

RESEARCH ARTICLE

Sleep reactivity mediates the relationship between sensory-processing sensitivity and insomnia symptoms severity: A cross-sectional correlational study

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Abstract

Sensory-processing sensitivity (SPS) is a temperamental trait that describes individual differences in sensitivity to environmental stimuli. Previous studies have shown that highly sensitive individuals are more vulnerable to stress and to sleep-related difficulties. In light of this evidence, we hypothesized that SPS is associated with an increase in insomnia symptoms and that this correlation would be mediated by increased perceived stress and sleep reactivity. To test this hypothesis, we conducted a cross-sectional study on 358 adults who completed a survey that included self-report measures of sensitivity, perceived stress, sleep reactivity, and insomnia symptoms. Correlation analysis revealed that SPS was positively related to both stress-related and sleep-related variables. We then conducted a mediation analysis, which revealed that SPS was positively related to insomnia symptoms and that this relationship was fully mediated by sleep reactivity but not mediated at all by perceived stress. The current findings suggest that sleep reactivity may contribute to the development of insomnia symptoms in highly sensitive individuals. Therefore, these results suggests that sleep reactivity should be assessed in highly sensitive individuals and that it could be important to evaluate and further study this relationship.

KEYWORDS

highly sensitive person, insomnia, sensory processing sensitivity, sleep disturbances, sleep reactivity, stress

1 | INTRODUCTION

Insomnia is a common chronic condition that manifests as sleep onset and maintenance difficulties, dissatisfaction with sleep quantity and quality, as well as daytime consequences, such as fatigue, reduced alertness, and irritability. Epidemiological studies have documented that almost 30% of the adult population reports insomnia symptoms,

while almost 10% of the population is affected by insomnia syndrome as defined by precise diagnostic criteria (Morin et al., 2006; Ohayon, 2002). The aetiology of insomnia is complex since many factors can be accounted for its onsets. However, it is well established in the literature that stress is a key component contributing to its development (Bastien et al., 2004; Healey et al., 1981). An influential theory about insomnia aetiology is the 3P model developed by

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Spielman et al. (1987). The model posits that three types of factors are essentially involved in the transition from normal sleep to chronic insomnia: predisposing, precipitating, and perpetuating factors. According to this model, predisposing factors are physiological and psychological characteristics that, when specific circumstances (such as stressful events) occur, increase the likelihood that an individual will experience sleep problems. Thus, predisposing factors in interaction with precipitating factors lead to the development of insomnia symptoms, which can be maintained and aggravated by perpetuating factors, such as inadequate sleep hygiene and conditioned arousal (Perlis et al., 1997).

Both personality and temperamental traits have been extensively investigated in sleep research as factors involved in insomnia development and maintenance. As reviewed by van de Laar et al. 2010, poor sleepers and insomniacs, compared to normal sleepers, are characterized by maladaptive personality traits (e.g. internalizing behaviour, perfectionism, introversion, and somatization). Neuroticism has been frequently reported as a personality trait associated with insomnia syndrome and predictive of poor sleep quality and insomnia symptoms severity (e.g., Duggan et al., 2014; Larsgård & Saksvik-Lehoullier, 2017; LeBlanc et al., 2007; Williams & Moroz, 2009). Moreover, several studies have found that depressive, cyclothymic, and anxious temperaments were related to poor sleep quality, dysfunctional sleep patterns, and insomnia symptoms in non-clinical populations (Deguchi et al., 2017; Oniszczenko et al., 2019; Ottoni et al., 2011). In conclusion, personality traits and temperaments that are related to emotional distress and stress reactivity have reportedly been associated with insomnia.

Interestingly, emotional and physiological reactivity are also key features of the temperamental trait known as sensory-processing sensitivity (SPS), recently introduced in the clinical literature (Aron & Aron, 1997; Aron et al., 2012). SPS is characterized by a greater awareness of environmental stimuli, depth of information processing, ease of over-stimulation, and higher reactivity towards stimulations (for a review, see Greven et al., 2019). Individuals with high levels of SPS - commonly defined as highly sensitive persons - describe themselves as being more sensitive to external sensory information, including lights, noise, smells, and internal stimuli such as caffeine, hunger, and pain (Aron & Aron, 1997). They strongly respond to both negative and positive environmental influences and they tend to show great empathic abilities (Aron & Aron, 1997; Aron et al., 2005; Bas et al., 2021; Lionetti et al., 2018). However, they also report being easily overwhelmed by stimulation, expressing the "need for solitude and quiet environments as a strategy to deal with or prevent overstimulation" (Bas et al., 2021, p. 10). It is estimated that roughly 20%–30% of the population is highly sensitive (Aron et al., 2012; Lionetti et al., 2018). Despite some similarities with other traits, such as neuroticism and introversion, SPS seems to be a distinct construct not fully captured by these traditional personality traits (Aron & Aron, 1997; Lionetti et al., 2019). Several studies have linked SPS to poor psychological health, including symptoms of

anxiety and depression (Bakker & Moulding, 2012; Brindle et al., 2015; Liss et al., 2008; Takahashi et al., 2020). In particular, high-sensitive individuals are more likely to experience elevated stress (Bakker & Moulding, 2012; Benham, 2006; Brindle et al., 2015; Gerstenberg, 2012) and to respond to such stress with a range of negative outcomes (Kenemore et al., 2023; Pluess et al., 2023).

1.1 | Sleep reactivity

As mentioned above, psychological and physiological predisposing factors interact with stressors to precipitate insomnia. Recently, a sleep-specific component of stress reactivity has been identified, namely *sleep reactivity* (Drake et al., 2004; for a review, see Kalmbach et al., 2018). The concept of sleep reactivity describes why certain individuals without a history of insomnia or other sleep disorders may experience acute sleep difficulties in response to stress exposure, while others seem unaffected by the same stressors. Even mild sleep challenges cause great sleep disruption in individuals with high sleep reactivity. A self-report measure, the Ford Insomnia Response to Stress Test (FIRST), has been developed for the assessment of sleep reactivity (Drake et al., 2004). Individuals with higher scores on the FIRST show increased disturbed sleep on the first night of nocturnal polysomnography (PSG) and after caffeine administration compared to individuals with lower scores on the FIRST (Drake et al., 2004, 2006). Furthermore, in good sleepers, high FIRST scores have been related to pre-sleep cognitive and somatic hyperarousal, neuroticism, rumination, and arousability predisposition - a psychological profile that typically characterizes chronic insomniacs (Fernandez-Mendoza et al., 2010). Finally, longitudinal studies have shown that sleep reactivity is a significant risk factor for the development of insomnia (Drake et al., 2014; Jarrin et al., 2014; Kalmbach et al., 2016).

1.2 | The current study

As a temperamental trait, SPS is related to both increased stress reactivity and psychological distress. Thus, following the 3P model (Spielman et al., 1987), SPS could play a role in the predisposition for insomnia, as it is reasonable to hypothesize that highly sensitive individuals may be more at risk of suffering from sleep difficulties, especially in presence of stress, than less sensitive ones. To date, relatively few studies have investigated the relationship between SPS, as defined by Aron and Aron (1997), and sleep disturbances. A cross-sectional study exploring the impact of SPS on children's daily functioning found that those with high SPS experienced more sleep problems, such as difficulties initiating sleep and returning to sleep after nocturnal awakenings, compared to a group of children with average or low SPS (Botterberg & Warreyn, 2016). Similarly, in a recent qualitative study, one of the

interviewees reported greater difficulty in falling asleep due to their tendency to “mull things over” at bedtime (Bas et al., 2021, p. 8). Another recent study found that subjects scoring higher on the Highly Sensitive Person (HSP) scale - a psychometric measure developed to assess trait sensitivity (Aron & Aron, 1997) - reported increased nightmare frequency and increased nightmare distress than subjects with lower scores on the HSP scale (Carr et al., 2021). However, a study investigating the relationship between SPS and insomnia symptoms as well as the role of stress in this relationship is still lacking.

Thus, we designed a cross-sectional study to investigate the relationships between SPS, perceived stress, sleep reactivity, and insomnia symptoms. Based on the reviewed evidence on highly sensitive individuals, we hypothesized that higher SPS would be associated with higher perceived stress and higher sleep reactivity, as well as increased insomnia symptoms. Evidence already exists about the positive relationship between SPS and perceived stress (Benham, 2006; Gerstenberg, 2012; Kenemore et al., 2023), while no previous study directly tested the correlation between SPS and sleep reactivity, and between SPS and insomnia symptoms. We further hypothesized that perceived stress and sleep reactivity would mediate the relationship between SPS and insomnia symptoms, as stress has been related to both increased SPS (Kenemore et al., 2023; Pluess et al., 2023) and insomnia symptoms (Kalmbach et al., 2018; Morin et al., 2003). Given the role of neuroticism in both stress reactivity and sleep disturbances (Duggan et al., 2014; Fernandez-Mendoza et al., 2010; Larsgård & Saksvik-Lehouillier, 2017; LeBlanc et al., 2007; Luo et al., 2023; Williams & Moroz, 2009), as well as its relationship with SPS (Lionetti et al., 2019), we control for its effect in this study, as also suggested by Aron et al. (2012). However, we did not control for the effect of the other Big Five traits, as they are not consistently related to either sleep disruption (van de Laar et al., 2010) or SPS (Lionetti et al., 2019).

2 | METHODS

2.1 | Participants

The sample size needed for this study was determined with Monte Carlo power analysis, which is the best practice for determining power and sample size in mediation models (Schoemann et al., 2017). By setting a target power of minimum 0.80, correlation coefficients between variables of medium size (0.30 and 0.40), 1000 replications and 20,000 Monte Carlo draws for each replication, and a confidence interval of 95%, we obtained a target sample size of about 250 participants to achieve a power of 0.80, while with 350 participants the power would be of 0.95. Therefore, we aimed to collect data from 250 to 350 participants.

We enrolled 358 participants aged between 18 and 73 years (mean age = 34.75 ± 11.67 ; 275 females). Of the 358 participants, the majority were highly educated (63% with a tertiary degree; mean

years spent in education = 15.76 ± 2.79) and employed (60%). Twenty-four (24; 6.7%) participants reported having or having been diagnosed with a mental health condition. Fifteen (15; 4.1%) participants reported having or having been diagnosed with a sleep disorder. We decided not to remove participants with past or current psychological or sleep disorders from the analysis as they did not significantly alter the pattern of results, nor did they show outlier values for any of the measured variables.

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of the Department of Psychology of the Sapienza University of Rome.

2.2 | Procedure

Participants completed a cross-sectional online survey through Google Forms. The survey took approximately 20 min to be completed. The survey study was promoted via social networking sites (Instagram, Facebook, LinkedIn), online forums, mailing lists, and word of mouth. The purpose of the study was described to the participants in the online advertisement, and detailed information about the study procedure was provided before signing the informed consent. After providing informed consent, participants completed a battery of online questionnaires (described in the “Materials” section below). Participation was voluntary, and all data were collected anonymously. In case participants withdrew before the completion of the survey, no data were saved.

2.3 | Materials

The survey included questions regarding demographic characteristics, medical history, and sleep hygiene, as well as self-administered scales assessing trait sensitivity, neuroticism, perceived stress, chronotype, sleep reactivity, and insomnia symptoms.

2.3.1 | Demographic characteristics and medical history

The following information was collected: age (in years), sex, level of education (in years), employment status (student, employed, unemployed, retired), previous or current diagnosis of psychological disorders, and previous or current diagnosis of sleep disorders.

2.3.2 | Sleep hygiene

Participants rated the occurrences of the following evening behaviours, on a scale from Never (0) to Always (4): consumption of caffeinated beverages or other stimulants in the evening, physical activity prior to bedtime, cognitively or emotionally stimulating activities in the evening prior to sleep. In addition, information about

bed and sleeping environment comfort was collected (possible answers were Yes = 1 or No = 0).

2.3.3 | Highly sensitive person scale

To assess trait sensitivity, we used the 12-item Highly Sensitive Person scale (HSP-12; Pluess et al., 2023). Each item is evaluated on a 7-point Likert scale (from 1 = "Not at all" to 7 = "Completely"). This scale includes different components of sensitivity such as ease of excitation (e.g., "Do you get rattled when you have a lot to do in a short amount of time?"), low sensory threshold (e.g., "Are you bothered by intense stimuli, like loud noises or chaotic scenes?"), and aesthetic sensitivity (e.g., "Do you notice and enjoy delicate or fine scents, tastes, sounds, works of art?"). A total score was computed as the overall sum of items, and higher total scores indicate higher levels of trait sensitivity. In our sample, HSP-12 showed good internal reliability, Cronbach's alpha = 0.81 and McDonald's omega = 0.81.

2.3.4 | Neuroticism

We used the Neuroticism subscale (8 items) of the Big Five Inventory (BFI; Italian adaptation by Ubbiali et al., 2013) to assess participants' disposition to experience negative affectivity (e.g., "I see myself as someone who is depressed, blue"). Ratings were made using a 5-point Likert scale ranging from 1 ("Disagree strongly") to 5 ("Agree strongly"), with higher scores corresponding to higher levels of neuroticism. The Neuroticism scale showed good internal reliability, with Cronbach's alpha = 0.83 and McDonald's omega = 0.84.

2.3.5 | Perceived Stress Scale

The Perceived Stress Scale (PSS; Italian adaptation by Mondo et al., 2021) is a 10-item self-report questionnaire developed to measure the degree to which life situations that occurred in the last month are perceived as stressful by participants (e.g., "In the last month, how often have you found that you could not cope with all the things that you had to do?"). Participants rated each item on a 5-point Likert scale from 0 ("Never") to 4 ("Very often"). Perceived Stress Scale total score ranges from 0 to 40, with higher scores indicating higher perceived stress. In our sample, the PSS showed excellent internal reliability, Cronbach's alpha = 0.89 and McDonald's omega = 0.90.

2.3.6 | Reduced Morningness–Eveningness Questionnaire

We administered the reduced version of the Morningness–Eveningness Questionnaire to determine chronotype (rMEQ; Italian adaptation by Natale et al., 2006). The Reduced Morningness–

Eveningness Questionnaire (rMEQ) is a 5-item self-administered questionnaire. Participants were asked to identify their preferred rising and bed times, their level of fatigue in the first half-hour after waking, the time of day when they believed their physical and mental performance is at its peak, and whether they considered themselves morning or evening-type individuals. The total score ranges from 4 to 25, with higher scores indicating a morningness chronotype and lower scores an eveningness chronotype. Reduced Morningness–Eveningness Questionnaire also showed acceptable internal reliability in our sample, Cronbach's alpha = 0.72 and McDonald's omega = 0.73.

2.3.7 | Ford Insomnia Response to Stress Test

The Ford Insomnia Response to Stress Test (FIRST; Italian adaptation by Palagini et al., 2016) is a 9-items self-report instrument that assesses individual predisposition to experience sleep disturbances under stressful conditions (i.e., sleep reactivity). Respondents were asked to rate the likelihood of experiencing sleep difficulties in response to stressful life events, such as after having a bad day at work or after an argument, on a scale ranging from 1 ("Not likely") to 4 ("Very likely"). The total score ranges between 9 and 36 and a score of 18 or greater is indicative of stress-related sleep reactivity. In our sample, the FIRST scale showed excellent reliability, Cronbach's alpha = 0.89 and McDonald's omega = 0.89.

2.3.8 | Insomnia Severity Index

The Insomnia Severity Index (ISI; Italian adaptation by Castronovo et al., 2016) is a self-report questionnaire that assesses the severity and impact of insomnia symptoms over a 1-month interval. The ISI comprises seven items assessing the severity of sleep-onset, sleep maintenance and early morning awakening difficulties, satisfaction with current sleep pattern, interference of sleep difficulties with daytime functioning, noticeability of current sleep problems to others, and distress caused by sleep difficulties. Each item is rated on a 5-point Likert scale (e.g., 0 = no problem; 4 = very severe problem). In our sample, ISI total score revealed good internal reliability, with Cronbach's alpha = 0.84 and McDonald's omega = 0.85.

2.4 | Data analysis

As a first step, bivariate Pearson's correlation analysis was conducted between demographic, sleep-related, and psychological variables. As we conducted a high number of correlations, we considered significant only relationships with $p < 0.01$ and $r > 0.20$. The aim of this analysis was twofold: it aimed to assess the relationship patterns between the measured variables and to identify the demographic variables that could be included as covariates in the subsequent analyses.

Our next analysis was a multiple linear regression, which allowed us to test the hypothesized relationship patterns already investigated in correlation analysis, while accounting for covariates. In particular, we tested the relationship between SPS and stress, SPS and insomnia, and both SPS and stress on insomnia while controlling for demographics (sex and age), psychological variables (neuroticism), and chronotype (rMEQ score). This analysis could also be considered diagnostic for the subsequent mediation models. For each regression model, we reported the unstandardized coefficients (estimates) along with their 95% confidence intervals computed over 1000 bootstrap samples, and their respective standardized coefficients (β). Moreover, the model on ISI included two steps of computation: in the first, only the HSP-12 was included as a predictor, while PSS and FIRST were entered in the second step. This allowed us to evaluate both the direct effect of HSP-12 on the dependent variables and how this effect varied while also including the stress-related measures.

As our last analysis, we conducted a mediation model with the HSP-12 as the predictor, FIRST and PSS as the mediators, and ISI as the dependent variable. The model included sex, age, neuroticism, and rMEQ as covariates. The model was conducted by means of PROCESS for R version 4.1 (Hayes, 2022), using model 4 (basic mediation model) with bias-corrected 95% confidence intervals computed over 5000 bootstrap samples. Based on the obtained pattern of relationships, we computed the power of our analysis again via the Monte Carlo power analysis (Schoemann et al., 2017). By setting the sample size to 350, correlation coefficients and standard deviations for variables as measured in our sample, we obtained power for the two indirect paths of 1.00 with a 95% confidence level, which decreased to 0.97 when increasing the confidence level to 99%. This power analysis suggested that our model and sample size were more than adequate in order to obtain meaningful results.

3 | RESULTS

The correlations between demographic, sleep-related, and psychological variables are shown in Table 1. As reported, age was related to decreased neuroticism and perceived stress, and increased morningness. Sex female was related to increased sleep reactivity, with males reporting lower levels of such variable. The presence of sleep problems was related to increased ISI scores. Being an "evening type" was related to an increased presence of pre-sleep negative habits, such as assuming stimulating substances, doing exciting activities, or studying and working before sleeping. Doing exciting activities just before sleeping was also positively correlated to neuroticism and stress. Overall, only sex and age revealed a meaningful pattern of correlations with the psychological variables, while the pre-sleep habits or bed/room discomfort were not related to changes in sleep-related problems. Therefore, in the subsequent analyses, we included age and sex as covariates.

We then inspected the relationship pattern between the psychological variables and the sleep disturbance indexes. The result of this analysis is reported in Table 2. As shown, the HSP-12 score was positively correlated with neuroticism, stress, sleep reactivity, and sleep disturbance. Neuroticism was strongly and positively correlated with perceived stress, sleep reactivity, and sleep disturbance. Perceived stress and sleep reactivity were positively correlated, and both were related to increased insomnia symptoms. This analysis was supportive of the expected pattern of results, in particular with SPS positively related to the presence of both stress and sleep-related problems.

We then moved to regression analysis. Table 3 reports the result of the regression models tested with the coefficients only for the effect of the main tested variables, that is, HSP-12, FIRST, and PSS.

TABLE 1 Correlation coefficients between demographic, sleep-related, and psychological variables.

	HSP-12	Neuroticism	PSS	rMEQ	FIRST	ISI
Age	-0.04	-0.21**	-0.26**	0.32**	-0.04	-0.03
Sex	0.18**	0.19**	0.12*	0.08	0.25**	0.04
Education level	0.19**	-0.07	-0.13*	-0.04	-0.05	-0.06
Psychological disorders	0.11*	0.09	0.11*	-0.05	0.03	0.14**
Sleep disorders	-0.03	0.09	0.13*	-0.01	0.11*	0.27**
Pre-sleep habits: Stimulating substances	-0.07	0.03	0.06	-0.29**	-0.08	0.03
Pre-sleep habits: Intense physical activity	-0.08	-0.03	0.01	-0.10	-0.01	0.03
Pre-sleep habits: Exciting activities	0.10	0.20**	0.21**	-0.30**	0.06	0.09
Pre-sleep habits: Studying or working	0.01	0.06	0.11*	-0.31**	0.03	0.07
Uncomfortable bed	0.03	0.06	0.09	-0.05	0.01	0.09
Uncomfortable room	0.12*	0.08	0.05	-0.06	0.02	0.08

Note: Sex was coded as 0 = male, 1 = female. Education level was coded as years spent in education. Psychological and sleep-related problems are coded as 0 = absent or not reported, 1 = present. Significance level is reported as * $p < 0.05$, ** $p < 0.01$.

Abbreviations: FIRST, Ford Insomnia Response to Stress Test; HSP-12, Highly Sensitivity Person scale - 12 items; ISI, Insomnia Severity Index; PSS, Perceived Stress Scale; rMEQ, reduced Morningness-Eveningness Questionnaire.

The complete regression results, also including the effects of the covariates and confound variables can be accessed in the Supplementary materials (see Table S1, S2, and S3). As reported, the HSP-12 score predicted the FIRST score, but not the PSS score. Moreover, the HSP-12 score significantly predicted the ISI score, but this relationship was not significant in step 2 model including also FIRST and PSS. Both FIRST and PSS are significantly and positively related to the ISI score.

We then conducted the subsequent mediation model including the HSP-12 as the predictor, the FIRST and PSS as mediators, and the ISI score as the dependent variable (see Figure 1). Path coefficients with their relative SE, upper and lower bootstrapped confidence intervals, and significance, are reported in Table 4. For the sake of clarity, we did not report in the main text the effect of

covariates (see the Supplementary materials, Table S4, for the complete pattern of results). In the model, HSP-12 did not relate to PSS significantly, while it was related to a significant increment in FIRST score. HSP-12 was not directly correlated to ISI, while both PSS and FIRST were. On this basis, the test of mediated effect revealed a completely mediated path from HSP-12 to ISI through FIRST. Instead, the mediated path from HSP-12 to ISI through PSS was not significant. The total effect of HSP-12 on ISI was significant. Overall, this result showed that sensitivity was related to increased insomnia symptoms and that this relationship was fully mediated by increased sleep reactivity. Instead, the relationship of sensitivity with perceived stress was not significant, nor it mediated the effect of sensitivity on insomnia symptoms.

TABLE 2 Correlation coefficients between psychological variables and insomnia.

	HSP-12	Neuroticism	PSS	MEQ	FIRST
Neuroticism	0.28**	\			
PSS	0.24**	0.67**	\		
rMEQ	-0.10	-0.15**	-0.20**	\	
FIRST	0.32**	0.44**	0.39**	-0.08	\
ISI	0.25**	0.42**	0.47**	-0.17**	0.48**

Note: Significance level is reported as * $p < 0.05$, ** $p < 0.01$.

Abbreviations: FIRST, Ford Insomnia Response to Stress Test; HSP-12, Highly Sensitivity Person scale - 12 items; ISI, Insomnia Severity Index; PSS, Perceived Stress Scale; rMEQ, reduced Morningness-Eveningness Questionnaire.

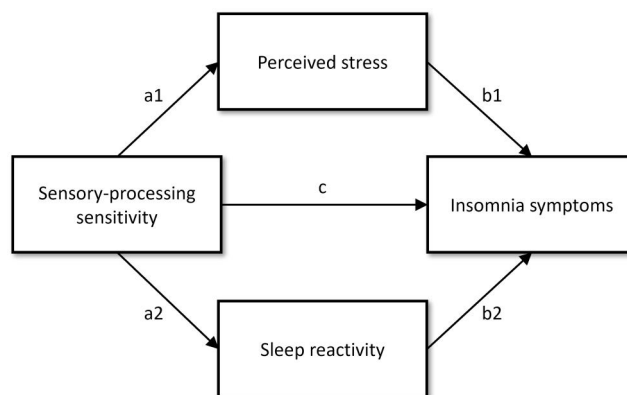


FIGURE 1 The mediation model tested. For the sake of clarity, covariates and their relative paths are not shown.

Dependent variable	Effect	Estimate	95% CI		β	Fit R^2
			LL	UL		
FIRST	(Intercept)	4.53*	0.30	8.53	/	0.261**
	HSP-12	0.09**	0.04	0.14	0.19	
PSS	(Intercept)	-3.01	-1.82	7.56	/	0.474**
	HSP-12	0.03	-0.01	0.08	0.05	
ISI	(Intercept)	-2.58	-6.70	1.59	/	0.214**
	HSP-12	0.05**	0.01	0.1	0.14	
	(Intercept)	-4.38*	-8.24	-0.93	/	0.354**
	FIRST	0.27**	0.19	0.36	0.33	
	PSS	0.19**	0.11	0.27	0.28	
	HSP-12	0.02	-0.02	0.07	0.06	

Note: Significance level is reported as * $p < 0.05$, ** $p < 0.01$.

Abbreviations: 95% CI, bootstrapped confidence intervals; FIRST, Ford Insomnia Response to Stress Test; HSP-12, Highly Sensitivity Person scale - 12 items; ISI, Insomnia Severity Index; LL and UL, lower and upper limits of CI; PSS, Perceived Stress Scale.

TABLE 3 Regression models on different dependent variables with unstandardized and standardized coefficients.

TABLE 4 Path coefficients for mediation model with Insomnia Severity Index (ISI) as outcome.

Path	Estimate	SE	95% CI		p
			LL	UL	
HSP-12 → PSS (a1)	0.029	0.024	-0.018	0.076	0.227
HSP-12 → FIRST (a2)	0.090	0.023	0.038	0.138	<0.001
HSP-12 → ISI (c)	0.025	0.020	-0.016	0.065	0.180
PSS → ISI (b1)	0.188	0.040	0.108	0.265	<0.001
FIRST → ISI (b2)	0.274	0.044	0.188	0.363	<0.001
Indirect effects					
HSP-12 → PSS → ISI (a1 × b1)	0.005	0.005	-0.003	0.015	
HSP-12 → FIRST → ISI (a2 × b2)	0.025	0.008	0.010	0.041	
Total effect	0.030	0.009	0.013	0.048	

Note: Coefficients for the covariates (age, sex, neuroticism, and rMEQ) was not reported here, please see Table S5 for the complete list of paths.

Abbreviations: 95% CI, bootstrapped confidence intervals; FIRST, Ford Insomnia Response to Stress Test; HSP-12, Highly Sensitivity Person scale - 12 items; ISI, Insomnia Severity Index; LL and UL, lower and upper limits of CI; PSS, Perceived Stress Scale.

4 | DISCUSSION

The current study investigated for the first time the relationship between SPS as conceived and assessed with the HSP scale, perceived stress, sleep reactivity, and insomnia symptoms, with the hypothesis that (i) SPS would be related to higher perceived stress, higher sleep reactivity, as well as increased insomnia symptoms, and that (ii) the relationship between SPS and insomnia symptoms would be mediated by SPS relationship with stress variables. Overall, the study's results support our hypotheses, although not completely.

Our first hypothesis was partly supported. Indeed, in correlation analyses, we found significant positive correlations between the HSP-12 score and PSS, FIRST, and ISI scores. The positive relationship between SPS and sleep disturbances has been previously reported by a few studies (Bas et al., 2021; Boterberg & Warreyn, 2016; Carr et al., 2021). Therefore, our results are consistent with these previous studies and confirm the positive link between SPS and sleep difficulties. Our results also support the well-known relationship between SPS and stress, as we found a positive correlation between HSP-12 and PSS, and between HSP-12 and FIRST. While the former has been reported in previous studies (Benham, 2006; Gerstenberg, 2012; Kenemore et al., 2023), the latter has been not. However, in regression analyses, the HSP-12 score significantly predicted increased FIRST and ISI scores, but not the PSS score. A possible explanation could lie in controlling for the effect of neuroticism, which has been shown to be strongly related to psychological distress (Luo et al., 2023). Additionally, this effect of neuroticism has been observed in previous SPS studies. For instance, Grimen and colleagues (2016) showed that neuroticism was a better predictor of psychological health complaints than SPS. Since previous literature has supported a dissociation between SPS and neuroticism (Aron & Aron, 1997; Lionetti et al., 2019; Smolewska et al., 2006),

future studies need to better clarify their distinct impact on psychological distress.

Concerning our second hypothesis, which proposed that stress would mediate the effects of SPS on insomnia symptoms, only the FIRST was a significant mediator of the relationship between HSP-12 and ISI, while perceived stress was not. Unlike the PSS, which measures psychological stress in terms of a perceived lack of control over life situations and feelings of being overwhelmed, the FIRST specifically measures the sleep-related component of stress reactivity (Drake et al., 2004). Considering this specificity and the predictive role of sleep reactivity in insomnia development (Drake et al., 2014), the FIRST was a better mediator in our model than the PSS. Additionally, previous studies have shown that healthy individuals with higher scores on the FIRST show increased susceptibility to novel situations and caffeine, as well as difficulties in disengaging from negative stimulations (Drake et al., 2004, 2006), characteristics that have also been reported in highly sensitive individuals (Aron & Aron, 1997; Bas et al., 2021). While these latter findings are drawn from qualitative studies, an intriguing pattern of overlap has emerged between the constructs measured with the HSP-12 and the FIRST questionnaires, in which the susceptibility and reactivity to stimuli seem to play a key role in both. Future studies should be conducted to further elucidate the relationships between these two constructs and corroborate our observations.

4.1 | Future directions

In light of our results, SPS might be regarded as a temperament trait linked to sleep problems and insomnia. Our findings showed that it enhances increases sleep reactivity, leading to increased symptoms of insomnia sleep reactivity, which in turn leads to an increase in insomnia symptoms. However, it is important to point out that this

construct shares strong similarities with the concepts of arousability (Coren, 1988) and hyperarousal (Perlis et al., 1997; Riemann et al., 2010), two constructs extensively studied in relation to the aetiology and perpetuation of insomnia. For instance, the enhanced awareness of environmental stimuli reported by highly sensitive individuals is an experience often described as lacking a filter and might be responsible for impaired sleep in individuals with high levels of SPS (Bas et al., 2021; Boterberg & Warreyn, 2016; Carr et al., 2021). Indeed in poor sleepers and insomnia patients, many studies have documented enhanced sensory processing and sensory gating impairments around sleep onset and during PSG sleep which have been related to sleep initiation and maintenance issues (e.g., Bastien et al., 2008; Killgore et al., 2013; Milner et al., 2009). Another SPS feature that may be related to arousability and hyperarousal and therefore may interfere with sleep is the greater depth of processing. Depth of processing relates to the level of cognitive elaboration of information, which also pertains to the process of “relating it [that is, information] to the past and projecting its consequences into the future” (Aron et al., 2012, p. 267). Depth of processing has been described in high SPS individuals as “a general thoughtfulness or a sense of long-term consequences” (Boterberg & Warreyn, 2016, p. 84). While Depth of processing could be related to empathic abilities, aesthetic sensitivity, and creativity exhibited by highly sensitive individuals (Acevedo et al., 2014; Bridges & Schendan, 2019), it might also lead to the employment of maladaptive thought processes such as worry and rumination (Bas et al., 2021; Boterberg & Warreyn, 2016). These maladaptive cognitive processes are frequently employed by insomniacs at bedtime, interfering with sleep initiation (Perlis et al., 1997; Spielman et al., 1987). Thus, future studies should verify these observations using an experimental approach and better clarify the similarities and differences between SPS, arousability, and hyperarousal.

4.2 | Clinical implications

Our findings may be particularly valuable to therapists treating highly-sensitive individuals. With the knowledge that more sensitive individuals may be more susceptible to sleep difficulties during stressful periods, therapists could provide sleep hygiene recommendations to their clients as a means of addressing and preventing these issues. Another practical suggestion could be to assess sleep reactivity in highly-sensitive patients, so to estimate their susceptibility to developing an insomnia disorder. Highly-sensitive patients reporting also a higher level of sleep reactivity should be preventively informed of their increased risks to take proper actions. Finally, the efficacy of CBT-i and other forms of psycho-educational interventions for sleep disturbances may be further investigated in high-sensitive individuals, as they would benefit more from psychological interventions and other positive environmental influences than low-sensitive individuals (Pluess & Boniwell, 2015). Moreover, mindfulness-based interventions could be beneficial for highly sensitive individuals, as mindfulness could both counteract the stress-driven decrease in sleep

quality (see Simone et al., 2020) and reduce pre-sleep arousal due to rumination and worries (Ong & Manber, 2011).

4.3 | Limitations

The findings of this study have to be seen in the light of several limitations. First, the study had a cross-sectional design, which precludes any definite conclusions about the direction of the relationship between the variables investigated. Experimental and longitudinal studies looking at the relationships between SPS, stress, and sleep disturbances would be informative; for example, the sleep-wake patterns of individuals with low and high levels of SPS could be assessed by means of sleep diaries and actigraphic measurements during times of high versus low stress, in order to better elucidate the pattern of relationship between the variables. Another limitation is that the current study only included self-report measures. Participants' beliefs regarding the nature of the relationships between the variables investigated as well as the retrospective nature of the measurements employed could have biased our findings. Thus, prospective study designs, including behavioural and physiological measurements of sleep, such as sleep diaries, actigraphy or PSG, and physiological measures of stress (e.g., heart rate variability), would provide more reliable results. Finally, the current sample was selected by random sampling, which raises concerns about the generalizability of our results to more specific populations of interest (e.g., individuals with insomnia disorder). Indeed, our population was relatively homogeneous, consisting mainly of highly-educated and employed women. Therefore, future studies should employ more refined sampling methods, such as the stratified sampling, to corroborate the relationships observed in the present study.

AUTHOR CONTRIBUTIONS

All the authors contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon request.

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