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Research article

Sensory sensitivity, intolerance of uncertainty and sex differences predicting anxiety in emerging adults

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ABSTRACT

As multiple vulnerability factors have been defined for anxiety disorders, it is important to investigate the interactions among these factors to understand why and how some individuals develop anxiety. Sensory Sensitivity (SS) and Intolerance of Uncertainty (IU) are independent vulnerability factors of anxiety, but their unique relationship in predicting anxiety has rarely been studied in non-clinical populations. The objective of this investigation was to examine the combined effects of SS and IU on self-reported anxiety in a sample of university students. In addition, with the frequently reported sex bias in anxiety literature, we expected that the combined effects of vulnerability factors would be different for females and males. A convenience sample of 313 university students, ages 17–26 years was recruited. The participants completed the Intolerance of Uncertainty Scale (IUS-12), the Adult/Adolescent Sensory Profile (AASP), and the Beck Anxiety Inventory (BAI). Results of moderated mediation analyses demonstrated a strong partial mediation between SS and anxiety through IU, providing evidence that IU, a cognitive bias against the unknown, was one mechanism that explained how SS was related to anxiety. Further, the effect of IU on anxiety was approximately twice as strong in females. Our results highlight the importance of studying the unique relationships among multiple vulnerability factors to better understand anxiety susceptibility in emerging adults.

1. Introduction

Anxiety disorders are highly prevalent with heritability estimates reported as 30%–50% in twin studies [54]. Individuals with anxiety often experience substantial difficulties in academic, work, and social domains [16]. Mean age of onset for anxiety disorders is reported as 21.3 years, ranging between 17 and 25 years, a developmental period defined as emerging adulthood [1]. Due to the transitional nature of this period and exposure to increased life responsibilities, emerging adults are faced with increased emotional challenges, including heightened anxiety [1]. Findings suggest multiple biological, psychological, and environmental risk factors underlie anxiety ([40,47]). As the co-occurrence of these individual risk factors increase the susceptibility of anxiety disorders ([18, 40]), it is important to study the synergistic nature of these risks to understand the paths to anxiety. In this study, we explored anxiety risks using a developmental psychopathological framework that considers the combined, interactive and dimensional nature of vulnerability factors ([15,39]). Further, dimensional models to mental health problems emphasize the continuity of psychopathological conditions exist as traits in the population [33]. According to these models it is critical to examine multiple factors simultaneously to understand why some contextual situations become maladaptive and lead to psychopathology, whereas others appear more

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resilient when faced with adversity [22]. In this study, we investigated the combined effects of three vulnerability factors on anxiety; sensory sensitivity (SS), intolerance of uncertainty (IU) and sex differences. In the literature these factors have been frequently associated with anxiety in both clinically diagnosed and community samples ([24,31]).

1.1. SS and IU as risk factors in anxiety

According to Dunn in 1997 [21], SS is a type of sensory processing pattern, characterized by tension, nervousness, and a general discomfort in reaction to sensory input [21]. High levels of SS are common in clinically diagnosed groups including anxiety disorders [24]. At the same time, heightened sensory responsiveness is observed in the general population [41] and is frequently associated with sleep disturbances and emotion regulation difficulties [51].

Intolerance of Uncertainty (IU) is a cognitive trait characterized by the tendency to perceive uncertain events as threatening and uncontrollable [25]. When high IU individuals are exposed to uncertainty, they report high anxiety [43] and are more likely to engage in maladaptive coping strategies (i.e., avoidance) to mitigate uncertainty [52]. Evidence suggests that SS leads to a hypersensitivity toward stimuli [23], whereas IU has been associated with an attentional bias toward environmental uncertainty, and greater expectancy of threat [30]. While SS and IU are individually associated with anxiety, very limited research has focused on the inter-relationship between SS and IU in predicting anxiety. The few studies in which SS and IU have been explored in combination are focused primarily on Autism Spectrum Disorder (ASD) (i.e., [28]). In a recent review, South and Rogers [55] proposed that the pathway from SS and anxiety is mediated through IU in ASD groups. IU, a mechanism known to magnify the association between daily stressors and anxiety [14] is associated with increased monitoring, reactivity to uncertainty, and an overestimation of environmental threat [31]. Uljarević, Carrington and Leekam [58] studied the relation between SS (using the Highly Sensitive Person Scale) and anxiety and found that IU mediated this relationship in mothers of children diagnosed with ASD. Uljarević et al. [58] suggested that overwhelming environmental stimuli experienced in high SS individuals make the environment appear less certain. Uljarević et al. [58] proposed that IU is a mechanism that leads SS to anxiety, such that overwhelming stimuli leads to uncertainty, which may further evoke anxiety.

1.2. Sex differences in anxiety

Significant female bias has been reported in anxiety disorders [36]. Further, females generally report higher scores on constructs that have been shown to increase susceptibility to anxiety, such as anxiety sensitivity [48]. In a recent study, Gao, Ping and Liu [27] found that anxiety was the most prevalent mental health concern in Chinese college students, with females more often reporting higher anxiety severity in the first few years of college. Males and females also differ in emotion regulation strategies; males are likely to suppress emotions, in contrast, females are more likely to investigate and attend to their emotions [20]. Bardeen and Stevens [4] suggested that females tend to ruminate on stressors that lead to cognitive resource depletion when faced with stressful situations. Limited cognitive resources lead to difficulty interpreting and understanding emotions, and heightened anxiety, particularly in females [4]. McLean, Asnaani, Litz and Hofmann [45] reported that anxious women are more likely to utilize emergency medical services (i.e., urgent care services) compared to anxious men, suggesting a greater burden of anxiety in females.

1.3. Current study

Few studies, mostly with individuals with ASD have explored the inter-relationships between SS, IU, and anxiety ([28,35,58]). However, there has been limited research analyzing combined effects of sensory and cognitive vulnerability factors on anxiety while also accounting for sex differences within non-clinical populations. Due to the high prevalence rate of anxiety among emerging adults ([1,49,53]), especially in undergraduate students, it is important to investigate the pattern of the relationships among vulnerability factors that increase the risk of anxiety disorders in this group. In addition, regardless of culture and ethnicity particularly young females are at a significant risk of anxiety ([19,27,61]). In sum, as multiple co-occurring risk factors have been documented in anxiety [59], in this study we examined the synergistic nature of SS, IU, and sex differences in order to gain a better understanding of the possible paths to anxiety especially in typically developing emerging adults. Overall, we hypothesized that high sensitivity is associated with high anxiety and this relationship will be mediated through IU. In addition, we also expected that the relationship between SS, and anxiety via IU would be moderated by sex, and the effect will be stronger for females. However, due to the lack of research in this area, we did not specify the path in which the moderation would take an effect.

2. Method

2.1. Participants

Three hundred and thirteen undergraduates aged 17–26 years (138 females, 171 males, and 4 other genders) were recruited through an online Psychology Research Pool Website (SONA), and through posters displayed throughout the university campus for two consecutive studies. Data collection from this convenience sample continued from September 2016 to 2018 (pre Covid-19) and the participants were given research credits. Self-report data from the two studies were merged to increase the sample size. Both studies and data merge processes received clearance from Brock University's Research Ethics Board (REB) # 16–065. Twenty-five participants failed to complete various questionnaires and four participants did not identify as either male or female (i.e. identified as non-binary)

were excluded from the analyses. Although there is considerable variability in how individuals choose to identify and express their gender, for the purpose of this study, 'sex' was categorized as male and/or female. The resulting sample included 284 participants (51.3% female).

2.2. Measures

2.2.1. Intolerance of Uncertainty Scale-12 (IUS-12, carleton, Norton & Asmundson, 2007a)

The Intolerance of Uncertainty Scale-Short Form (IUS-12) measures reaction to uncertainty (e.g., "I can't stand being taken by surprise") and is a 12-item short form of the original 27-item scale [12]. The IUS-12 is highly correlated with the original IUS scale (r = 0.96) with high internal consistency [Cronbach's alpha = .91; as reported in Carleton, Norton & Asmundson [13]]. Cronbach's alpha for the present sample was .90.

2.2.2. Beck Anxiety Inventory (BAI, Beck & Steer, 1993)

The Beck Anxiety Inventory (BAI) [6]is a 21-item self-report instrument used to measure anxiety severity (e.g., "fear of the worst happening") in adolescent/adult populations [5]. Beck et al. [5] reported high internal consistency (Cronbach's alpha = .92) and a one-week test-retest reliability coefficient of 0.75. Internal consistency observed in the present sample was .93.

2.2.3. Adolescent/adult sensory profile (AASP; Brown & Dunn, 2002)

The AASP is a 60-item, four quadrant model used to measure sensory processing and its effect on daily functioning in adolescent (age 11+) and adult populations. Score values for each quadrant have been established in a healthy population (N = 495; [10]), although for this study, only one quadrant (SS) (e.g., "I startle easily to unexpected or loud noises"), was explored. The reliability coefficient alpha for SS = 0.81 [10]. Internal consistency observed in the present sample for SS = 0.73.

2.3. Procedure

Participants were scheduled for a 60-min session, during which participants provided written consent and completed self-report questionnaires. For the aims of this research only AASP/*SS*-scale, IUS-12 and BAI were analyzed.

2.4. Statistical analyses

Correlations among study variables (SS, IU, anxiety, and sex) were evaluated and the linear regression via the PROCESS macro for SPSS 24 [34] was utilized to test whether IU mediated the association between SS and anxiety, and whether sex moderated this relationship. First, simple mediation was employed using model 4 of the PROCESS macro for SPSS to investigate whether the relationship between SS and anxiety is mediated through IU.

Second, an exploratory moderated-mediation model was employed to test all three paths (a, b & c path) of the mediation between SS, IU, and anxiety. To investigate the moderation of sex, the following models were used from the PROCESS macro: model 7 was used to investigate the *a path* (between SS and IU); model 14 was used to investigate the *b path* (between IU and anxiety); model 5 was used to investigate the *c path* (between SS and anxiety). Statistical significance was defined as a two-tailed p value less than 0.05.

3. Results

3.1. Preliminary analyses and final sample

Three BAI outliers with z-scores >2.58 were winsorized to reduce potential bias in the sample [26]. The assumption of univariate normality was supported through visual inspection of study variables' histograms and by low values of skewness and kurtosis (within ± 2). Linear relationships among all continuous variables were supported via visual inspection of scatterplots. Multicollinearity was assessed using the variance inflation factor (VIF) generated from a linear regression containing all substantive predictors and covariates with a random number variable as the outcome. All VIF values were within range (below 10) and all tolerance levels were above 0.02 suggesting that the amount of multicollinearity in the model was not substantial enough to warrant concern.

Table 1
Bivariate correlations among sensory sensitivity, intolerance of uncertainty, anxiety and sex (n = 284).

	1	2	3	4	M ± SD
1. SS	–				38.39 ± 8.340
2. Anx.	.56**	–			15.88 ± 12.41
3. IU	.53**	.54**	–		34.06 ± 9.379
4. Sex	.29**	.36**	.20**	–	–

Note. Correlations among study variables. SS, Sensory Sensitivity; Anx., Anxiety; IU, Intolerance of Uncertainty. **p < .01 (two tailed).

3.2. Bivariate correlations (all variables)

Table 1 provides the mean, SD, and correlation of each of the associated variables. Results indicated that there was a moderate-to-large, positive correlation between SS and anxiety ($r = 0.56$, $p < .01$) and SS and IU ($r = 0.53$, $p < .01$). There was a moderate-to-large correlation between anxiety and IU ($r = 0.54$, $p < .01$). Additionally, there was a small-to-moderate, positive correlation between sex and SS ($r = 0.29$, $p < .01$), sex and anxiety ($r = 0.36$, $p < .01$), and sex and IU ($r = 0.20$, $p < .01$).

3.3. Mediating role of IU on the association between SS and anxiety

First, a mediation model (Model 4; Hayes, 2018) was conducted using the PROCESS macro for SPSS to test whether SS is indirectly associated with anxiety via IU (see Fig. 1). Table 2 provides results of the mediation analysis demonstrated a significant total effect (path *c*) of SS on total anxiety score ($B = 0.83$, $SE = 0.07$, $p = .000$). A significant *a* path ($B = 0.59$, $SE = .06$, $p = .000$) indicated a positive association between SS and IU, and a significant *b* path ($B = 0.46$, $SE = 0.07$, $p = .000$) indicated a positive association of IU on anxiety. With respect to indirect effects, results of the mediation model indicated that the indirect effect of SS on anxiety, through IU was statistically reliable ($B = 0.27$, $SE = 0.05$, 95% bootstrapped CIs [0.184; 0.374]). For bootstrapping, 10,000 samples were drawn. However, the direct association between SS and anxiety (*c path*) remained significant after accounting for the effects of IU in the model, suggesting a partial mediation. To determine the role of IU as a mediator between SS and anxiety, a Sobel test was conducted. Results of the Sobel test demonstrated a strong partial mediation of IU on the association between SS and anxiety ($Z = 5.51$, $p < .001$) thus supporting our first hypothesis that SS was associated with higher levels of anxiety and that IU represented one of the possible indirect pathways from SS to anxiety.

3.4. Moderation and moderated mediation analyses

In the second step, we employed a moderated regression analysis [(via PROCESS Models 5, 7, and 14) [34]] to investigate if sex moderated the three relationships among SS, IU, and anxiety (a, b, and c path in Fig. 1). There was no evidence of moderation by sex for the SS and IU relationship (a path) ($B = -0.07$, $SE = 0.13$, $p = .56$, 95% CIs [0.131, for the SS and anxiety relationship ($B = 0.25$, $SE = 0.14$, $p = .08$, 95% CIs [-0.038, 0.537].

However, there was evidence that sex moderated the IU and anxiety relationship, along with evidence that sex moderated the indirect relationship between SS and anxiety via IU (PROCESS Model 14 and illustrated in Fig. 2). As shown in Table 3, after introducing sex into the model, the interaction between IU and sex was a significant predictor of anxiety ($B = 0.24$, $SE = 0.12$, 95% CIs [0.002, 0.485]). Significant moderation was probed by a simple slope analysis to characterize the relationship between IU and anxiety separately for males and females (see Fig. 3). The results of the simple slopes analyses indicated that the relationship between IU and anxiety was stronger in females ($B = .55$, $SE = 0.08$, $p = .000$, 95% CIs [0.377, 0.727) compared to males ($B = 0.30$, $SE = 0.09$, $p < .05$, 95% CIs [0.117, 0.500]; see Table 4). The relationship between IU and anxiety was moderated by sex, and the effect was twice as strong in females.

The moderation by sex extended as well to the indirect effect described in the initial analysis. For males, the indirect effect of SS to anxiety by IU was 0.18 ($SE = 0.05$; 95% CI [0.08, 0.29]; whereas for females, the indirect effect was twice as large at 0.33 ($SE = 0.06$; 95% CI [0.20, 0.45]. The index of moderated mediation was 0.14 ($SE = 0.07$; 95% CI [0.01, 0.28], suggesting that this difference was not due to chance alone and that IU plays a stronger mediating role for females compared to males.

4. Discussion

In this study, we hypothesized IU as a possible mechanism between SS and anxiety, and sex moderating this relationship in typically developing, emerging adults. Consistent with previous findings [51], our results revealed that SS was a strong predictor of anxiety. Additionally, our findings support hypothesis 1; IU partially, but significantly mediated the relationship between SS and anxiety.

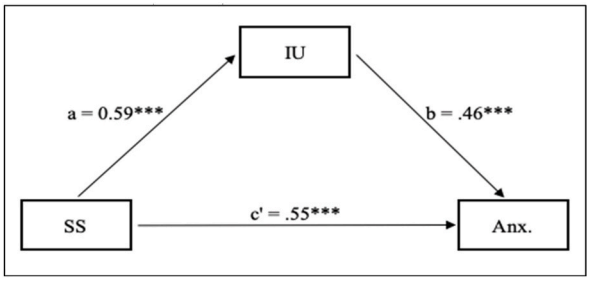

Fig. 1. Mediation Model (Model 4)
Note. The mediation model (unstandardized coefficients). SS, Sensory Sensitivity; IU, Intolerance of Uncertainty; Anx., Anxiety.
***p < .001.

Table 2
Mediation analysis (n = 284).

Variable	Path *c*		Path *c'* and *b*		Path *a*		Path *a*b*			
	B	*SE*	*B*	*SE*	*B*	*SE*	*B*	*SE*	*LLCI*	*ULCI*
SS	.83	.07	.55	.08	.59	.06	.27	.05	.184	.374
IU	–	–	.46	.07	–					
R^2adj	.308		.394		.278					
F	125.2		91.42		108.7					

Note. Analyses conducted using PROCESS model 4. SS, Sensory Sensitivity; IU, Intolerance of Uncertainty.

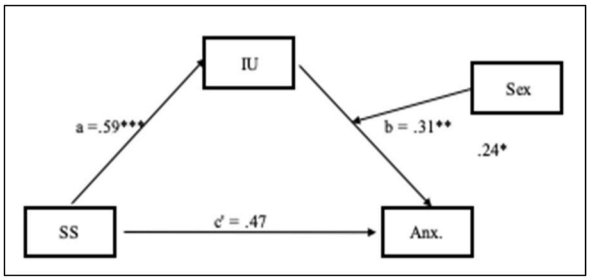

Fig. 2. *Moderated Mediation (Model 14).*
Note. The moderated mediation (unstandardized coefficients). SS, Sensory Sensitivity; IU, Intolerance of Uncertainty; Anx., Anxiety.
*$p < .05$, **$p < .01$, ***$p < .001$.

Table 3
Moderated mediation analysis (n = 284).

Outcome: Anxiety					
Variable	*B*	*SE*	*t*	LLCI	UCLI
SS	.47	.081	*5.785***	0.308	0.626
IU	.31	.097	3.168**	0.117	0.500
Sex	5.02	1.17	4.305***	2.724	7.313
IU * Sex	.24	.123	1.987*	0.002	0.485

Note. Analyses conducted using PROCESS model 14. SS, Sensory Sensitivity; IU, Intolerance of Uncertainty. *$p < .05$, **$p < .01$, ***$p < .001$.

The SS to anxiety pathway is multi-factorial and is reportedly mediated through various coping styles. For example, tendency to focus on emotional distress [37], low mindfulness [56] and poor coping of emotional anguish [46] are highly anxiogenic risks for those high in SS. In addition, the SS to anxiety pathway may be influenced by impairments in bottom-up sensory processing such as inefficient sensory-gating [17] that leads to anxious apprehension and altered sensory perceptual processing [50]. IU, a personality trait strongly associated to attentional (Fergus & Carleton, 2016) and interpretational [9] biases, is also known to amplify attention and anxiety-provoked startle response [7] toward novel stimuli, making uncertain situations highly anxiogenic [31].

Aron, Aron and Jagiellowicz [2] argued that sensory overstimulation prompts certainty-seeking behaviour to gain control over uncontrollable situations. In addition, MacLennan, Rossow and Tavassoli [42] reported that in ASD groups, IU mediated the pathway between SS and anxiety and suggested that altered sensory interpretation amplifies the uncertainty of everyday situations, and leads to difficulty generating expectations of situational stimuli. Thus, heightened reactivity to one's environment (SS), paired with a strong sense that uncertainty is aversive and leads to greater anxiety, was supported by our findings.

In addition, our results support hypothesis 2; Sex moderated the pathway between IU and anxiety, and this effect was significantly stronger in females, suggesting lower tolerance of uncertainty in females. Evidence of heightened IU in females is controversial; some studies report significant sex differences ([51,60]), whereas others report no difference [8]. According to Yeler et al. [60], female emerging adults reported higher IU and were most significantly impacted by uncertainty. Further, females tend to experience a strong startle reactivity [11] and self-reported heightened sensitivity, panic, and distress when exposed to stress that leads to rumination [38], lack of perceived control, and anxiety [57]. Stress associated with IU, paired with difficulty coping with negative emotions, may lead to maladaptive coping of uncertainty [52], and the overestimation of threat [30]. Situational control or mastery is also reportedly lower in females [44], and limits the capacity to cope with everyday stressors involving uncertainty [62]. As such, we speculate that sex differences in the coping and interpretation of sensory input and uncertainty may be one possible mechanism that explains why IU more strongly mediates the SS to anxiety relationship in females.

In contrast to Pellicano and Burr's [50] notion that SS is maintained through bottom-up processing; Goldstein Ferber et al. [30]

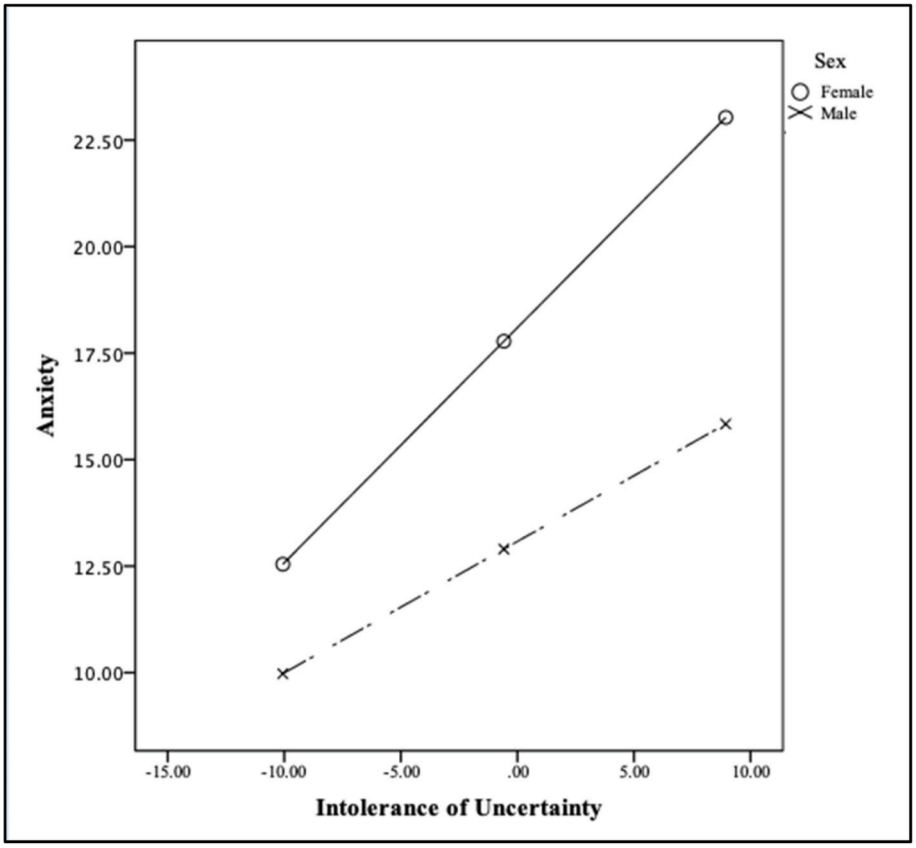

Fig. 3. *Conditional Effects in Males and Females.*
Note. Conditional effects of IU on anxiety across males and females.

Table 4
Conditional effects of IU on anxiety across males and females.

	B	*SE*	LLCI	UCLI
Male	.31	.097	0.1168	0.5002
Female	.55	.089	0.3769	0.7269

Note. Conditional Effects of IU on Anxiety in Males and Females.

suggested that maladaptive responding to sensory information stems from biased cognitive (top-down) processing. According to Gluck, Lynn, Dritschel and Brown [29], females are more likely to interpret ambiguous situations through biased past beliefs that make the environment appear more threatening/unpleasant. Elevated levels of IU, driven through biased interpretations (poor coping) may create distorted views of uncertainty that lead to anxiety [30]. In a recent study, Gao et al. [27] found that anxiety was one of the most persistent mental health concerns among Chinese university students. Results of this study found that anxiety tends to dissipate toward the fourth year, perhaps as students become more accustomed to the university routine (therefore less uncertainty) and develop better coping strategies ([27,40]). Gao and colleagues [27] also reported that females were more significantly impacted by anxiety, and this anxiety was related to drinking habits and body image, especially in the first and second year of university that may suggest differences in female coping.

Contradictory findings report higher IU in males [3], which may be attributed to cultural biases (i.e., heightened societal expectations for males in Iranian academic settings). In females, low perceived control [44], might increase the use of maladaptive coping (i.e., rumination) in response to uncertainty [38]. In this study, SS and IU are risks of anxiety in both males and females, however heightened risk of anxiety in females may be partially attributed to interpretational, coping and/or situational factors that differ between sexes. Further empirical research is necessary to test these possible explanations.

4.1. Limitations

There are some limitations of this study. First, although still controversial in the literature, undergraduate participants may not

represent the general population [32]. Therefore, these findings should be replicated in community and clinical samples as well as with different age groups not only to assume the generalizability of the model but also to ensure consistency of a dimensional approach to the investigation of anxiety risks. For this reason, it is also important to explore anxiety severity (mild, moderate, severe) as a differential outcome of the relationship among the vulnerability factors, and perhaps the relationship between SS, IU and anxiety is further exemplified in those with more severe, and clinical levels of anxiety. Second, there are also known challenges related to using self-report questionnaires. Self-report questionnaires may include response bias as anxiety may be under or over reported. Future research should experimentally manipulate IU by creating both certain and uncertain conditions to explore the mechanisms (i.e., coping strategies) that drive the relationship between IU and anxiety, while accounting for individual differences. Third, we analyzed sex as a binary (male and female) variable. Future studies should account for the spectrum of genders in this model.

4.2. Conclusions

Overall, our findings demonstrate that SS is a strong predictor of anxiety, and highlights the contribution of IU as one potential mechanism responsible for heightened anxiety often observed in individuals high in SS. In addition, findings also provide evidence of sex differences with respect to IU and anxiety, and we suggest sex differences in the response to uncertainty in females. Such knowledge may redefine our understanding of the cognitive mechanisms that underlie sex differences in the tolerance of uncertainty and anxiety, and may partially explain the female sex disparity in anxiety. Understanding the mechanisms that contribute to increased anxiety in emerging adults, especially in university students, is crucial to inform support and prevention practices in higher education.

Author contribution statement

Veronica Panchyshyn: Conceptualization; Analyzed and interpreted the data; Wrote the paper. Ayda Tekok-Kilic: Conceived and designed the study; Analyzed and interpreted the data; Wrote the paper. Jan C. Frijters: Analyzed and interpreted the data; Conceptualization; Review & editing;. Christine Tardif-Williams: Analyzed and interpreted the data; Conceptualization; Review & editing.

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Data availability statement

Data is not available.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e14071.

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