduction: The ever-increasing prominence of the internet and digital technology in our society requires a deeper examination of how these developments alter perception of our bodies and emotions. One such consequence is the emergence of Problematic Use of the Internet (PUI) - an array of compulsive or addictive behaviors mediated by the web that detrimentally affect an individual's functioning. This suggests that some people may be shifting their consciousness from the physical realm to the digital world. The objective of this study was to investigate how shortcomings in interoception (the sensibility to bodily signals) and alexithymia (an inability to identify and express emotions) might contribute to PUI.

Methods: The Internet Addiction Test (IAT), the Toronto Alexithymia Scale (TAS-20), and the Multidimensional Assessment of Interoceptive Awareness (MAIA) were used to assess a sample of 1076 adolescents and young adults aged between 16 and 26 years via an online survey. Data analysis was based on *t*-test, correlations and multivariate regression.

Results: 26.8% ($n = 288$) of participants met the criteria for moderate PUI. Individuals with PUI displayed higher levels of alexithymia ($p < 0.001$) and diminished abilities in certain aspects of interoceptive sensibility, including placing trust in their own bodily signals ($p = 0.006$), not responding excessively to uncomfortable sensations with worry ($p < 0.001$), and not denying them ($p = 0.006$). Multivariate modelling revealed associations between PUI and the following factors: having a boyfriend/girlfriend (aOR = 5.70), substance use (aOR = 1.78), difficulty in identifying feelings (aOR = 1.09), externally oriented thinking (aOR = 1.05), low disposition in perceiving body sensations (aOR = 0.25), tendency to become distracted (aOR = 0.82) or excessively worried (aOR = 0.11) in the face of pain. Furthermore, the analysis indicated how these aspects of body perception may be interrelated, either enhancing or reducing the risk of PUI when examined individually, collectively, or in combination.

Conclusions: This study underlines the potential connection between difficulties in the mind-body interaction and the development of PUI. It suggests a bidirectional relationship between excessive digital device use and distorted bodily interoceptive processes in PUI, reinforcing the notion that individuals struggling with emotion identification and expression may be more prone to excessive internet usage. To further comprehend the relevance of these constructs in PUI, it is necessary to conduct more targeted investigations and longitudinal studies.

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1. Introduction

1.1. Diagnostic characteristics of problematic use of the internet

Problematic Use of the Internet (PUI) is an umbrella term encompassing various maladaptive behaviors associated with internet use. These behaviors include but are not limited to online gambling, pornography consumption, excessive shopping, video gaming, email checking, messaging, social media overuse, and streaming [1]. The increasing prevalence of internet use and the consequent rise in PUI cases have led the World Health Organization to identify PUI as a global public health issue [2]. Various pathological behaviors that can manifest online, such as gambling disorder, compulsive sexual behavior disorder, compulsive-buying shopping disorder, and gaming disorder, have been recognized as distinct entities in the International Classification of Diseases, 11th edition (ICD-11) [3,4,5]. Additionally, in 2013, Internet Gaming Disorder (IGD) was listed in an appendix of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), highlighting the need for further investigation into this subject [6].

The prevalence of PUI varies widely in the general population, ranging from 2.6% to 25.4% [7,8,9,10], with males [9] and younger individuals [11] being more predisposed. The highest prevalence rates are found in the Middle East, while Northern and Western Europe demonstrate the lowest [7,8]. This variation can be attributed to factors such as the diversity of the populations studied, the array of psychometric tools utilized for assessment, and the different operational definitions of PUI adopted in these studies [12].

1.2. Phenomenology of problematic use of the internet

The classification of PUI has been a topic of ongoing debate: should it be viewed as an addictive disorder, or does it more closely align with obsessive-compulsive spectrum disorders or impulse-control disorders [1,13]? Supporting its classification as an addictive disorder, gaming disorder has been designated an 'Addictive Behavior' in the ICD-11. Furthermore, certain PUI behaviors exhibit addiction-like characteristics such as impaired control, craving, functional impairment, and persistence despite negative consequences [14,15,16,17,18,19]. Neuroimaging studies have also identified structural and functional paradigms that mirror those found in addiction. Similar to substance addictions, brain regions associated with reward, craving, and emotions have shown increased activation during internet use and cue exposure, especially in the context of problematic video game use. These regions encompass critical areas within the field of addiction neuroscience, such as the nucleus accumbens, amygdala, prefrontal cortex, and insula [20].

However, the alternative perspective suggests that some internet activities, such as cyberchondria, repetitive email checking, and excessive video streaming or shopping, exhibit compulsive elements. These include intolerance of uncertainty, difficulty in decision-making, the need for reassurance, and rigidity [21,22,23,24,25]. Moreover, impulsivity and emotional dysregulation have been identified as risk factors for developing PUI, highlighting its potential alignment with impulse-control disorders [26,27,28]. In this context, it has been demonstrated that interoceptive processes play a mediating role in the presence of impulse control difficulties. Impaired interoception may predispose individuals to impulsive behaviors, a hypothesis that has also been posited in the context of certain problematic internet-mediated behaviors [29,30].

1.3. Interoception in addictive behaviors

Interoception, the ability to perceive and interpret bodily changes prompted by external or internal stimuli, informs our emotional and behavioral responses [31,32,33]. This concept has been recently delineated into interoceptive accuracy (the objective recognition of bodily changes, such as heartbeat), interoceptive sensibility (the subjective

experience and trust in these bodily modifications, assessed via self-report questionnaires), and interoceptive awareness (the alignment of interoceptive accuracy and sensibility) [34,35].

Interoception plays a pivotal role in addiction via three key pathways: the subjective pleasure experienced from substance use; the conscious recollection of this pleasurable experience; and decision-making, involving the evaluation of negative consequences versus the pleasure derived from substance use [36]. In this final pathway, impulsivity plays a crucial role. Individuals who exhibit greater accuracy in anticipating their interoceptive state have demonstrated enhanced ability to manage cravings and exhibit elevated levels of trait self-control [29].

These patterns, modulated by interoceptive processes, encompass diverse facets of sensing, interpreting, and integrating information, including attention, detection, discrimination, accuracy, insight, sensibility, and self-report [37]. The insular cortex processes this proficiency, serving as a central hub for interoception [38,39,40,41,42]. For instance, smoking triggers sensory effects in the airways, which the insula identifies as pleasurable and memorizes [43]. The absence of these stored somatic signals induces a physical craving sensation in the insular cortex. Additionally, the lack of the desired substance can lead to an intensified urge, enhancing the salience of the somatic marker representation [44,36]. These processes are associated with the insula's functional connections with the impulsivity network (including the ventral striatum, amygdala, and nucleus accumbens) and the reflection-oriented system (comprising the dorsolateral and ventromedial prefrontal cortices).

However, the role of interoceptive processes in addiction remains under discussion [44]. Early studies demonstrated that brain lesions disrupting the insular cortex can halt addictive behaviors, implying a crucial role for the insula in maintaining such behaviors [45]. Conversely, recent functional neuroimaging studies have revealed reduced insular cortex activity in addiction patients during decision-making tasks [46], while structural neuroimaging studies have shown a diminished gray matter volume of the insular cortex in substance use patients [47].

1.4. Interoception and alexithymia

Deficiencies in interoceptive sensibility have been associated with alexithymia, a multifaceted psychological construct deeply intertwined with affective dysregulation [48]. Alexithymia encompasses (i) challenges in understanding and expressing emotions, (ii) difficulties in distinguishing emotions from physical sensations, (iii) an externally oriented cognitive style marked by a limited capacity for self-reflection, and (iv) restricted imagination [49]. A negative correlation between alexithymia and interoceptive sensibility has been observed, particularly among patients, suggesting that as alexithymia increases, interoceptive accuracy tends to decrease in both healthy and clinical populations [50,48].

Alexithymic traits have been positively linked to PUI, suggesting a pattern of excessive internet use as a mechanism for emotion regulation and addressing unsatisfied social needs [51,52,53]. In line with this, a growing body of literature postulates that alexithymia plays a pivotal role in the evolution of addictive behaviors in general [54,55].

1.5. Aims of the present study

Interoceptive sensibility and alexithymia have been associated with addictive behaviors and are pivotal in influencing the relationship between an individual and their own body, in the case of the former, and the relationship between an individual and others, in the case of the latter. Therefore, we hypothesize that there is a dynamic interplay between these relationships, which may become disrupted in the context of excessive internet use and an overreliance on internet-mediated interactions.

Considering the limited availability of evidence in this regard, this study sets out to (i) compare individuals at risk of PUI with those not at risk in terms of demographic characteristics, interoceptive sensibility, and alexithymic traits; (ii) construct a multivariable model to investigate variables associated with PUI. The study population was comprised of adolescents and young adults, a demographic notably at a higher risk of developing internet-related addictive behaviors.

2. Materials and methods

2.1. Design

This is an observational, cross-sectional study.

2.2. Participants and procedure

An online survey targeted at individuals aged 16–26 years was developed using *Google Forms*. The decision to adopt this specific 10-year age range was motivated by the aim to specifically focus on individuals in the developmental stages of adolescence and young adulthood, given that this particular age group exhibits a higher prevalence of PUI. The survey was administered in Italian and distributed to Italian participants, with no specific reference to PUI in the heading or title. It was disseminated across numerous high schools in central and southern Italy, with additional exposure gained through online advertisements and social media. The sole inclusion criterion was an age range of 16 to 26 years, while the only exclusion criterion was the presence of a major psychiatric diagnosis (i.e., mood disorders, anxiety disorders, psychoses, or substance use disorders) currently being treated with psychopharmacological medication. The recruitment period spanned from April 10th, 2020 to November 30th, 2020.

2.3. Measures

The survey was divided into two sections. In the first, participants provided socio-demographic information (age, sex, marital status, job status, education), and disclosed details about alcohol and substance use, smoking habits, and family psychiatric history. In the second section, participants completed self-report questionnaires including the Internet Addiction Test (IAT), the Toronto Alexithymia Scale (TAS-20) and the Multidimensional Assessment of Interoceptive Awareness (MAIA).

The IAT is a 20-item assessment exploring the influence of internet use on participants' family, social, and work environments. Utilizing a five-point scale, total scores can range from 20 to 100, with 20–49 indicating mild internet use, 50–79 suggesting moderate PUI, and 80–100 signaling severe PUI [56,57,58,59,60]. The risk for PUI was established in presence of IAT scoring 50 or above [23,13]. The instrument displayed good internal consistency in this sample, with a Cronbach's alpha of 0.894.

The TAS-20 is a 20-item self-report tool evaluating alexithymic traits on a five-point scale. Total scores can range from 20 to 100: scores under 51 indicate non-alexithymia, 51–60 suggest borderline alexithymia, and over 60 denote alexithymia [61]. This instrument also features three internal subscales: difficulty describing feelings, difficulty identifying feelings, and externally-oriented thinking [62,63]. In this sample, the TAS-20 showed good internal consistency, with a Cronbach's alpha of 0.825.

Finally, the MAIA is a 32-item self-report test, evaluated on a 6-point scale (0–5), that assesses interoceptive sensibility [35]. This instrument explores 8 independent state-traits: noticing (i.e., awareness of uncomfortable, comfortable, and neutral body sensations), not-distracting (i.e., tendency not to ignore or distract oneself from feelings of pain or discomfort), not-worrying (i.e., tendency not to worry or experience emotional distress with sensations of pain or discomfort), attention regulation (i.e., ability to sustain and control attention to body

sensations), emotional awareness (i.e., awareness of the connection between body sensations and emotional states), self-regulation (i.e., ability to regulate distress by attention to body sensations), body listening (i.e., active listening to the body for insight), and trusting (i.e., experience of one's body as safe and trustworthy) [64,65,66]. The MAIA demonstrated good internal consistency in this sample, with a Cronbach's alpha of 0.895.

2.4. Statistical analysis

We performed descriptive statistics, using means and standard deviations for continuous variables, and proportions for dichotomous and categorical variables. To compare participants with and without PUI in a univariable analysis, we utilized the independent sample *t*-test and chi-square test, as appropriate. Subsequently, we conducted a multivariable logistic regression to identify PUI predictors, using an IAT score of ≥ 50 as a cut-off. Expert opinions guided the selection of variables for the model. We checked for multicollinearity using a variance inflation factor threshold of 5 and tested interaction terms involving subscales with a *p*-value cut-off of 0.05. We evaluated the model's goodness of fit with the Hosmer and Lemeshow test, and calculated adjusted odds ratios (aORs) and 95% confidence intervals (CIs).

All statistical analysis was performed using Stata (StataCorp LLC, 4905 Lakeway Drive, College Station, TX 322, USA), version 17.0. A two-sided *p*-value < 0.05 was considered statistically significant.

2.5. Ethics

The study was approved on March 27, 2020 by the Institutional Review Board of the Department of Neuroscience, Imaging and Clinical Sciences, University "G. d'Annunzio", Chieti, Italy (Prot. 042/2020) and fully complied the guidelines of the Ethical Committee.

Participants were asked to participate without financial incentives and were required to read and consent to an information sheet. For participants under the legal age, parental consent was requested. We ensured full anonymity throughout the study process. The study procedures adhered to the guidelines established by the Declaration of Helsinki [67].

3. Results

3.1. Socio-demographic characteristics and problematic use of the internet

The final sample consisted of 1076 participants who completed all psychometric instruments. The majority were female (M/F: 378/698, 64.9% female), with an average age of 20.3 years (range 16–26 years). The average IAT score was 42.9 (range 20–100). 26.8% ($n = 288$) of participants met the criteria for moderate PUI (IAT ≥ 50). The average IAT score for the PUI-risk group was 59, compared to 37 for the group not at risk. The PUI-risk group tended to be younger ($t = 3.426$; $p = 0.001$), with a different marital status ($t = 12.785$; $p = 0.003$), smokers ($t = 4.972$; $p = 0.026$), and substance users ($t = 7.689$; $p = 0.006$). Detailed characteristics of the sample and comparisons between groups are provided in [Table 1](#) and in [Fig. 1](#).

3.2. Interoceptive sensibility, alexithymia, and problematic use of the internet

Participants at risk for PUI scored higher on the three internal constructs of the TAS-20: difficulty in describing feelings ($t = -7.234$; $p < 0.001$), difficulty identifying feelings ($t = -11.062$; $p < 0.001$) and externally oriented thinking ($t = -3.899$; $p < 0.001$).

Those who experienced PUI scored lower on internal dimension related to perceiving one's body as dependable and trustworthy ($t = 2.742$; $p = 0.006$), and showed an increased inclination to be easily distracted ($t = 2.728$; $p = 0.006$) or anxious ($t = 5.979$; $p < 0.001$) when

Table 1
Socio-demographic and PUI characteristics in the whole sample (n = 1076).

	Non-PUI (n = 788)		PUI (n = 288)		Total (n = 1076)		Statistics (t/Chi-Square)	p-value
Age, years	20.55	3.38	19.75	3.31	20.33	3.37	3.426	0.001
Sex, male, n (%)	269	34.1	109	37.8	378	35.1	1.095	0.295
Education, n (%)							5.043	0.163
Below high school	212	26.9	81	28.1	293	27.2		
High school diploma	390	49.5	153	53.1	543	50.5		
University degree or higher	178	22.6	53	18.4	231	21.5		
Job status, n (%)							2.781	0.427
Student	624	79.2	239	83	863	80.2		
Fulltime job	80	10.2	20	6.9	100	9.3		
Part-time job	33	4.2	11	3.8	44	15.3		
Unemployed	46	5.8	17	7.3	63	5.9		
Marital status, n (%)							12.785	0.003
Single	610	77.4	220	76.4	830	77.1		
Married/in a stable relation	54	6.9	8	2.8	62	5.8		
Divorced	0	0	1	0.3	1	0.1		
With a boyfriend/girlfriend	118	15	59	20.5	177	16.4		
Smoking habit, n (%)	200	25.4	93	32.3	293	27.2	4.972	0.026
Alcohol use, n (%)	446	56.6	155	53.8	601	55.9	0.805	0.370
Substance use, n (%)	54	6.9	35	12.2	89	8.3	7.689	0.006
Psychiatric family history, n (%)	70	8.9	27	9.4	97	9	0.054	0.817

Data are reported as mean ± SD or as n and percentage per class. Statistics: Student's t-test and Chi Square test, as appropriate.

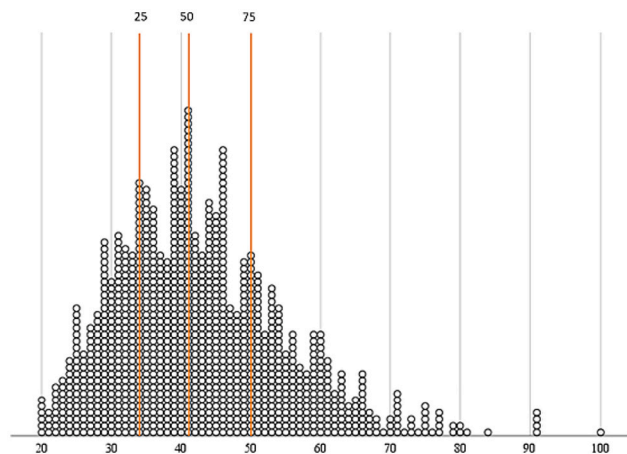


Fig. 1. Distribution of participants based on their IAT scores, along with corresponding percentiles.

confronted with unpleasant sensations. Detailed data are presented in [Table 2](#).

3.3. Multivariable logistic regression

The logistic regression revealed that being in a relationship with a

Table 2
Interoceptive sensibility and alexithymia measures in the whole sample (n = 1076).

	Non-PUI (n = 788)		PUI (n = 288)		Total (n = 1076)		Statistics (t)	p
MAIA noticing	3.34	0.96	3.37	0.89	3.35	0.94	-0.348	0.728
MAIA not-distracting	2.33	0.95	2.15	0.99	2.28	0.96	2.728	0.006
MAIA not-worrying	2.32	1.02	1.91	0.94	2.21	1.02	5.979	<0.001
MAIA attention regulation	3.02	0.92	2.90	0.86	2.98	0.91	1.826	0.068
MAIA emotional awareness	3.25	1.12	3.46	1.07	3.30	1.11	-2.732	0.006
MAIA self-regulation	3.08	1.06	3.06	1.00	3.07	1.05	0.332	0.740
MAIA body listening	2.60	1.25	2.65	1.22	2.61	1.24	-0.566	0.572
MAIA trusting	3.39	1.20	3.16	1.13	3.33	1.19	2.742	0.006
TAS-20 total	44.49	10.90	52.56	11.57	46.65	11.64	-10.575	<0.001
TAS-20 difficult describing feelings	12.60	4.49	14.85	4.53	13.20	4.61	-7.234	<0.001
TAS-20 difficult identifying feelings	16.93	6.79	22.28	7.62	18.36	7.41	-11.062	<0.001
TAS-20 externally oriented thinking	17.31	4.63	18.56	4.71	17.65	4.68	-3.899	<0.001

MAIA: Multidimensional Assessment for Interoceptive Awareness; TAS-20: Toronto Alexithymia Scale. Data are reported as mean ± SD. Statistics: Student's t-test.

boyfriend/girlfriend (aOR = 5.70; 95%CI: 1.45–22.49) and substance use (aOR = 1.78; 95%CI: 1.01–3.13) were both linked to PUI. Higher scores on two of the TAS-20 subscales, “difficulty identifying feelings” (aOR = 1.09; 95%CI: 1.06–1.12) and “externally-oriented thinking” (aOR = 1.05; 95%CI: 1.01–1.09), were found to be associated with PUI. Conversely, low disposition in perceiving body sensations, (noticing, aOR: 0.24; 95%CI: 0.09–0.70), trend toward a dysfunctional emotional response to negative body signals (not-distracting, aOR: 0.82; 95%CI: 0.69–0.96) and toward an excessive worry about them (not-worrying, aOR: 0.11; 95%CI: 0.02–0.60) were associated with PUI. The model also highlighted the interaction between certain variables. It suggested that the concurrent presence of higher scores on the MAIA noticing and MAIA not-worrying subscales, as well as on the MAIA noticing and MAIA trusting subscales, were linked to a higher risk for PUI. However, intriguingly, having higher scores on all three subscales seemed to somewhat restore the low odds of PUI (aOR = 0.85; 95%CI: 0.74–0.98). For further details refer to [Table 3](#).

4. Discussion

The present study supports the theory of an imbalance in mind-body interactions among individuals with PUI. We investigated the implications of bodily interoceptive sensibility and alexithymia in a group of adolescents and young adults from the general population who are at risk of PUI. The findings revealed that individuals with PUI exhibited heightened alexithymic characteristics and reduced interoceptive capabilities in certain areas. The logistic regression analysis substantiated

Table 3
Logistic regression model.

	Adjusted Odds ratio	p	[95% conf. interval]	
Age, years	1.01	0.734	0.95	1.07
Sex, male, n (%)	0.89	0.505	0.64	1.25
Marital status				
Married/in a stable relation	0.63	0.741	0.04	9.72
With a boyfriend/girlfriend	5.70	0.013	1.45	22.49
Job status				
Fulltime job	0.95	0.878	0.50	1.81
Part-time job	1.03	0.940	0.46	2.32
Unemployed	1.19	0.615	0.61	2.30
Psychiatric family history, yes	0.26	0.068	0.06	1.11
Substance use, yes	1.78	0.044	1.01	3.13
Smoking habit, yes	1.19	0.372	0.81	1.74
Alcohol use, yes	0.78	0.162	0.58	1.09
MAIA noticing	0.24	0.009	0.09	0.70
MAIA not-distracting	0.82	0.016	0.69	0.96
MAIA not-worrying	0.11	0.010	0.02	0.60
MAIA attention regulation	0.93	0.555	0.74	1.17
MAIA emotional awareness	0.96	0.647	0.80	1.15
MAIA self-regulation	1.03	0.765	0.84	1.28
MAIA body listening	1.03	0.698	0.87	1.22
MAIA trusting	0.46	0.167	0.15	1.38
TAS-20 difficult describing feelings	1.03	0.187	0.99	1.07
TAS-20 difficult identifying feelings	1.09	<0.001	1.06	1.12
TAS-20 externally oriented thinking	1.05	0.008	1.01	1.09
Marital status * MAIA self-regulation				
Married/in a stable relation	0.82	0.659	0.32	1.99
With a boyfriend/girlfriend	0.61	0.023	0.40	0.93
Psychiatric family history, yes * MAIA body listening				
MAIA noticing * MAIA not-worrying	2.10	0.003	1.29	3.41
MAIA noticing * MAIA trusting	1.40	0.032	1.03	1.90
MAIA not-worrying * MAIA trusting	1.43	0.166	0.86	2.35
MAIA noticing * MAIA not-worrying * MAIA trusting	0.85	0.021	0.74	0.98
Constant	2.21	0.700	0.04	124.22

the significant correlation between PUI and a range of factors, such as being in a relationship with a boyfriend/girlfriend, higher substance use, greater difficulty in identifying feelings, externally-oriented thinking, a diminished disposition to perceive bodily sensations, a heightened tendency to deny and an excessive propensity to worry about negative bodily signals. Interestingly, the influence of dimensions of interoceptive sensibility on PUI varied when evaluated individually, as a pair or collectively. This suggests that while each of these variables associates independently to PUI, their interactions might also play a critical role in determining the severity and impact of the condition.

4.1. Prevalence rates of problematic use of the internet

Our study found a PUI prevalence rate of 26.8%, a substantial increase compared to most literature data on young Western populations. This higher prevalence could be attributed to the timing of our study's recruitment and testing phases, which coincided with the onset of the Covid-19 pandemic, a period characterized by strict public health measures limiting social interactions [68,69]. This social restriction might have amplified problematic online behaviors and addiction tendencies in general, a finding consistent with other studies indicating increased internet use during the pandemic breakdown [70,71,72,8]. Our results indicate that while PUI is highly prevalent, the severity among the studied sample is moderate, as suggested by a median IAT score of 59 among those at risk. Further underscoring this point, only 3.1% of these participants meet the criteria for severe PUI (IAT ≥ 80). Future research necessitates the incorporation of systematic, high-

quality methodologies to screen, diagnose and measure the severity of PUI [73].

Substance use was found to be more prevalent among individuals with PUI. This observation, which aligns with previous research [74,15], underscores the importance of considering comorbid substance use in the assessment of PUI and taking a comprehensive approach that addresses the potential common factors contributing to both conditions. Future research should further investigate the efficacy of interoception-based interventions, such as mindfulness-based cognitive therapy, for addressing PUI, particularly in light of their proven effectiveness in SUDs [75].

The association of PUI with being in a relationship with a boyfriend/girlfriend may appear counterintuitive. This association may be partly attributed to the fact that individuals with a boyfriend/girlfriend, compared to those who are married, tend to be younger in age, indirectly placing them at a higher risk of PUI. In general, according to existing literature, being in a relationship seems to offer protective effects against the risk of PUI.

4.2. Interoceptive sensibility, alexithymia, and problematic use of the internet

The positive association between alexithymia and PUI aligns with the hypothesis that individuals with difficulties in identifying and expressing their emotions might resort to internet use as a coping mechanism [51,76,52]. In these instances, individuals may resort to using the internet as a tool to streamline communication, effectively bypassing the complexities associated with physical presence, immediate proximity, and direct observation of others [77,78]. This suggests that the internet might serve as a safety mechanism for those who struggle with face-to-face interactions, offering a medium where communication can be managed and controlled more comfortably. Alternatively, the causal relationship between alexithymia and PUI might be interpreted from a different perspective. Excessive internet use could paradoxically strengthen difficulties in managing emotions in real-world social interactions. The lack of exposure to in-person emotional cues and responses might further exacerbate and perpetuate the underlying alexithymic condition.

Our findings also reveal a novel interplay between interoceptive sensibility skills and internet use, marking the first study of its kind examining this relationship among young adults and adolescents. The pattern of interoceptive abilities that emerges provides valuable insights into how individuals with PUI perceive and respond to internal bodily sensations, and how these responses might contribute to their over-reliance on the internet. Specifically, those identified with PUI appeared to demonstrate a diminished awareness of their own bodily sensations and struggled to differentiate between comfortable, uncomfortable, and neutral bodily sensations, suggesting an overall detachment or disconnection from their physical selves. This could potentially reduce their ability to regulate emotions or manage stress effectively, since bodily sensations often provide key signals to understand and respond to emotional states. The reduced interoceptive sensibility might also indicate difficulties in self-regulation, an ability that helps control impulsive behaviors. Moreover, individuals with PUI displayed a pronounced inclination to distract themselves from bodily sensations and failed to elicit appropriate affective responses in the face of unpleasant sensations, further underscoring a disconnection from their bodies and an avoidance of negative internal states. This could be seen as a maladaptive coping mechanism where instead of addressing discomfort, they resort to the internet as an escape or distraction.

Overall, our study unveiled complex dynamics between different facets of interoception - trusting bodily sensations, avoiding them, and recognizing them - which seem to reciprocally influence each other and the extent of internet use. The interplay between these elements of interoception suggests a nuanced and intricate connection between one's physiological self-awareness and the relationship with digital media. It

points to the importance of fostering healthier interoceptive practices and sensibility, which could prove instrumental in addressing and potentially mitigating PUI.

While the role of interoceptive processes has been comprehensively explored in the context of SUDs [79,80] and gambling disorder [81,82], its influence on PUI remains relatively uncharted. Notably, interoception has been investigated to some extent in IGD [83]. In an attempt to decipher IGD, [30] proposed a tripartite neurocognitive model that postulates the dependence of IGD on three principal systems: an impulsivity network driven by the ventral striatum, a reflection-oriented system guided by prefrontal mechanisms, and an interoceptive system that modulates the activity of the former two. Within this model, interoceptive processes are perceived as the bridge that registers and mediates both physical and psychological signals from the environment. Neuroimaging studies have indirectly confirmed the role of the insular cortex, which is a key component of the interoceptive system, in these processes. Particularly in deprivation conditions, activation of the insular cortex is associated with an enhanced activity in the reward system and decreased prefrontal activity, indicative of a reduced cognitive control [83]. Furthermore, a diminished functional connectivity between the insula and the executive cortices has been observed in individuals with IGD [84,85]. This insular activation has also been demonstrated in gamers when exposed to game-related stimuli, with the intensity of activation positively correlating with the self-reported urge to engage in gaming in response to visual cues [86]. This finding underlines the significant role of the interoceptive system in mediating impulsive and reflective behaviors in IGD, possibly extending its relevance to the broader context of PUI.

The emergence of PUI can be seen as the product of an intricate interplay of various factors. Among these, the inability to accurately comprehend and convey emotions, and a propensity for altered internal sensibilization to both positive and negative stimuli, are hypothesized to play a significant role. These factors align with Wei et al.'s tripartite model of IGD, suggesting that alterations in interoceptive sensibility might contribute to the manifestation of PUI in two major ways. Firstly, such alterations may heighten impulsive behaviors associated with PUI. This is in line with the understanding that interoception is key to modulating emotional and cognitive responses, including impulsive behaviors [29]. Secondly, alterations in interoceptive sensibility might disturb the internal sensation of satiety associated with the healthy use of the internet and exacerbate the discomfort associated with internet "withdrawal". This implies that interoception might play a crucial role in maintaining a balanced relationship with internet use and in mediating the withdrawal symptoms when access is denied.

However, there is also a plausible rationale for an association in the opposite direction. Excessive engagement with the internet could potentially create a feedback loop wherein the resultant positive reinforcement leads to alterations in interoceptive sensibility. The chronic nature of PUI might trigger an imbalance between heightened impulsivity and cognitive control. As the condition persists, it may induce changes in executive functions, inhibitory control, decision-making processes, and ultimately, the interoceptive insular system.

4.3. The "Digitalized Self"

In addition to the addiction-spectrum perspective, both interoceptive sensibility and alexithymia could also be conceptualized as expressions of a wider mind-body disconnect phenomenon. This suggests that individuals with PUI may struggle with fully engaging with their physical bodies and the emotional elements of their lived experiences. In this perspective, PUI might serve as a coping mechanism to navigate these difficulties, providing a pathway to device-mediated relationships or a means to bypass disturbing emotions [27]. Alternatively, deficits in bodily interoception may arise as an aftermath of persistent and intense immersion in digital environments [87]. Though our study is cross-sectional and limits the possibility of inferring causation, it

contributes significantly to the emerging concept of the "Digitalized Self", a growing construct conceived as an evolving component of self-identity, responding to the rapid and widespread digitalization of the world and interpersonal relationships [88]. It is postulated to induce neurocognitive and neurobiological modifications involved in numerous psychosocial and cultural processes. The "Digitalized Self" encompasses the potential for transformation in various dimensions of the self, including emotions, attitudes, and experiences, as our lives become more entwined with digital technology. This shift could potentially lead to changes in our fundamental experiences of space and time [89]. Along these lines, we could speculate the experiences of "bodily suspension" and "emotional blunting" as emerging elements of the "Digitalized Self". This evolving concept suggests a need for further understanding of how our growing digital interactions are impacting our sense of self. This could be particularly relevant in the context of PUI, where physical engagement and emotional richness may be suspended in favor of digital interactions. Such transformations may further reinforce the cycle of PUI, underscoring the importance of considering these aspects in therapeutic interventions.

4.4. Study limitations

While the current study provides important insights, several limitations should be acknowledged. Firstly, it is important to take into consideration that the study excluded participants who self-reported a psychiatric disorder. It also showed a predominance of females in the sample examined, possibly due to a greater trend of the female sex to take part in the survey. Those elements may have introduced a sampling bias, leading to a less accurate estimation of the actual prevalence and severity of PUI. We used IAT to assess the risk for PUI. Despite being among the most commonly utilized instruments with robust levels of validity and reliability, the IAT has limitations, such as its tendency to assess internet usage in its entirety - ranging from gaming, shopping, and online gambling, to social networking, viewing pornography, and streaming videos. Each of these activities may have unique correlations and impacts on users, and these nuances may have been overlooked in our generalized approach. Our study lacks information about factors that are known to be associated with alexithymia and potentially interoceptive sensibility—such as attachment styles, traumatic experiences, childhood maltreatment, and self-concept inadequacies [52], or impulsivity [90]. Another notable limitation is the predominance of participants at risk for PUI who presented with a moderate level of the disorder. Finally, it is important to note that the cross-sectional design of the study precludes the establishment of causal relationships between the variables.

5. Conclusions

The growing interest in PUI and its associated psychopathological correlates underscores the importance of advancing our understanding of these phenomena, as they remain relatively underexplored. An integral part of this endeavor lies in investigating the interrelationships between PUI and various psychological constructs, to better discern the complex underpinnings of this condition. Our study underscores the pivotal role that alexithymic traits and altered interoceptive sensibility play among young individuals at risk for PUI, offering speculative insights into the potential rationale behind this intricate interplay. There is a need for further research, particularly longitudinal studies, to explore in greater depth the implications of these observational findings within the realm of PUI, particularly among those grappling with a severe form of the disorder. If substantiated, such findings could potentially pave the way for the development of therapeutic interventions aimed at fostering body reconnection and enhancing emotion recognition capabilities.

Declaration of Competing Interest

Giovanni Martinotti has been a consultant and/or a speaker and/or has received research grants from Angelini, Doc Generici, Janssen-Cilag, Lundbeck, Otsuka, Pfizer, Servier, and Recordati.

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The remaining authors declare that the research was conducted in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

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