Interplay of Socio-Emotional Vulnerability and Physiological Stress Response: Unraveling Distress Patterns Amidst the COVID-19 Pandemic

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Abstract

The COVID-19 pandemic led to increased internalizing symptoms (IS) among adults, with notable interindividual differences. Cross-sectional studies suggest that both biological (physiological stress) and psychological (socio-emotional) factors independently contribute to IS. This longitudinal study examined whether physiological stress during the pandemic moderated the relationship between socio-emotional vulnerability and IS. In June 2020, 94 adults (average age 34.16) provided a 6cm hair sample, allowing the quantification of cumulative hair cortisol concentrations (HCC) during the three months preceding the pandemic (Seg.A) and the three months of the pandemic's first wave in Quebec, Canada (Seg.B). We calculated HCC reactivity (rHCC) as the percent change between the two segments. A socio-emotional composite score (SECS) was derived using the Anxiety Sensitivity Index, Intolerance of Uncertainty Scale, and Perseverative Thinking Questionnaire. Every three months from June 2020 to March 2021, participants completed the Depression Anxiety Stress Scales and Impact of Event Scale. Analyses revealed an interaction between Time, SECS, and rHCC on stress, and between SECS and rHCC on depressive symptoms. High rHCC was associated with a stronger correlation between SECS and stress symptoms in September and December 2020, significant transition periods during the pandemic in Quebec. Additionally, individuals with high rHCC exhibited fewer depressive symptoms, irrespective of time. Our findings suggest that the activation of the physiological stress system at the beginning of the pandemic increased stress during subsequent transition periods and mitigated depressive symptoms over time in individuals with greater socio-emotional vulnerability, contributing to the literature on vulnerability and protective factors towards enduring stressors.

1. Introduction

The COVID-19 pandemic has had profound implications for global mental health (Hossain et al., 2020). Control measures implemented to curb the virus spread, such as quarantines and social distancing protocols, have led to an increase in feelings of isolation and a sense of disconnection from social support networks (Hwang et al., 2020). Additionally, the shift to remote work and online education has introduced new challenges related to stress and work-life balance (Gigauri, 2020). These pressures have led to a surge in conditions like clinical anxiety and major depression, which significantly affect daily functioning (for a review, see Daly & Robinson, 2022). Even healthy adults have reported elevated levels of distress, marked by heightened symptoms of depression, stress, anxiety (for a meta-analysis, see Robinson et al., 2022), and post-traumatic stress symptoms (PTSS; for a systematic review, see Hong et al., 2021). Some studies have identified specific demographic variables as vulnerability factors, such as being a woman (Sun et al., 2023) and a parent (Westrupp et al., 2023).

Still, according to a meta-analysis encompassing 137 unique studies from 134 cohorts of youths and adults, the impact of the pandemic on mental health has varied greatly (Sun et al., 2023). Despite speculation of a potential worsening effect on mental health, the meta-analysis revealed that most estimates of symptom change for general mental health, anxiety, and depression were near zero and not statistically significant (Sun et al., 2023). The varied mental health effects of COVID-19 highlight the need to comprehend vulnerability and protective factors under chronic stress. This understanding could facilitate early detection and tailored interventions during crises like pandemics, improving support for at-risk individuals.

Prior to COVID-19, research has identified several socio-emotional factors associated with distress during chronic stress or traumatic events. These factors include anxiety sensitivity, the fear of anxious symptoms causing illness or increased anxiety (Naragon-Gainey, 2010); intolerance of uncertainty, a person's adverse responses to ambiguity (Boswell et al., 2013); and perseverative cognitions, which involve intrusive, recurrent thoughts about negative events (Sorg et al., 2012). These factors, typically highly correlated, have individually been linked to the development, chronicity, and severity of clinical anxiety, post-traumatic stress disorder (PTSD), and major depressive disorders (Clancy et al., 2022; Gentes & Ruscio, 2011; Makovac et al., 2016, 2020;

Naragon-Gainey, 2010; Yang et al., 2014; Yook et al., 2010). However, previous studies have primarily focused on assessing the individual predictive value of these factors on internalizing distress rather than considering their combined contribution. To address this gap, our research group recently investigated the combined contribution of these factors, which we referred to as the "*socio-emotional composite score*" (SECS), in predicting internalizing symptoms in response to COVID-19 among youth aged 9 to 14 years old (Raymond, Bilodeau-Houle, et al., 2022; Raymond, Provencher, et al., 2022). The integration of these predictors in the SECS holds the potential to provide a more comprehensive and global understanding of the role of socio-emotional vulnerability in internalizing distress among adults.

Another factor influencing internalizing distress following a stressful/traumatic event is the physiological stress response (Pacella et al., 2017; Petrowski et al., 2020; Steudte-Schmiedgen et al., 2015). This response entails a cascade of physiological alterations initiated when the brain perceives a threat. One of the key systems activated in response to stress is the hypothalamic-pituitary-adrenal (HPA) axis, which ultimately leads to the production of the stress hormone cortisol (Sapolsky et al., 2000). Typically, cortisol levels are assessed through saliva samples, providing insights into acute concentrations of basal (reflecting diurnal rhythm) or reactive cortisol (indicating stress-induced response (Gray et al., 2018)). In recent years, an increasing number of studies have explored the use of hair samples as a method for quantifying cortisol (Stalder et al., 2017). Unlike saliva, hair samples offer the advantage of examining cumulative cortisol secretion over an extended period, as hair grows at approximately one centimetre per month, providing a retrospective measure of long-term biological stress (Stalder et al., 2017).

While short-term activation of the HPA axis is adaptive, sustained imbalances can be detrimental to mental health due to the abundance of cortisol receptors in brain regions critical for cognitive and emotional regulation (Fries et al., 2005; Lupien et al., 2009). Therefore, any deviation from normal cortisol levels, whether high or low, can negatively impact mental health (Dziurkowska & Wesolowski, 2021). For example, Steudte-Schmiedgen et al. (2015) demonstrated that lower hair cortisol concentrations (HCC) before trauma exposure were associated with a greater increase in PTSS among soldiers. This result suggests that the role of cortisol extends beyond being a mere stress indicator to potentially serving as a buffer against intensifying stress outcomes. Conversely,

other studies presented a different perspective, suggesting that elevated HCC post-trauma were predictive of increased long-term depressive (Petrowski et al., 2020) and PTS (Pacella et al., 2017) symptoms. This could also imply that while a surge in cortisol could be protective in some situations and for some individuals, sustained high levels may set the stage for long-term psychological distress.

Several factors may explain the discrepancies in these results. A significant factor is the timing of HCC assessment. Some studies measure pre-trauma cortisol levels to indicate baseline cortisol (Steudte-Schmiedgen et al., 2015), while others assess post-trauma levels to reflect the stress system's reactivity to trauma (Pacella et al., 2017; Petrowski et al., 2020). However, without baseline measures, it is difficult to determine if post-trauma levels accurately represent the system's response to the stressor. In this context, our team recently demonstrated that a greater increase in HCC at the beginning of the pandemic predicted fewer PTSS in children at the onset of the pandemic (Bilodeau-Houle et al., 2024). Second, these seemingly contrasting findings not only compel us to delve deeper into the complex relationship between cortisol levels and mental health outcomes in high-stress situations but also to consider the interplay between cortisol and socio-emotional vulnerabilities in predicting distress following exposure to stressors. More specifically, they raise the question of whether abnormal cortisol responses to stress, especially when compounded by pre-existing socio-emotional vulnerabilities, could be the foundation of the enduring psychological impacts observed in the aftermath of major stressful events, such as the COVID-19 pandemic.

This layered understanding could hold the key to better comprehending the interaction between physiological and socio-emotional factors during the pandemic, providing insights into the development and maintenance of stress-related disorders. This study aimed to investigate the role of typical socio-emotional predictors of distress, including anxiety sensitivity, intolerance of uncertainty, and perseverative cognition, alongside hair cortisol secretion, in predicting distress longitudinally throughout the enduring stressor of the COVID-19 pandemic. First, we hypothesized that higher socio-emotional vulnerability would be associated with higher levels of symptoms. Second, we hypothesized that these results would be modulated by HCC, though the direction of the association remained unclear due to conflicting and relatively limited findings in the literature.

By examining these factors, we aim to contribute to the scientific literature on vulnerability and protective factors towards enduring stressors.

2. Material and Methods

2.1 Participants

This study was approved by the ethics committee of the *Centre intégré universitaire de santé et de services sociaux de l'Est-de-l'Île-de-Montréal*. Participants for this study were enlisted based on their prior involvement in one of our laboratory-based experiments conducted between 2017 and 2019 (T0). These previous research aimed to 1) study observational fear learning within families (for further details on the purpose of the study, methods used, and obtained results, see (Marin et al., 2020) and (Bilodeau-Houle et al., 2020)) and 2) study the effect of stress on fear conditioning and fear extinction among healthy young adults (Peyrot et al., 2024, Peyrot et al., unpublished). For these two larger studies, participants were recruited through advertisements on social media and posters in the surroundings of our research centre. We reached out to 232 of the original participants who had previously agreed to be recontacted for future studies. Of these, 156 (67.24%) agreed to participate in this follow-up study (June 2020; T1), which aimed to 1) assess internalizing distress longitudinally between June 2020 and March 2021, and 2) evaluate the participants' HCC in response to the COVID-19 pandemic (refer to **Figure 1** for a timeline overview). The selection of participants from previous studies facilitated longitudinal assessment of variables related to fear conditioning and fear extinction; however, these aspects, while integral to the original studies, were not the focus of the present report and thus were not included in the analysis. Participants were included in the main analyses only if they met the two following criteria: 1) having completed the three questionnaires evaluating socio-emotional vulnerability (refer to the Measures section - **Section 2.2**), and 2) having provided a 6cm hair sample (refer to the Hair Sample Collection section). As a result, the final sample size was comprised of 90 participants (75 women; 83.3%) aged between 19 and 54 years old (M = 34.16, SD = 8.86).

At T0, all participants were free of chronic physical illnesses, psychopathologies, and were not taking medication. At T1 (June 2020), four participants reported that they had a past or current psychiatric disorder diagnosed by a health care professional. Given that psychiatric disorders can

influence the HPA axis activity and consequently impact HCC (Stalder et al., 2017), we ran our analyses twice (once including these four subjects, once without). As the inclusion of these participants did not significantly impact our findings, all participants were included in the final set of analyses.

2.2 Measures

2.2.1 Questionnaires assessing socio-emotional vulnerability

Anxiety Sensitivity Index (ASI): The ASI (Reiss et al., 1986) measures anxiety sensitivity. It consists of 16 items, rated on a 5-point Likert scale ranging from 0 (very little) to 4 (very much). The total ASI score ranges from 0 to 64. The English version typically shows Cronbach's alpha coefficients ranging from 0.80 to 0.90 (Deacon et al., 2003). The validated French version (Verreault et al., 2007) used in this study demonstrated a Cronbach's alpha coefficient of 0.85.

Intolerance of Uncertainty Scale 12 (IUS-12): The IUS-12 (Carleton et al., 2007) consists of 12 items with response choices in the form of a 5-point Likert scale ranging from 1 (not at all corresponding) to 5 (completely corresponding). The IUS-12 is the validated short version of the IUS-27 (original French version: Freeston et al., 1994). It assesses reactions to uncertainty, ambiguous situations, and the future. The overall internal consistency of the IUS-12 is excellent, with a Cronbach's alpha coefficient of 0.91 (Carleton et al., 2007). The items are divided into two subscales: unacceptability and avoidance of uncertainty, and uncertainty-related frustration, both of which have Cronbach's alpha coefficients of 0.85 for internal consistency (Carleton et al., 2007). The original French version of the IUS-12 has an internal consistency of 0.85 (Freeston et al., 1994).

Perseverative thinking questionnaire (PTQ): The PTQ (Ehring et al., 2011) measures the trait of rumination. It consists of 10 items, with responses chosen on a Likert scale ranging from 0 = "never" to 4 = "almost always". The overall score ranges from 0 to 40. A high score indicates a greater tendency to have repeated negative thoughts. The French version of the questionnaire, which was used in the current study, has excellent internal consistency with a Cronbach's alpha coefficient of 0.92 (Devynck et al., 2017).

2.2.1 Questionnaires assessing psychological distress

Depression, Anxiety and Stress Scale (DASS-21): The DASS-21 (Lovibond & Lovibond, 1995) is a validated scale used to assess depression, anxiety, and stress. It consists of 21 items, with responses chosen on a Likert scale ranging from 0 (does not apply to me at all) to 3 (applies very much to me or most of the time). It comprises three subscales: depression, anxiety, and stress. The total score for the depression subscale is defined as follows: 0-9 = normal, 10-12 = mild depression, 13-20 = moderate depression, 21-27 = severe depression, and 28-42 = extremely severe depression. For the anxiety subscale, a score of 0-6 is considered normal, 7-9 as mild anxiety, 10-14 as moderate anxiety, 15-19 as severe anxiety, and 20-42 as extremely severe anxiety. For the stress subscale, 0-10 is considered normal, 11-18 as mild stress, 19-26 as moderate stress, 27-34 as severe stress, and 35-42 as extremely severe stress. The test has good internal consistency with Cronbach's alpha coefficients ranging from 0.89 to 0.94 (Norton, 2007). We utilized the French version of the questionnaire, developed by Donald Martin's team at the University of Ottawa, which is available online (Donald, 2012). The French version of the questionnaire also has good internal consistency with Cronbach's alpha coefficients ranging from 0.80 to 0.91 (Donald, 2012).

Impact of Event Scale-Revised (IES-R): To assess perceived stress in response to a traumatic event, we used the French version of the IES-R (Brunet et al., 2003), which has been validated and translated from the original English version (see Creamer et al., 2003 for psychometric properties). The IES-R is based on the DSM-IV and highly correlated with the Posttraumatic Stress Disorder Checklist (PCL; (Weathers et al., 2013)), based on the DSM-V (Sveen et al., 2016). The IES-R consists of 22 items, and responses are chosen based on a Likert scale ranging from 0 (not at all) to 4 (extremely). The overall score is obtained by summing the scores of each item (ranging from 0-88). A score of 0-23 is defined as normal, 24-32 as having mild psychological impact, 33-36 as having moderate psychological impact, and above 37 as having severe psychological impact. It is also possible to calculate scores based on the three subscales of post-traumatic symptoms: re-experiencing, avoidance, and hyperarousal (physiological reactions). Both the original (English) and the French versions of the questionnaire show good internal consistency, with Cronbach's alpha coefficients ranging from 0.81 to 0.93, depending on the subscales (Brunet et al., 2003; Christianson & Marren, 2012).

2.3 Procedure

2.3.1 Questionnaires completion

Participants completed the French versions of these questionnaires via Qualtrics, an online based and highly secure platform. To access the platform, a personalized URL link was sent to each participant via email at each study timepoint. In June 2020 (T1), during the first trimester of the pandemic, participants responded to questions about their current or past psychiatric disorders and filled out the PTQ. In September 2020 (T2), participants completed the ASI and the IUS-12.

To track distress over the course of a year since the onset of the pandemic, participants filled out the IES-R and DASS-21 questionnaires at four different time points: June 2020 (T1), September 2020 (T2), December 2020 (T3), and March 2021 (T4). This allowed assessing distress during the first year of the pandemic.

2.3.2 Hair sample collection

In June 2020 (T1), participants were instructed to collect hair samples at home. As demonstrated by Enge et al. (2020), self-collection of hair samples is a valid method to measure HCC. For our study, participants needed to provide a sample of 6 cm in length (to allow for the analysis of two 3 cm segments within the same sample). As hair grows 1 cm per month on average (Stalder & Kirschbaum, 2012), each segment (A and B) should represent a period of approximately three months: Segment A represents hair growth from mid-December 2019 to mid-March 2020 (before the start of the first wave of COVID-19 in Canada) and Segment B represents hair growth from mid-March 2020 to mid-June 2020 (corresponding to the first wave of the pandemic in Canada; see **Figure 1** for timeline overview).

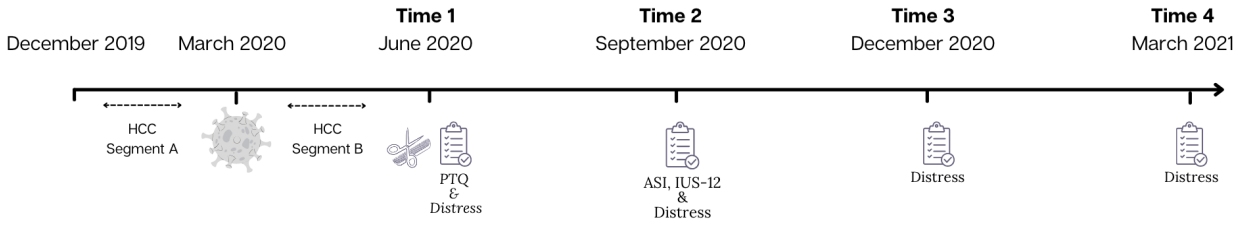

Figure 1. Timeline overview. Timeline of hair collection and questionnaires completion. Distress was assessed using the Depression, Anxiety and Stress Scale and the Impact of Event Scale-Revised. ASI: Anxiety Sensitivity Index; HCC: Hair cortisol concentrations; IUS-12: Intolerance of Uncertainty Scale 12; PTQ; Perseverative Thinking Questionnaire.

Participants were instructed to collect their hair sample from the occipital region of the scalp. To do so, participants had to comb their hair, separate a strand of at least 1 cm wide, and place the hair clamps 1 cm from the scalp to hold the hair in place. To ensure that the sample was sufficient, participants were told to lay their sample on a piece of cardboard provided by our research team. The cardboard featured several lines that were separated by 1 cm (similar to those on a ruler) to help the participant determine whether more/less hair needed to be added to their sample. Then, they had to cut the section of hair as close to the scalp as possible with a pair of scissors. The sample was then layed on the piece of aforementioned cardboard, secured with adhesive tape, and inserted in a plastic bag and envelope provided by our team. Participants sent their hair samples to the laboratory in a postage-paid envelope. After the hair collection, participants completed an online home-based questionnaire assessing their hair characteristics (e.g., washing frequency, hair products (type and frequency of use)).

2.4 Hair analyses

Wash and steroid extraction procedures were conducted at the Centre for Studies on Human Stress in Canada (http://humanstress.ca/saliva-lab/general-information/). For each participant, two 3 cm segments of hair (25 mg each) were analyzed separately to quantify cortisol concentrations in the corresponding periods (Segments A and B). Samples were assayed in duplicate using a luminescence immunoassay (detection range: 0.005–4 µg/dl; intra-assay coefficient of variation was 5.24 %; inter-assay coefficient of variation was 8.78 %). Salimetrics specifies that reliable analyses should have intra- and inter-assay coefficients of variation lower than 10 % and 15 %, respectively.

2.5 Statistical analyses

Analyses were run using IBM SPSS Statistics, version 26. Data were examined and standardized data (Z scores) below -3.29 or above 3.29 (thresholds based on Tabachnick & Fidell, 2007) were considered outliers and thus, winsorized. The winsorization process allows to minimize the influence of outliers by replacing the extreme values by the maximum and/or minimum values at the established thresholds (Tabachnick & Fidell, 2007). Two participants presented extreme elevated HCC (one participant on Segment A, one on Segment B). At T1, two participants presented extreme elevated scores on depressive and stress symptoms. At T4, two presented extreme elevated scores on PTS and anxiety symptoms. Analyses were run twice: once including the winsorized values and once excluding them. As no difference was found between the two sets of analyses, winsorized data were included in the final analyses. Since our sample primarily consisted of women (83.3 %) and to prevent our results from being influenced by sex bias, the analyses were performed a second time excluding men. As the same results were obtained, men were included in the final analyses. The distribution of our variables was also assessed for skewness and kurtosis prior to conducting the statistical analyses. Using indices for acceptable limits of ± 2 (Curran et al., 1996), data were found to be normally distributed. Therefore, no transformation was applied to the raw values.

2.4.1 Initial treatment of the data

Socio-emotional composite score: In order to create a socio-emotional composite score (as used previously by our team (Raymond, Bilodeau-Houle, et al., 2022; Raymond et al., 2023; Raymond, Provencher, et al., 2022), z-scores were generated for each of the following questionnaires: ASI, IUS-12, and PTQ and were then averaged for each participant, providing a weighted score, and is referred to as the *socio-emotional composite score* (SECS).

Body mass index: Given previous studies showing that body mass index (BMI) significantly influences cortisol secretion (Törnhage & Alfvén, 2006; Odeniyi et al., 2015), height and weight were obtained at T1 (time of hair collection). BMI was calculated using the following formula: weight in kilograms divided by height (m^2).

Relative change in hair cortisol concentration: To quantify the relative change in hair cortisol concentrations (rHCC), we calculated the percentage change between Segment A (pre-pandemic) and Segment B (during the pandemic). This was computed using the formula: ((Segment B-Segment A)/Segment A)*100. This measure reflects the proportional change in cortisol levels in reference to the onset of the pandemic.

Internalizing distress: To select appropriate covariates while limiting the number of statistical analyses performed on a relatively small sample, combined with the fact that the same potential covariates apply to all of the selected internalizing symptoms, we conducted preliminary analyses on a composite score of internalizing distress over the four timepoints. We created a composite score of internalizing distress. Z-scores were generated for each of the following DASS-21 subscales: stress, anxiety, depressive, and post-traumatic stress symptoms. These scores were then averaged for each participant, providing a weighted score. This score is referred to as the *internalizing distress composite score*.

2.4.2 Preliminary analyses

First, the correlations between the main predictors were examined before pooling them to calculate the SECS. Next, we verified the correlations between depressive, anxiety, stress and PTS symptoms as well as their descriptive statistics across the four time points (minimum, maximum, mean, SD and N > clinical threshold).

Finally, we conducted preliminary analyses using a linear mixed model to select the covariates to include in the final model. The potential covariates considered in the analysis included various socio-demographic measures (sex, age, ethnicity, relationship status, occupational status, annual income and highest level of education completed) as well as BMI, variables known to influence the predictors of interest and/or the dependant variables. The inclusion criterion for variables was set at $p < .100$.

2.4.3 Main analyses

Thereafter, we conducted four linear mixed models to predict changes in the three subscales of the DASS-21 (depressive, anxiety and stress symptoms) as well as in the total score of the IES-R (PTS symptoms). Restricted maximum likelihood (REML) was applied (Banks et al., 1985). 'Subjects' were considered as a random effect. Time (four levels: T1 to T4), sex (two levels: women, men), the SECS, rHCC as well as the interaction terms between Time*SECS, Time*rHCC, and Time*SECS*rHCC were entered as predictors. Between-subjects and within-subjects post-hoc comparisons were performed using Sidak's multiple comparisons test. Based on the preliminary analyses, sex, BMI and occupational status were entered as covariates in the main analyses. Finally, other forms of internalizing symptoms were included as covariates in the models to ensure that the results were not better explained by other symptom forms. For example, in models where depressive symptoms were the outcome variable, stress, anxiety, and PTS symptoms were included as covariates.

3. Results

3.1 Sample characteristics

Sample characteristics are presented in **Table S1,** which can be found in the Supplemental material document.

3.2 Preliminary analyses

The model tested to select the covariates revealed a main effect of Time (see **Table S2** of the Supplemental material for statistical indices). However, during post-hoc analyses, no significant differences were found between the pairs of timepoints that were compared (p-values > .134). We also found an effect of sex and relationship status. Specifically, post-hoc analyses indicated that women and individuals who were not in a relationship reported significantly higher levels of internalizing distress than men and those who were in a committed relationship.

We also found that, as expected, the socio-emotional predictors included in the composite score were correlated, and that the internalizing distress measures (depression, stress, anxiety, and PTSS) were correlated with each other. These results are presented in **Tables S3** and **S4** of the Supplemental material document.

SECS (mean z-scores) varied between -1.12 and 2.41 (M = 0.00, SD = 0.80) Descriptive statistics for depressive, anxiety, stress and PTS symptoms as a function of the four study timepoints are presented in **Table S5** (Supplemental material).

The participants had mean HCC levels of 15.77 pg/mg (SD = 14.76) in Segment A and 16.85 pg/mg (SD = 23.87) in Segment B. Upon conducting a repeated measures ANOVA to examine the Time effect between the two segments, we found no significant main effect of Time [$F(1,78) = 0.246$, $p = .621$], Sex [$F(1,78) = 0.063$, $p = .802$], or Time*Sex interaction [$F(1,78) = 0.850$, $p = .327$]. The two segments displayed a strong correlation [$r = .836$; $p < .001$], emphasizing the importance of employing rHCC to circumvent multicollinearity. Subsequently, we used the percentage change between the two segments (rHCC) to reduce iterations and increase our statistical power. rHCC (%) varied between -89.74 and 378.95 (M = 0.07, SD = 68.91).

3.3 Main analyses

Depressive symptoms

For depressive symptoms (see **Table 1** for statistical indices), the model revealed main effects of stress, PTS symptoms and SECS. We also found a SECS*rHCC interaction. Simple slopes analyses revealed that SECS positively predicted depressive symptoms (irrespective of Time) in individuals with low rHCC, but not in those with high rHCC (see **Figure 3A** for statistical indices). The other main and interaction effects of the model were non-significant.

	Numerator *df*	Denominator *df*	F	*p*
Covariates				
Relationship status	1	79.981	0.306	.582
PTS symptoms	1	277.293	12.229*	<.001
Anxiety symptoms	1	266.544	3.478	.063
Stress symptoms	1	263.327	69.403*	<.001
Sex	1	82.804	0.582	.448
BMI	1	85.256	1.276	.262
Main effects				
Time	3	81.227	1.465	.230
SECS	1	103.658	3.885*	.050
rHCC	1	87.299	1.630	.205
Interactions				
Time x rHCC	3	79.730	0.473	.702
Time x SECS	3	78.364	0.410	.746
SECS x rHCC	1	81.543	4.889*	.030
Time x SECS x rHCC	3	78.335	0.894	.448

Table 1. General linear model results for depressive symptoms. BMI: Body mass index; rHCC: hair cortisol concentrations reactivity; PTSS: post-traumatic stress symptoms; SECS: socio-emotional composite score. *indicates statistical significance set at $p < .05$.

Anxiety symptoms

For anxiety symptoms (see **Table 2** for statistical indices), the model revealed a main effect of PTS and depressive symptoms. We also found a main effect of SECS, where greater SECS predicted greater anxiety symptoms, irrespective of Time ($\beta = .579$, $p < .022$). The other main and interaction effects of the model were non-significant.

	Numerator *df*	Denominator *df*	F	*p*
Covariates				
Relationship status	1	80.278	1.180	.326
PTS symptoms	1	275.692	14.126*	<.001
Stress symptoms	1	291.792	43.815*	<.001
Depressive symptoms	1	277.652	2.724	.100
Sex	1	80.882	0.054	.818
BMI	1	79.463	1.986	.163
Main effects				
Time	3	84.860	0.706	.551
SECS	1	103.937	5.387	.022
rHCC	1	89.050	1.915	.170
Interactions				
Time x rHCC	3	90.210	0.950	.420
Time x SECS	3	81.229	1.094	.356
SECS x rHCC	1	84.069	0.552	.460
Time x SECS x rHCC	3	81.334	1.903	.136

Table 2. General linear model results for anxiety symptoms. BMI: Body mass index; rHCC: Hair cortisol concentrations reactivity; PTSS: post-traumatic stress symptoms; SECS: socio-emotional composite score. *indicates statistical significance set at $p < .05$.

Stress symptoms

For stress symptoms (see **Table 3** for statistical indices), we found a main effect of Time, depressive and anxiety symptoms. The model also revealed a main effect of SECS as well as Time*SECS and Time*SECS*rHCC interactions. Simple slopes analyses revealed that rHCC moderated the association between SECS and stress symptoms at T2 (September 2020) and T3 (December 2020; see **Figure 3B** for statistical indices). Specifically, higher SECS combined with elevated rHCC was associated with increased stress symptoms at both T2 and T3.

	Numerator *df*	Denominator *df*	F	*p*
Covariates				
Relationship status	1	79.752	0.401	.807
PTS symptoms	1	295.026	0.507	.477
Depressive symptoms	1	276.393	78.611*	<.001
Anxiety symptoms	1	273.312	5.076*	<.001
Sex	1	84.406	1.707	.195
BMI	1	84.061	0.978	.326
Main effects				
Time	3	86.725	3.886*	.012
SECS	1	102.519	11.840*	<.001
rHCC	1	92.946	0.435	.511
Interactions				
Time x rHCC	3	88.903	1.436	.238
Time x SECS	3	84.407	3.476*	.020
SECS x rHCC	1	86.818	0.025	.875
Time x SECS x rHCC	3	83.707	3.656*	.016

Table 3. General linear model results for stress symptoms. BMI: Body mass index; rHCC: Hair cortisol concentrations reactivity; PTSS: post-traumatic stress symptoms; SECS: socio-emotional composite score. *indicates statistical significance set at $p < .05$.

Post-traumatic stress symptoms

For PTSS (see **Table 4** for statistical indices), we found main effects of depressive and anxiety symptoms as well as a main effect of sex and Time. Post-hocs revealed greater PTSS in women compared to men (p = .020) and that PTSS at T1 (June 2020) were greater than those at T2 (September 2020; p = .020) and those at T4 (March 2021; p = .001). No other pairwise comparisons reached statistical significance (p > .130). Finally, we found a main effect of SECS, where greater SECS predicted increased PTSS, irrespective of Time (β = .250, p = .023).

	Numerator *df*	Denominator *df*	F	*p*
Covariates				
Relationship status	1	79.942	1.616	.178
Depressive symptoms	1	280.413	13.941*	<.001
Anxiety symptoms	1	292.92	10.458*	<.001
Stress symptoms	1	273.325	0.598	.440
Sex	1	82.156	5.171*	.026
BMI	1	84.933	2.023	.159
Main effects				
Time	3	81.015	5.535*	.002
SECS	1	107.366	5.355*	.023
rHCC	1	90.899	0.009	.926
Interactions				
Time x rHCC	3	82.357	0.485	.693
Time x SECS	3	79.257	1.942	.130
SECS x rHCC	1	85.477	0.33	.567
Time x SECS x rHCC	3	80.445	0.415	.743

Table 4. General linear model results for post-traumatic stress symptoms. BMI: Body mass index; rHCC: Hair cortisol concentrations reactivity; SECS: socio-emotional composite score. *indicates statistical significance set at p < .05.

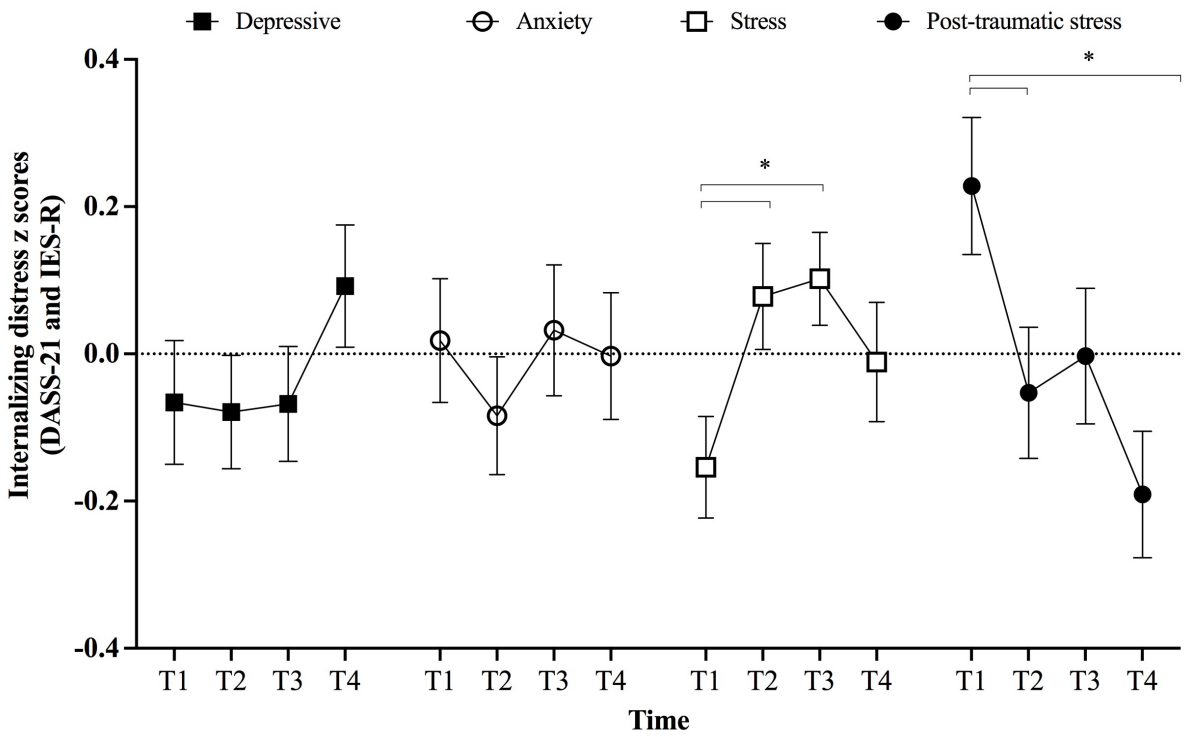

Figure 2. Depressive, stress, anxiety and post-traumatic stress symptoms over time. Z score means are adjusted for time, sex, BMI, SECS, rHCC and the other forms of internalizing symptoms. T1: June 2020; T2: September 2020; T3: December 2020; T4: March 2021. Error bars represent the standard error of the mean. *indicates statistical significance set at $p < .05$.

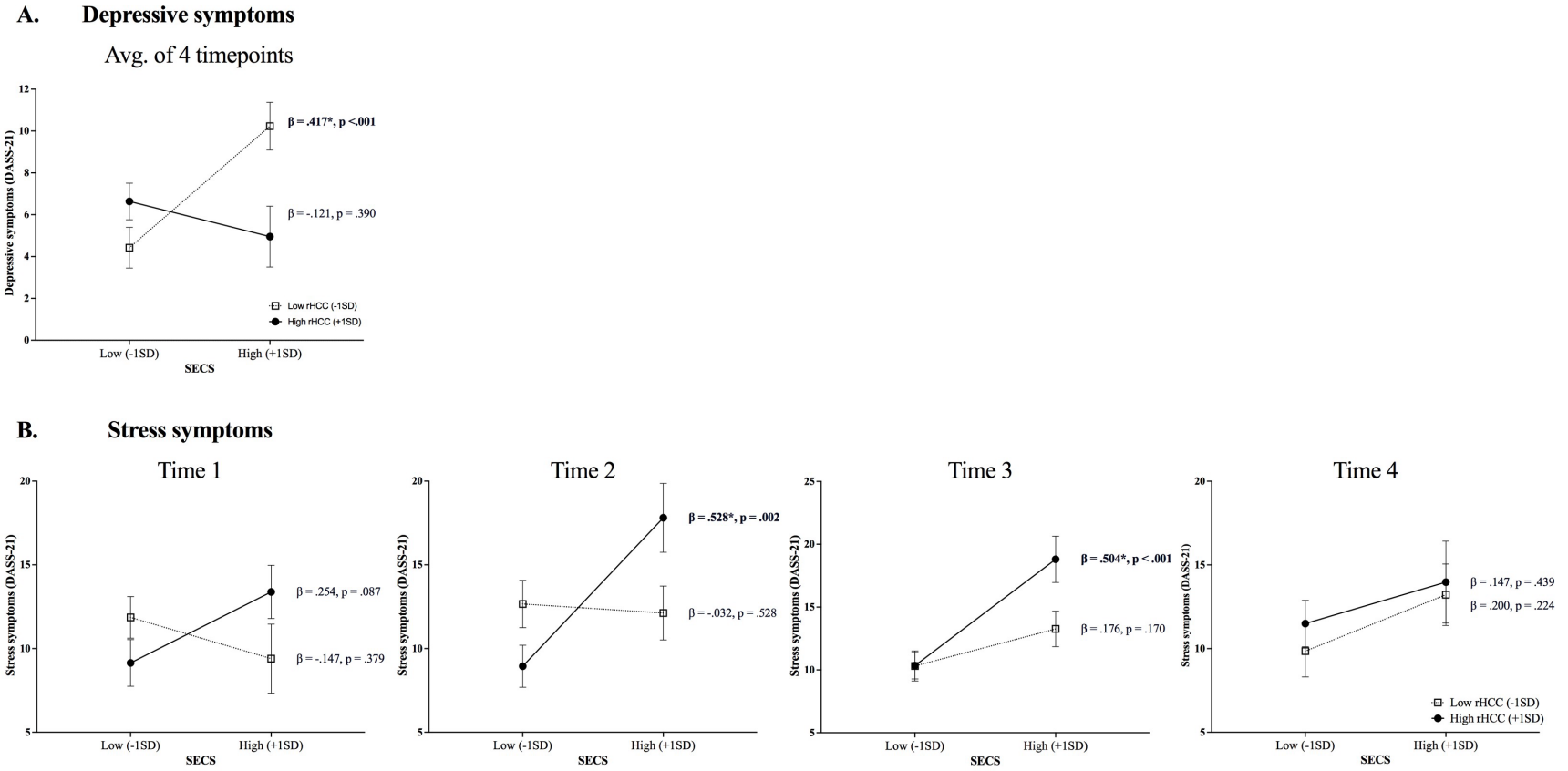

Figure 3. Moderation analyses for depressive (A) and stress (B) symptoms. **A.** rHCC moderates the association between SECS and depressive symptoms, irrespective of Time. Mean depressive symptoms across the four timepoints. **B.** rHCC moderates the association between SECS and stress symptoms at Time 2 and Time 3. Means are adjusted for the following covariates: sex, BMI and other forms of internalizing symptoms. SECS of 1SD below and above the mean are presented on each panel. Error bars represent the standard error of the mean. Avg.: Average; rHCC: Hair cortisol concentrations reactivity; SECS; socio-emotional composite score. * indicates statistical significance set at $p < .05$.

4. Discussion

Our longitudinal research, carried out in Quebec, Canada throughout a year of the COVID-19 pandemic, explores the intricate interplay between socio-emotional vulnerability to psychopathology, physiological stress response (as denoted by a reactivity in hair cortisol concentrations [rHCC]), and the resulting distress stemming from the pandemic among healthy adults. The unfolding global health crisis offered a unique context to assess the influence of these factors over time, allowing us to delve into the dynamic and potentially adaptive nature of the stress response in the face of a pervasive stressor.

Contrary to some expectations, we observed that participants' internalizing symptoms, notably depressive and anxious symptoms, remained stable for the year following the first COVID-19-related lockdown. This observation is consistent with the meta-analysis undertaken by Sun and colleagues (2023), indicating the absence of a temporal impact on internalizing symptoms following the COVID-19 pandemic. However, we did note an increase in subjective stress symptoms at Time 2 (September 2020) and Time 3 (December 2020). This might be attributable to the specific circumstances related to the pandemic that were present during these periods in Quebec, Canada. For example, the September timeframe corresponds to the "back to school" period, potentially impacting our participant population, which consisted of parents of school-going children (40%) and university students (60%), being particularly relevant since students in the Greater Montreal area were home-schooled since March 2020 due to pandemic-related measures. The December period (T3) coincided with the holiday periods, when family gatherings were curtailed last minute due to pandemic restrictions, and the imposition of Quebec's first curfew. The perception of novelty, uncontrollability, and unpredictability in these situations, which are scientifically proven to increase stress (Dickerson & Kemeny, 2004; Mason, 1968), likely influenced the observed rise in stress symptoms. Unfortunately, we lack early pandemic (March 2020) measures of stress symptoms. The availability of such data might have facilitated an analysis of whether this pattern was manifest during the onset of the pandemic, a period characterized by significant adaptation requirements.

In contrast to the increase in post-traumatic stress symptoms (PTSS) reported by other studies (for a systematic review, see Hong et al., 2021), we found an attenuation of PTSS over the year following the first lockdown. This might be attributed to the recruited participants, who were healthy subjects, gradually becoming accustomed to the COVID-19 environment and the restrictions imposed. Such adaptation could lead to a decrease in COVID-19 related PTSS, such as avoidance behaviors, intrusive thoughts about the pandemic, and heightened arousal levels in response to pandemic-related triggers.

We also sought to discern whether internalizing distress was influenced by personal determinants, like socio-emotional vulnerability to psychopathology. As hypothesized, we found that a heightened expression of socio-emotional vulnerability predicted amplified depressive, anxiety, stress and post-traumatic stress (PTS) symptoms in healthy adults in the year following the COVID-19-related lockdown, regardless of the measurement time. This finding builds upon prior research from our team, which demonstrated a similar relationship between the same socio-emotional vulnerability score and the emergence of heightened internalizing symptoms over the year following confinement measures in children (Raymond , Provencher, et al., 2022). This result complements the diathesis-stress, model indicating how pre-existing vulnerabilities (diathesis) in individuals interact with external stressors (like the pandemic), thereby influencing the trajectory of psychological outcomes (for a review, see (Broerman, 2020)). Although this model is widely accepted within the scientific community, it has faced critiques over the last decade (Elwood et al., 2009). A primary critique is its oversimplification of the complex interplay between biological predispositions and environmental stressors, often failing to account for the nuanced ways individuals respond to these influences (Belsky & Pluess, 2009). Our results address this critique by demonstrating that socio-emotional vulnerabilities modulates the association between biological predisposition (here, the physiological stress system) and distress in the aftermath of an enduring stressor such as a pandemic. These findings enrich the theoretical understanding of continuous stress effects and underscore the importance of considering both pre-existing vulnerabilities and ongoing physiological stress in predicting psychological outcomes.

Indeed, our research revealed a significant interplay between SECS and HCC reactivity to the pandemic in forecasting stress and depressive symptoms. More precisely, individuals exhibiting

elevated socio-emotional vulnerability alongside pronounced cortisol reactivity reported escalating stress levels at Time 2 (September 2020) and Time 3 (December 2020). As mentioned above, these periods marked substantial adaptive challenges, concurrent with the observed surge in stress symptoms.

Though it may at first seem paradoxical, elevated cortisol levels in this context do not necessarily denote vulnerability, but could potentially serve as a protective factor. Indeed, the engagement of the HPA axis (Sapolsky et al., 2000) during periods of stress is an indispensable physiological response in healthy adults (Milisav et al., 2012). This response is crucial for mobilizing energy reserves and adapting to stress-inducing events, consequently preventing energy depletion (Milisav et al., 2012). Essentially, an adaptive stress response encompassing an active HPA axis may function as a beneficial adaptive mechanism during high-stress periods, helping vulnerable individuals to adjust effectively while conserving energy reserves. Furthermore, our observation that heightened HCC reactivity plays a crucial role in moderating the relationship between SECS and depressive symptoms over time lends additional support to this proposed protective mechanism. This observation implies that rHCC could serve as a protective factor, diminishing the impact of socio-emotional vulnerability on depressive symptoms during the pandemic. We should clarify that this proposed protective effect is not present at specific time points but is rather observed throughout the first year following the onset of the pandemic, irrespective of time.

We also need to consider the HCC assessment's timing, which occurred only at the pandemic's onset. This highlights the question of whether individuals maintained HPA axis activation consistently throughout the studied period, suggesting a trait-like characteristic during stress and adaptation. It is crucial to recognize that HPA reactivity could fluctuate at different pandemic stages, indicating nuanced responses to various stressors. A thorough evaluation of this reactivity over time could enhance the understanding of the long-term adaptation mechanisms within the physiological stress system.

Importantly, our findings offer substantial understanding into the correlational association between internalizing symptoms and physiological system activation in association with highly stressful or potentially traumatic events. Notably, the nature of this association varies, with some research

suggesting a positive association (Pacella et al., 2017; Petrowski et al., 2020) while others indicating a negative one (Steudte-Schmiedgen et al., 2015). The discrepancies observed may in fact depend on the unique vulnerabilities of individuals experiencing the specific event under consideration, underlining the complexity of the association between physiological stress responses and internalizing symptoms.

Our study has some limitations that should be acknowledged. Firstly, while our findings suggest that SECS significantly predicts distress in adults during the COVID-19 pandemic, the clinical implications of this remain uncertain. Indeed, only a small percentage of our sample met the established clinical thresholds for the symptoms of psychological distress that were assessed. Consequently, more research is needed to fully understand the factors contributing to the development of psychopathology following exposure to enduring stressors such as the pandemic. Secondly, it is important to acknowledge that our study's limited sample size prevented us from testing potential moderating effects of variables such as sex, age, socio-economic status, and employment status. Previous research has identified these factors as contributing to an individual's vulnerability to experiencing distress during the COVID-19 pandemic (Santana et al., 2021). Due to the smaller sample, we were unable to thoroughly explore how these factors might interact with socio-emotional vulnerability and impact the levels of distress reported by participants. Future studies with larger and more diverse samples would be essential to gain a comprehensive understanding of these potential moderating effects. Another limitation lies in the reliance on self-reported measures, which could introduce bias. Replication of these results using triangulation of different sources, such as clinician-administered assessments, would be beneficial. Also, a significant limitation of this study pertains to the timing of data collection for the questionnaires comprising the composite score of socio-emotional vulnerability. Indeed, while the questionnaire measuring perseverative cognition was administered at T1 (simultaneously with the first time point assessing internalized distress), measures of anxiety sensitivity and intolerance of uncertainty were taken three months later, at T2. Although these constructs are generally considered stable over time (Allemand et al., 2013), it is impossible to rule out the possibility that the pandemic may have modulated these personality traits (either increasing or decreasing) between T1 and T2. Additionally, our sample was predominantly composed of women and included a relatively wide range of ages. Given previous studies that have shown sex/gender- and age-related differences in

response to the COVID-19 pandemic, future research with larger sample sizes should analyze the moderating role of sex/gender in these analyses to better understand these dynamics. Finally, while the use of a composite score was suitable for assessing general vulnerability to psychopathology, it restricted the analysis of the specific contributions of anxiety sensitivity, intolerance to uncertainty, and perseverative cognition. Future studies with larger sample sizes should aim to investigate the unique impact of each of these components. Despite these limitations, our study has several strengths, including its longitudinal design, which provides valuable information about the progression of distress throughout the pandemic. Furthermore, our pre-pandemic recruitment of a healthy adult population enables us to suggest directionality in the association between socio-emotional vulnerability, rHCC and distress. The findings indicate the presence of distress in healthy adults during the pandemic and underscore the importance of long-term follow-ups to understand the factors that may contribute to the development of psychopathologies.

In conclusion, our longitudinal study during the COVID-19 pandemic has revealed the complex relationship between socio-emotional vulnerability, physiological stress response, and psychological distress in adults. These findings have broad implications, contributing to the theoretical literature on individual protective and vulnerability factors when faced with a stressful/traumatic event. The COVID-19 pandemic has provided a unique opportunity to examine the human stress response in a real-world setting. Our work contributes to the growing knowledge of how socio-emotional and physiological factors influence mental health during stressful events and emphasizes the need for comprehensive approaches to address distress during global crises. As we continue to navigate the consequences of the pandemic and prepare for potential future stress events, our research offers guidance for interventions that aim to reduce distress and enhance resilience in the face of significant challenges.

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References

Allemand, M., Steiger, A. E., & Hill, P. L. (2013). Stability of Personality Traits in Adulthood. *GeroPsych*, *26*(1), 5–13. https://doi.org/10.1024/1662-9647/a000080

Belsky, J., & Pluess, M. (2009). Beyond diathesis stress: Differential susceptibility to environmental influences. *Psychological Bulletin*, *135*(6), 885–908. https://doi.org/10.1037/a0017376

Bilodeau-Houle, A., Bouchard, V., Morand-Beaulieu, S., Herringa, R. J., Milad, M. R., & Marin, M.-F. (2020). Anxiety Sensitivity Moderates the Association Between Father-Child Relationship Security and Fear Transmission. *Frontiers in Psychology*, *11*. https://www.frontiersin.org/article/10.3389/fpsyg.2020.579514

Bilodeau-Houle, A., Raymond, C., & Marin, M.-F. (2024). It's all in the hair: Association between changes in hair cortisol concentrations in reaction to the COVID-19 pandemic and post-traumatic stress symptoms in children over time. *Psychoneuroendocrinology*, *164*, 107019. https://doi.org/10.1016/j.psyneuen.2024.107019

Boswell, J. F., Thompson-Hollands, J., Farchione, T. J., & Barlow, D. H. (2013). Intolerance of Uncertainty: A Common Factor in the Treatment of Emotional Disorders. *Journal of Clinical Psychology*, *69*(6). https://doi.org/10.1002/jclp.21965

Broerman, R. (2020). Diathesis-Stress Model. In V. Zeigler-Hill & T. K. Shackelford (Eds.), *Encyclopedia of Personality and Individual Differences* (pp. 1107–1109). Springer International Publishing. https://doi.org/10.1007/978-3-319-24612-3_891

Brunet, A., St-Hilaire, A., Jehel, L., & King, S. (2003). Validation of a French version of the impact of event scale-revised. *Canadian Journal of Psychiatry. Revue Canadienne De Psychiatrie*, *48*(1), 56–61. https://doi.org/10.1177/070674370304800111

C. -J. Törnhage, & G. Alfvén. (2006). Diurnal Salivary Cortisol Concentration in School-aged Children: Increased Morning Cortisol Concentration and Total Cortisol Concentration Negatively Correlated to Body Mass Index in Children with Recurrent Abdominal Pain of Psychosomatic Origin. *Journal of Pediatric Endocrinology and Metabolism*, *19*(6), 843–854. https://doi.org/10.1515/JPEM.2006.19.6.843

Carleton, R. N., Norton, M. A. P. J., & Asmundson, G. J. G. (2007). Fearing the unknown: A short version of the Intolerance of Uncertainty Scale. *Journal of Anxiety Disorders*, *21*(1), 105–117. https://doi.org/10.1016/j.janxdis.2006.03.014

Christianson, S., & Marren, J. (2012). The impact of event scale—Revised (IES-R). *MedSurg Nursing*, *21*(5), 321–323.

Clancy, F., Prestwich, A., Ferguson, E., & O'Connor, D. B. (2022). Cross-sectional and prospective associations between stress, perseverative cognition and health behaviours. *Psychology & Health*, *37*(1), 87–104. https://doi.org/10.1080/08870446.2020.1867727

Creamer, M., Bell, R., & Failla, S. (2003). Psychometric properties of the Impact of Event Scale—Revised. *Behaviour Research and Therapy*, *41*(12), 1489–1496. https://doi.org/10.1016/j.brat.2003.07.010

Curran, P. J., West, S. G., & Finch, J. F. (1996). The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychological Methods*, *1*(1), 16–29. https://doi.org/10.1037/1082-989X.1.1.16

Daly, M., & Robinson, E. (2022). Depression and anxiety during COVID-19. *The Lancet*, *399*(10324), 518. https://doi.org/10.1016/S0140-6736(22)00187-8

Deacon, B. J., Abramowitz, J. S., Woods, C. M., & Tolin, D. F. (2003). The Anxiety Sensitivity

Index - Revised: Psychometric properties and factor structure in two nonclinical samples. *Behaviour Research and Therapy*, *41*(12), 1427–1449. https://doi.org/10.1016/s0005-7967(03)00065-2

Devynck, F., Kornacka, M., Baeyens, C., Serra, É., Neves, J. F. das, Gaudrat, B., Delille, C., Taquet, P., Depraete, O., Tison, P., Sgard, F., Rousseau, A., & Romo, L. (2017). Perseverative Thinking Questionnaire (PTQ): French Validation of a Transdiagnostic Measure of Repetitive Negative Thinking. *Frontiers in Psychology*, *8*. https://www.frontiersin.org/articles/10.3389/fpsyg.2017.02159

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin*, *130*(3), 355–391. https://doi.org/10.1037/0033-2909.130.3.355

Donald: French Translation of the DASS - Google Scholar. (n.d.). Retrieved August 8, 2023, from https://scholar.google.com/scholar_lookup?author=M.+Donald+&publication_year=2012&title=French+Translation+of+the+DASS+[website]

Dziurkowska, E., & Wesolowski, M. (2021). Cortisol as a Biomarker of Mental Disorder Severity. *Journal of Clinical Medicine*, *10*(21), 5204. https://doi.org/10.3390/jcm10215204

Ehring, T., Zetsche, U., Weidacker, K., Wahl, K., Schönfeld, S., & Ehlers, A. (2011). The Perseverative Thinking Questionnaire (PTQ): Validation of a content-independent measure of repetitive negative thinking. *Journal of Behavior Therapy and Experimental Psychiatry*, *42*(2), 225–232. https://doi.org/10.1016/j.jbtep.2010.12.003

Elwood, L. S., Hahn, K. S., Olatunji, B. O., & Williams, N. L. (2009). Cognitive vulnerabilities to the development of PTSD: A review of four vulnerabilities and the proposal of an integrative vulnerability model. *Clinical Psychology Review*, *29*(1), 87–100. https://doi.org/10.1016/j.cpr.2008.10.002

Enge, S., Fleischhauer, M., Hadj-Abo, A., Butt, F., Kirschbaum, C., Schmidt, K., & Miller, R. (2020). Comparison of hair cortisol concentrations between self- and professionally-collected hair samples and the role of five-factor personality traits as potential moderators. *Psychoneuroendocrinology*, *122*, 104859. https://doi.org/10.1016/j.psyneuen.2020.104859

Freeston, M. H., Rhéaume, J., Letarte, H., Dugas, M. J., & Ladouceur, R. (1994). Why do people worry? *Personality and Individual Differences*, *17*(6), 791–802. https://doi.org/10.1016/0191-8869(94)90048-5

Fries, E., Hesse, J., Hellhammer, J., & Hellhammer, D. H. (2005). A new view on hypocortisolism. *Psychoneuroendocrinology*, *30*(10), 1010–1016. https://doi.org/10.1016/j.psyneuen.2005.04.006

Gentes, E. L., & Ruscio, A. M. (2011). A meta-analysis of the relation of intolerance of uncertainty to symptoms of generalized anxiety disorder, major depressive disorder, and obsessive-compulsive disorder. *Clinical Psychology Review*, *31*(6), 923–933. https://doi.org/10.1016/j.cpr.2011.05.001

Gigauri, I. (2020). EFFECTS OF COVID-19 ON HUMAN RESOURCE MANAGEMENT FROM THE PERSPECTIVE OF DIGITALIZATION AND WORK-LIFE-BALANCE. *International Journal of Innovative Technologies in Economy*, *4(31)*, Article 4(31). https://doi.org/10.31435/rsglobal_ijite/30092020/7148

Gray, N. A., Dhana, A., Van Der Vyver, L., Van Wyk, J., Khumalo, N. P., & Stein, D. J. (2018). Determinants of hair cortisol concentration in children: A systematic review. *Psychoneuroendocrinology*, *87*, 204–214. https://doi.org/10.1016/j.psyneuen.2017.10.022

Hong, S., Kim, H., & Park, M. K. (2021). Impact of COVID-19 on post-traumatic stress symptoms in the general population: An integrative review. *International Journal of Mental Health*

Nursing, *30*(4), 834–846. https://doi.org/10.1111/inm.12875
Hossain, M. M., Tasnim, S., Sultana, A., Faizah, F., Mazumder, H., Zou, L., McKyer, E. L. J., Ahmed, H. U., & Ma, P. (2020). Epidemiology of mental health problems in COVID-19: A review. *F1000Research*, *9*, 636. https://doi.org/10.12688/f1000research.24457.1
Hwang, T.-J., Rabheru, K., Peisah, C., Reichman, W., & Ikeda, M. (2020). Loneliness and social isolation during the COVID-19 pandemic. *International Psychogeriatrics*, *32*(10), 1217–1220. https://doi.org/10.1017/S1041610220000988
Lovibond, P. F., & Lovibond, S. H. (1995). The structure of negative emotional states: Comparison of the Depression Anxiety Stress Scales (DASS) with the Beck Depression and Anxiety Inventories. *Behaviour Research and Therapy*, *33*(3), 335–343. https://doi.org/10.1016/0005-7967(94)00075-U
Lupien, S. J., McEwen, B. S., Gunnar, M. R., & Heim, C. (2009). Effects of stress throughout the lifespan on the brain, behaviour and cognition. *Nature Reviews Neuroscience*, *10*(6), 434–445. https://doi.org/10.1038/nrn2639
Makovac, E., Fagioli, S., Rae, C. L., Critchley, H. D., & Ottaviani, C. (2020). Can't get it off my brain: Meta-analysis of neuroimaging studies on perseverative cognition. *Psychiatry Research. Neuroimaging*, *295*, 111020. https://doi.org/10.1016/j.pscychresns.2019.111020
Makovac, E., Meeten, F., Watson, D. R., Herman, A., Garfinkel, S. N., D. Critchley, H., & Ottaviani, C. (2016). Alterations in Amygdala-Prefrontal Functional Connectivity Account for Excessive Worry and Autonomic Dysregulation in Generalized Anxiety Disorder. *Biological Psychiatry*, *80*(10), 786–795. https://doi.org/10.1016/j.biopsych.2015.10.013
Marin, M.-F., Bilodeau-Houle, A., Morand-Beaulieu, S., Brouillard, A., Herringa, R. J., & Milad, M. R. (2020). Vicarious conditioned fear acquisition and extinction in child–parent dyads. *Scientific Reports*, *10*(1), 17130. https://doi.org/10.1038/s41598-020-74170-1
Mason, J. W. (1968). A review of psychoendocrine research on the sympathetic-adrenal medullary system. *Psychosomatic Medicine*, *30*(5), Suppl:631-653. https://doi.org/10.1097/00006842-196809000-00022
Milisav, I., Poljsak, B., & Šuput, D. (2012). Adaptive Response, Evidence of Cross-Resistance and Its Potential Clinical Use. *International Journal of Molecular Sciences*, *13*(9), 10771–10806. https://doi.org/10.3390/ijms130910771
Naragon-Gainey, K. (2010). Meta-analysis of the relations of anxiety sensitivity to the depressive and anxiety disorders. *Psychological Bulletin*, *136*(1), 128–150. https://doi.org/10.1037/a0018055
Norton, P. J. (2007). Depression Anxiety and Stress Scales (DASS-21): Psychometric analysis across four racial groups. *Anxiety, Stress, & Coping*, *20*(3), 253–265. https://doi.org/10.1080/10615800701309279
Odeniyi, I. A., Fasanmade, O. A., Ogbera, A. O., & Ohwovoriole, A. E. (2015). Body mass index and its effect on serum cortisol level. *Nigerian Journal of Clinical Practice*, *18*(2), Article 2. https://doi.org/10.4314/njcp.v18i2
Pacella, M. L., Hruska, B., Steudte-Schmiedgen, S., George, R. L., & Delahanty, D. L. (2017). The utility of hair cortisol concentrations in the prediction of PTSD symptoms following traumatic physical injury. *Social Science & Medicine*, *175*, 228–234. https://doi.org/10.1016/j.socscimed.2016.12.046
Petrowski, K., Wichmann, S., Pyrc, J., Steudte-Schmiedgen, S., & Kirschbaum, C. (2020). Hair cortisol predicts avoidance behavior and depressiveness after first-time and single-event trauma exposure in motor vehicle crash victims. *Stress*, *23*(5), 567–576. https://doi.org/10.1080/10253890.2020.1714585

Peyrot, C., Provencher, J., Duplessis Marcotte, F., Cernik, R., & Marin, M.-F. (2024). Using unconditioned responses to predict fear acquisition, fear extinction learning, and extinction retention patterns: Sex hormone status matters. *Behavioural Brain Research*, *459*, 114802. https://doi.org/10.1016/j.bbr.2023.114802

Raymond, C., Bilodeau-Houle, A., Zerroug, Y., Provencher, J., Beaudin, M., & Marin, M.-F. (2022). Pre-pandemic socio-emotional vulnerability, internalizing and externalizing symptoms predict changes in hair cortisol concentrations in reaction to the COVID-19 pandemic in children. *Psychoneuroendocrinology*, *144*, 105888. https://doi.org/10.1016/j.psyneuen.2022.105888

Raymond, C., Pichette, F., Beaudin, M., Cernik, R., & Marin, M.-F. (2023). Vulnerability to anxiety differently predicts cortisol reactivity and state anxiety during a laboratory stressor in healthy girls and boys. *Journal of Affective Disorders*, *331*, 425–433. https://doi.org/10.1016/j.jad.2023.02.154

Raymond, C., Provencher, J., Bilodeau-Houle, A., Leclerc, J., & Marin, M.-F. (2022). A longitudinal investigation of psychological distress in children during COVID-19: The role of socio-emotional vulnerability. *European Journal of Psychotraumatology*, *13*(1), 2021048. https://doi.org/10.1080/20008198.2021.2021048

Reiss, S., Peterson, R. A., Gursky, D. M., & McNally, R. J. (1986). Anxiety sensitivity, anxiety frequency and the prediction of fearfulness. *Behaviour Research and Therapy*, *24*(1), 1–8. https://doi.org/10.1016/0005-7967(86)90143-9

Robinson, E., Sutin, A. R., Daly, M., & Jones, A. (2022). A systematic review and meta-analysis of longitudinal cohort studies comparing mental health before versus during the COVID-19 pandemic in 2020. *Journal of Affective Disorders*, *296*, 567–576. https://doi.org/10.1016/j.jad.2021.09.098

Santana, C. L. A., Manfrinato, C. V., Souza, P. R. P., Marino, A., Condé, V. F., Stedefeldt, E., Tomita, L. Y., & do Carmo Franco, M. (2021). Psychological distress, low-income, and socio-economic vulnerability in the COVID-19 pandemic. *Public Health*, *199*, 42–45. https://doi.org/10.1016/j.puhe.2021.08.016

Sapolsky, R. M., Romero, L. M., & Munck, A. U. (2000). How do glucocorticoids influence stress responses? Integrating permissive, suppressive, stimulatory, and preparative actions. *Endocrine Reviews*, *21*(1), 55–89. https://doi.org/10.1210/edrv.21.1.0389

Sorg, S., Vögele, C., Furka, N., & Meyer, A. H. (2012). Perseverative Thinking in Depression and Anxiety. *Frontiers in Psychology*, *3*. https://doi.org/10.3389/fpsyg.2012.00020

Stalder, T., & Kirschbaum, C. (2012). Analysis of cortisol in hair—State of the art and future directions. *Brain, Behavior, and Immunity*, *26*(7), 1019–1029. https://doi.org/10.1016/j.bbi.2012.02.002

Stalder, T., Steudte-Schmiedgen, S., Alexander, N., Klucken, T., Vater, A., Wichmann, S., Kirschbaum, C., & Miller, R. (2017). Stress-related and basic determinants of hair cortisol in humans: A meta-analysis. *Psychoneuroendocrinology*, *77*, 261–274. https://doi.org/10.1016/j.psyneuen.2016.12.017

Steudte-Schmiedgen, S., Stalder, T., Schönfeld, S., Wittchen, H.-U., Trautmann, S., Alexander, N., Miller, R., & Kirschbaum, C. (2015). Hair cortisol concentrations and cortisol stress reactivity predict PTSD symptom increase after trauma exposure during military deployment. *Psychoneuroendocrinology*, *59*, 123–133. https://doi.org/10.1016/j.psyneuen.2015.05.007

Sun, Y., Wu, Y., Fan, S., Santo, T. D., Li, L., Jiang, X., Li, K., Wang, Y., Tasleem, A., Krishnan, A., He, C., Bonardi, O., Boruff, J. T., Rice, D. B., Markham, S., Levis, B., Azar, M., Thombs-

Vite, I., Neupane, D., … Thombs, B. D. (2023). Comparison of mental health symptoms before and during the covid-19 pandemic: Evidence from a systematic review and meta-analysis of 134 cohorts. *BMJ*, *380*, e074224. https://doi.org/10.1136/bmj-2022-074224

Sveen, J., Bondjers, K., & Willebrand, M. (2016). Psychometric properties of the PTSD Checklist for DSM-5: A pilot study. *European Journal of Psychotraumatology*, *7*, 10.3402/ejpt.v7.30165. https://doi.org/10.3402/ejpt.v7.30165

Verreault, N., Marchand, A., Labrecque, J., & Marchand, L. (2007). *Validation de l'Index de sensibilité à l'anxiété auprès de la population québécoise francophone. 28*(258), 68.

Weathers, F. W., Litz, B. W., Keane, T. M., Palmieri, P. A., Marx, B. P., & Schnurr, P. P. (2013). *The PTSD Checklist for DSM-5 (PCL-5) – Standard.* https://www.ptsd.va.gov/

Westrupp, E. M., Bennett, C., Berkowitz, T., Youssef, G. J., Toumbourou, J. W., Tucker, R., Andrews, F. J., Evans, S., Teague, S. J., Karantzas, G. C., Melvin, G. M., Olsson, C., Macdonald, J. A., Greenwood, C. J., Mikocka-Walus, A., Hutchinson, D., Fuller-Tyszkiewicz, M., Stokes, M. A., Olive, L., … Sciberras, E. (2023). Child, parent, and family mental health and functioning in Australia during COVID-19: Comparison to pre-pandemic data. *European Child & Adolescent Psychiatry*, *32*(2), 317–330. https://doi.org/10.1007/s00787-021-01861-z

Yang, M.-J., Kim, B.-N., Lee, E.-H., Lee, D., Yu, B.-H., Jeon, H. J., & Kim, J.-H. (2014). Diagnostic utility of worry and rumination: A comparison between generalized anxiety disorder and major depressive disorder. *Psychiatry and Clinical Neurosciences*, *68*(9), 712–720. https://doi.org/10.1111/pcn.12193

Yook, K., Kim, K.-H., Suh, S. Y., & Lee, K. S. (2010). Intolerance of uncertainty, worry, and rumination in major depressive disorder and generalized anxiety disorder. *Journal of Anxiety Disorders*, *24*(6), 623–628. https://doi.org/10.1016/j.janxdis.2010.04.003