Turning Stress into Success

Changing beliefs about stress using neuroscience-informed stress education during adolescence

Riana Marie, BPsych (Honours)

(Formerly Riana Phillips)

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

College of Medicine and Dentistry

James Cook University

Submitted January 2022

Supervision

Table 1

Advisory Panel

Title	Name
Primary Advisor	Professor Brett McDermott
Secondary Advisor	Professor Zoltan Sarnyai
Secondary Advisor	Dr Joseph V. Moxon
Secondary Advisor (External)	Professor Sonia Lupien
Chair of the Candidature Committee	Dr Michelle Redman-MacLaren
Independent Academic	Associate Professor Robin Ray

Acknowledgments

I would like to sincerely thank my supervisors, Professor Zoltán Sarnyai, Professor Brett McDermott, Dr Joseph V. Moxon, and Professor Sonia Lupien, whose guidance and constructive feedback has helped me expand my limits, overcome many challenges, and grow as a researcher.

Professor Sarnyai, thank you for the endless support you have provided since my Honour's research five years ago. Thank you for helping me to become more confident and for opening your home to fantastic lab parties. Professor McDermott, thank you for helping from your clinical perspective, for teaching me about RevMan, and for being available in times of need.

I would sincerely like to thank Dr Moxon for his incredible support over the past two years. You have encouraged me to learn new skills and provided endless emotional support through your humour, encouragement, and wit. As you prefer to communicate in haiku, this is mine to you.

Thank you so much Joe

For telling all the dad jokes

And the help with R

You have done so much

I am forever thankful

You are a rock star

The research presented within this thesis would not have been possible without the support of collaborations. Thank you to my external supervisor, Professor Lupien, whose ambition and passion for educating researchers about the reproducibility crisis has been truly inspiring. To Audrey-Ann and Rebecca, I have thoroughly enjoyed working with you on the Stress N' Go project and wish you all the best with your research.

I am thankful for the financial contribution of James Cook University, without this aid, I would not have been able to conduct the research presented in this thesis. I would like to acknowledge the James Cook University staff who have provided me with assistance on my project,

in particular Dr Michelle Redman MacLaren, Associate Professor Robin Ray, Professor Sarah Larkins, Emeritus Professor Rhondda Jones, Professor Cate Nagle, Dr Emma Anderson, Helen Griffiths, and the Australian Institute of Tropical Health and Medicine (AITHM) staff. I would also like to thank the wonderful psychology department, who I had the pleasure of working with during my candidature, especially Associate Professor Kerry McBain, Dr Craig Thorley, Associate Professor Wendy Li, Dr Liza van Eijk, and the late Dr David Mitchell who I will forever be grateful to for his support and belief in me.

Working within the Laboratory of Psychiatric Neuroscience has been an exciting opportunity to meet many brilliant minds from around the world, many of whom have become my closest friends. Firstly, I would not be where I am today without my best friend and mentor, Dr Ann-Katrin Kraeuter. During my Honour's year, she has shown me the importance of a strong work ethic, passion, and kindness. She has been my rock over the last five years and is a true role model. Anni, I am so thankful to call you my family and look forward to visiting you, Gary, and my little nieces Annabelle, Olivia, Palmer, and Penny in your new home in England. To Dr Beena Suvarna, you are the kindest person I have ever met. You and your family (including Tashi) are all beautiful souls. Thank you for your help on my project, but more importantly, thank you for all the emotional support and love you have given me over these years. To Sabine Finlay, your efficiency amazes me every day. I have no doubts about how successful you will become in research during and after you finish your PhD. I have loved sitting opposite you at AITHM and will dearly miss our conversations (and Cody, the Honour's student, who had to endure them). Thank you for the delicious dinners, sweet treats, and for the countless hours of puzzling.

Finally, a big thanks to the Day Clan for welcoming me into their family, especially Debbie and John for the many beautiful homemade meals and Alex for his love over the past two years. To my mum, Karen, and sisters, Nicola and Lara, thank you for your endless support, encouragement, and love. To Ted, Bear, and Nala, I love you and would not be here without you.

My warmest thanks to everyone who has been there for me.

Declaration

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given. The extent of collaboration with others has been stated clearly and fully in the thesis and the co-authors of any publications included in this thesis have provided written statements of the nature of their contribution. As the copyright owner of this thesis, I grant James Cook University a permanent nonexclusive license to store, display or copy any or all the thesis, in all forms of media, for use within the University after this date, and to make the thesis freely available online to other persons or organisations. Every reasonable effort has been made to gain permission and acknowledge the owners of copyright material. I would be pleased to hear from any copyright owner who has been omitted or incorrectly acknowledged.

The research presented and reported in this thesis was conducted within the National Statement on Ethical Conduct in Human Research (2007), updated in 2018, in accordance with the National Health and Medical Research Council Act 1992. The proposed research methodology received clearance from the James Cook University Human Research Ethics Committee on the 24th of July, 2019 (Ethics number: H7727, Appendix).

Statement of the Contribution of Others

Table 2

Statement of the Contribution of Others

Nature of Assistance	**Contribution**	**Names, Titles, and Affiliations of Co-Contributors**
Intellectual support	Research conception Proposal writing Manuscript writing Editorial assistance	Professor Zoltan Sarnyai *(James Cook University)* Dr Joseph V. Moxon *(James Cook University)* Professor Brett McDermott *(James Cook University)* Professor Sonia Lupien *(University of Montreal)* Dr Oyelola Adegboye *(James Cook University)* Audrey-Ann Journault *(University of Montreal)* Rebecca Cernik *(University of Montreal)* Sabine Finlay *(James Cook University)* Dr Beena Suvarna *(James Cook University)* Dr Ann-Katrin Kraeuter *(Northumbria University)* Dr Paul Welch *(James Cook University)*
Financial support	Fee offset/waiver Stipend Write-up Grant Facilities	The Australian Government Research Training Program Scholarship College of Medicine and Dentistry Top-up and Doctoral Thesis Writing Scholarships Australian Institute of Tropical Health and Medicine
Data collection	Data collection Stress N' Go Program (English translation)	Audrey-Ann Journault *(University of Montreal)* Rebecca Cernik *(University of Montreal)* Dr Paul Welch *(James Cook University)*

	Quality Assessment (Systematic Reviews) Data Extraction	Dr Ann-Katrin Kraeuter *(Northumbria University)* Dr Beena Suvarna *(James Cook University)* Sabine Finlay *(James Cook University)*
Statistical Analysis	Data Analysis Statistical support	Audrey-Ann Journault *(University of Montreal)* Dr Joseph V. Moxon *(James Cook University)* Dr Oyelola Adegboye *(James Cook University)*
	Content Analysis	Dr Michelle Redman-MacLaren *(James Cook University)* Associate Professor Robin Ray *(James Cook University)*
Research Support	Ethical Guidance	Emeritus Professor Rhondda Jones *(James Cook University)* Professor Sarah Larkins *(James Cook University)* Professor Cate Nagle *(James Cook University)* Helen Griffiths *(James Cook University)*
	Cultural Mentor	Michael Illin

Publications Associated with this Thesis

Published

Chapter 6

Marie, R., Journault, A. A., Cernik, R., Welch, P., Lupien, S., McDermott, B., Moxon, J. V., & Sarnyai, Z. (2022). A cross-sectional study investigating Canadian and Australian adolescents' perceived experiences of COVID-19: Gender differences and mental health implications. *International journal of environmental research and public health*, *19*(7), 4407. https://doi.org/10.3390/ijerph19074407

Chapter 7

Phillips, R., Kraeuter, A.K., McDermott, B., Lupien, S., & Sarnyai, Z. (2020). Human nail cortisol as a retrospective biomarker of chronic stress: A systematic review. *Psychoneuroendocrinology, 123*, 104903. https://doi.org/10.1016/j.psyneuen.2020.104903 (selected for Editor's choice)

Conference Proceedings

Phillips, R., Kraeuter, A.K., McDermott, B., Lupien, S., & Sarnyai, Z. (2019). Human nail cortisol as a retrospective biomarker of chronic stress: A systematic review. *Psychoneuroendocrinology*. doi.org/10.1016/j.psyneuen.2019.07.064

Publications Outside of this Thesis

Kraeuter, A. K., Phillips, R., & Sarnyai, Z. (2020). The gut microbiome in psychosis from mice to men: A systematic review of preclinical and clinical studies. *Frontiers in Psychiatry*, 11, 799. https://doi.org/10.3389/fpsyt.2020.00799

Kraeuter, A. K., Phillips, R., & Sarnyai, Z. (2020). Ketogenic therapy in neurodegenerative and psychiatric disorders: From mice to men. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, 109913. https://doi.org/10.1016/j.pnpbp.2020.109913

Suvarna, B., Suvarna, A., Phillips, R., Juster, R. P., McDermott, B., & Sarnyai, Z. (2019). Health risk behaviours and allostatic load: A systematic review. *Neuroscience & Biobehavioral Reviews*, 108. 694-711. https://doi.org/10.1016/j.neubiorev.2019.12.020

Conference Proceedings

Phillips, R., Kraeuter, A.K., Loxton, H., & Mitchell, D., & Sarnyai, Z. (2019). The effects of N-methyl-D-aspartate receptor hypofunction on sociability and mirror-directed behaviours in mice. *International Behavioural Neuroscience Society.*

Thesis Abstract

Stress is the psychological or physiological response to demands or threats. The negative effects of chronic stress are well-known; however, the acute stress response can be adaptive and promote performance. Optimising stress via stress mindsets (metacognitive beliefs about stress) and the reappraisal of stress responses may offer a novel method of coping with unavoidable but controllable stressors, such as school or work (as discussed in *Chapter 1*). Adolescence is a period of heightened stress reactivity with approximately one-third of Australian adolescents experiencing psychological distress. The main aims of this thesis were to examine whether stress mindsets can be changed and whether a stress optimisation program, Stress N' go, can prime more stress-is-enhancing mindsets and promote mental health during adolescence.

A systematic review was conducted in *Chapter 2* to examine whether stress mindsets can be changed through short interventions or experimental manipulations. A qualitative synthesis of 12 studies suggested that adults can be primed to view stress as more "enhancing" using stress mindset or resilience skills training via multimedia presentations, memory recall, mental imagery, or virtual reality. Therefore, beliefs about stress can be modified in adults through intervention and may be associated with positive effects on work and academic performance as well as mental health.

Interventions employing both stress mindset and reappraisal theory have yet to be validated in the literature, which led to the development of *Chapter 3*, a stress optimisation program designed to promote more positive stress mindsets and mental health during adolescence. Private high school students (n = 236) from North Queensland, Australia were randomly assigned to either the Stress N' Go intervention (the stress optimisation program) or a control program with no emphasis on stress. Both the intervention and control programs promoted more stress-is-enhancing mindsets, which may be associated with the single-centre study design resulting in students discussing both programs with each other. However, the magnitude of this change in stress mindsets was significantly greater for the Stress N' Go intervention group (β = 0.16, p = .030, 95% *CI*: 0.02, 0.29), but no benefits were observed on adolescent mental health directly post-intervention. This finding may be due to the brief

testing period and may not capture the more indirect longitudinal changes associated with modifying stress beliefs. *Chapter 4* evaluated student perceptions of the Stress N' Go program. The program was enjoyed by the majority of students who responded to surveys post-videos (each video scored around 7 out of 10) and the content appeared to be comprehended by the students, but there was participant attrition that may have affected the generalisability of these findings. Students, however, suggested that the content could be more engaging through improved animations, more expressive audio, and additional stress management content.

Chapter 5 psychometrically assessed the primary outcome, the Stress Mindset Measure (SMM), in an Australian cohort from *Chapter 3* and an age-matched sample of adolescents in Canada who first tested the Stress N' Go program. These Australian and Canadian responses were from baseline data collected before the Stress N' Go program was implemented. The French-translated version of the SMM used in the Canadian sample appeared to be more reliable than the original English version utilised in the Australian sample, which might explain the smaller effect observed in *Chapter 3*.

As the program was implemented during the COVID-19 pandemic, it was important to explore what effect this may have had on adolescent stress levels and mental health. Using the same cross-cultural baseline data from *Chapter 5*, *Chapter 6* found that the Australian sample of adolescents was significantly less concerned or worried about COVID-19 than the Canadian sample, potentially due to remaining at school and fewer COVID-19 restrictions, compared to the Canadian adolescents who were in lockdown at the time of testing. Girls in both samples were reporting significantly greater concerns about COVID-19 and their mental health than boys, which highlights a need for future education programs to examine the moderating effect of gender roles. Overall, the efficacy of the current program does not appear to be greatly influenced by the Australian students' COVID-19 experience but more likely the primary outcome not reliably capturing more nuanced changes in stress beliefs (*Chapter 5*) or the small single-centre study design employed in *Chapter 3*.

Future stress education interventions could also examine a more comprehensive profile of stress, beyond self-report scales, by including biological samples within the methodology. One such emerging measure of chronic stress is explored in *Chapter 7*, which was a systematic review of nail cortisol that aimed to determine if human nail cortisol could be a more inclusive biomarker of retrospective chronic stress compared to hair cortisol (currently limited by hair type and availability). The period of chronic stress reflected by nail cortisol; however, remains unclear, suggesting the need for further investigations. Overall, this chapter represented a future direction of stress education programs, as nail cortisol may provide more insight into the underlying physiological changes associated with these interventions.

Collectively, findings from this thesis suggest that stress mindsets can be primed to be more positive, which may indirectly promote performance and mental health. The Stress N' Go education program primed more positive stress mindsets but had no direct benefits on student mental health post-intervention. Therefore, longitudinal investigations are warranted to investigate whether a change in stress mindset can alter coping strategy selection or future mental health outcomes. The online format of Stress N' Go was useful in the context of the COVID-19 pandemic but could be extended to rural and remote education. Overall, the Stress N' Go program may be a valuable tool in educational and non-clinical settings to help teach adolescents that stress does not always have to be a threat but instead a challenge that can expand their limits and promote growth.

Keywords: stress optimisation, stress mindsets, stress reappraisal, stress beliefs, mental health, adolescents

Thesis Roadmap

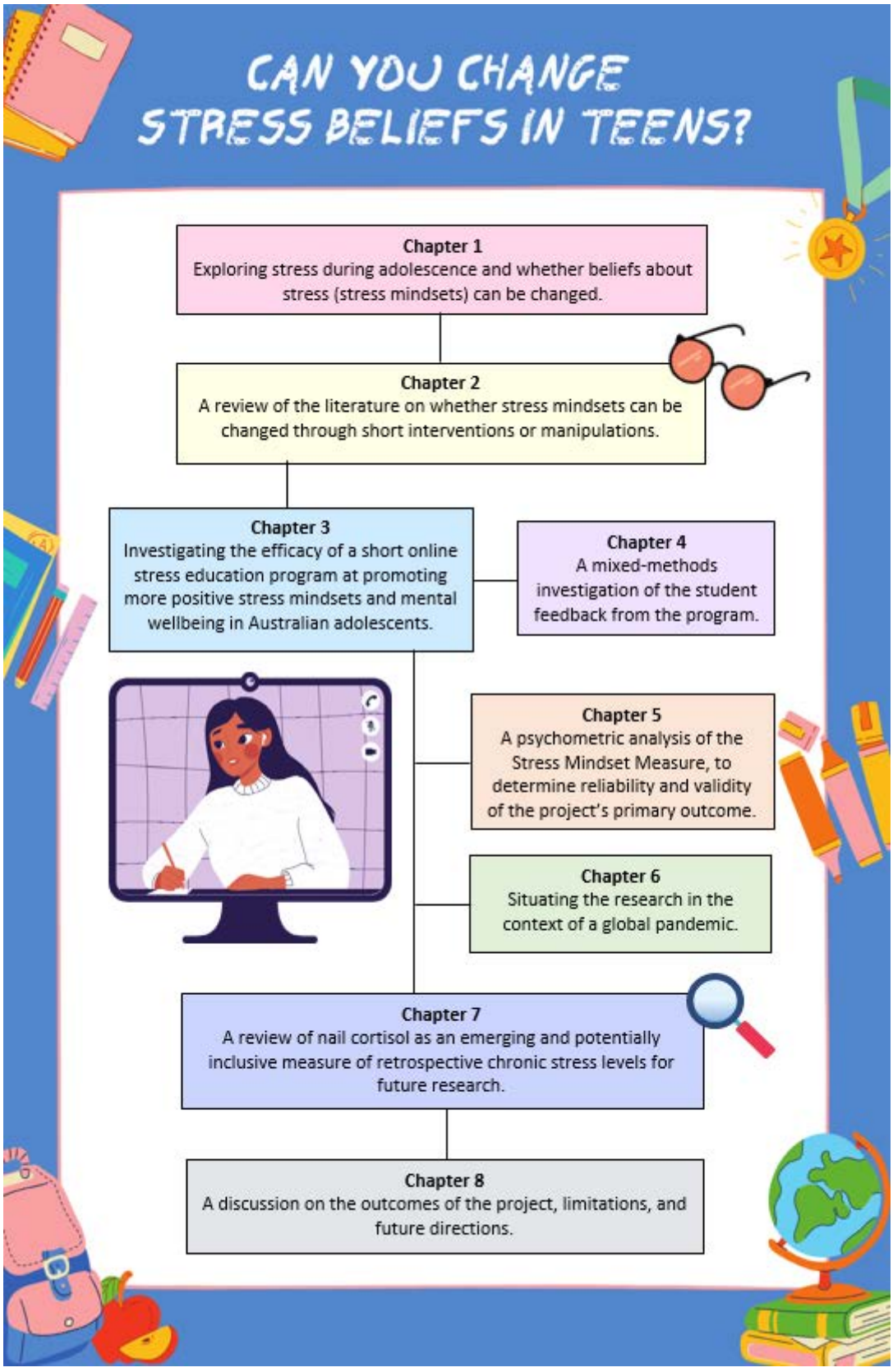


Table of Contents

List of Tables

List of Figures

CAN YOU CHANGE STRESS BELIEFS IN TEENS?

YOU ARE HERE

Chapter 1
Exploring stress during adolescence and whether beliefs about stress (stress mindsets) can be changed.

Chapter 2
A review of the literature on whether stress mindsets can be changed through short interventions or manipulations.

Chapter 3
Investigating the efficacy of a short online stress education program at promoting more positive stress mindsets and mental wellbeing in Australian adolescents.

Chapter 4
A mixed-methods investigation of the student feedback from the program.

Chapter 5
A psychometric analysis of the Stress Mindset Measure, to determine reliability and validity of the project's primary outcome.

Chapter 6
Situating the research in the context of a global pandemic.

Chapter 7
A review of nail cortisol as an emerging and potentially inclusive measure of retrospective chronic stress levels for future research.

Chapter 8
A discussion on the outcomes of the project, limitations, and future directions.

Chapter 1

Turning Stress into Success

Adolescence is a period of enhanced vulnerability to stressors, due to social, emotional, and physical changes, as well as heightened stress reactivity (Lupien et al., 2009; Romeo, 2013). Adolescence is defined by the World Health Organisation (2021), as the developmental period between childhood and adulthood (from ages 10 to 19). In 2020, Australian adolescents (15 to 19 years of age) reported that their biggest personal concerns were coping with stress, mental health, and their body image (Tiller et al., 2020). Approximately 25% (12 to 14 years old) to 38% (15 to 17 years old) of adolescents reported experiencing psychological distress, with females experiencing higher rates of distress compared to males (Headspace, 2020). Further, 43% of Australian adolescents reported feeling stressed either all or most of the time with only 2% seeking help from mental health organisations (McCrindle, 2021). In addition, the COVID-19 pandemic may further contribute to a higher risk of mental health concerns in adolescents across the world (Duan et al., 2020; Giannopoulou et al., 2021; Hafstad et al., 2021; Liang et al., 2020; Ma et al., 2021; Magson et al., 2021; Meda et al., 2021; Ravens-Sieberer et al., 2020; Rogers et al., 2021; Thorisdottir et al., 2021; Zhou et al., 2020). Although developmental trajectories cannot be reversed (Lupien et al., 2018), there is a need for preventative strategies to help adolescents learn how to cope with their stress and manage unavoidable but controllable stressors, such as school or examinations (Jamieson et al., 2018).

The Stress Response

Stress is the body's response to physical or psychological challenges (Folkman & Lazarus, 1984). The acute stress response (e.g., the fight or flight response) can be adaptive, as it allows the body to mobilise energy to react to stressors (stimuli that are deemed threats or demands) (Dhabhar, 2018). Conversely, repeated or unrelenting stress has been linked to disease (McEwen, 2017). Chronic stress can adversely affect cardiovascular, immune, gastrointestinal, and brain health (Juster et al., 2010; Yaribeygi et al., 2017), and there is a robust link between chronic stress and poor

mental health outcomes (Lupien et al., 2018; Lupien et al., 2009). However, it is still important to recognise the human stress response, as a protective evolutionary mechanism that exists to promote survival (Dhabhar, 2018).

The human stress response relies on the interaction of multiple neuroendocrine, autonomic, immune, and metabolic mediators attempting to maintain the body's homeostasis during stress, such as the sympathetic–adrenal–medullary (SAM) axis and the hypothalamic-pituitary-adrenal (HPA) axis (Juster et al., 2010; Sapolsky et al., 2000). The SAM axis regulates the "fight or flight" response by releasing epinephrine and norepinephrine (Juster et al., 2010); while the HPA axis is responsible for maintaining homeostasis within the body by releasing glucocorticoids (e.g., cortisol) (Juster et al., 2010; Sapolsky et al., 2000). The acute stress response promotes alertness, vigilance, cognition, attention, and pain relief (Tsigos et al., 2020). Energy is mobilised to vital organs to increase respiration, cardiovascular tone, and metabolism, and temporarily slow energy-consuming functions, such as digestion (Tsigos et al., 2020). The stress response is influenced by genetic, environmental, and developmental factors (Tsigos et al., 2020). Early life (prenatal, infant, and childhood) and adolescence are particularly critical periods of plasticity associated with the development of stress reactivity and increased vulnerability to stressors (Lupien et al., 2009; Tsigos et al., 2020).

Stress Appraisal and Coping

The acute stress response activates when an individual perceives a physiological or psychological stressor (Juster et al., 2010; Sapolsky et al., 2000). Folkman and Lazarus (1984) developed the Transactional Model of Stress to describe how individuals cognitively appraise stressors, which informs stress levels, and consequently coping mechanisms. Stressors can be primarily appraised as a *harm or loss, threat,* or *challenge*. *Harms or losses* are stressors that have already been experienced and have resulted in damage or negative consequences. Alternatively, *threats* are anticipated experiences that are appraised as too demanding or negative, and *challenge*s are situations that are expected to promote success and growth. The secondary appraisal of these

stressors involves the individual determining whether they have the resources to cope with the situation and can be either *emotion-* or *problem-focused* (Lazarus & Folkman, 1984). *Emotion-focused* strategies involve regulating the negative feelings associated with the stressor (e.g., rumination, meditation, emotional disclosure); whereas, *problem-focused* coping strategies focus on actively modifying, or eliminating stressors through behaviour (e.g., avoidance, problem-solving, social support, making plans). In a revised version of the transactional model, *meaning-focused* or *appraisal-focused* coping was discussed, where an individual's beliefs and values motivate their coping strategies (Folkman, 2008).

Coping efficacy has been linked to improved treatment outcomes in intervention studies (Kendall et al., 2016). Maladaptive coping beliefs (e.g., the belief that negative events are caused by oneself whereas positive events are caused by external forces) and strategies (e.g., avoidance or rumination) have been associated with adverse mental health outcomes, such as depression or poor emotion regulation (Groth et al., 2019; Heffer & Willoughby, 2017). In contrast, adaptive coping strategies (e.g., support seeking or problem-solving) have been positively related to resilience and mental health (Groth et al., 2019; Lee et al., 2017). Further, negative beliefs about coping (e.g., "When I perform poorly at school, I begin to doubt my abilities") during adolescence were associated with increased school stress; while teacher/peer support appeared to promote more positive coping beliefs (Haugan et al., 2021). With Australian adolescents reporting high levels of stress, it is therefore important to consider interventions that encourage more positive coping beliefs and strategies to promote mental health and wellbeing during this vulnerable developmental period.

Stress Optimisation

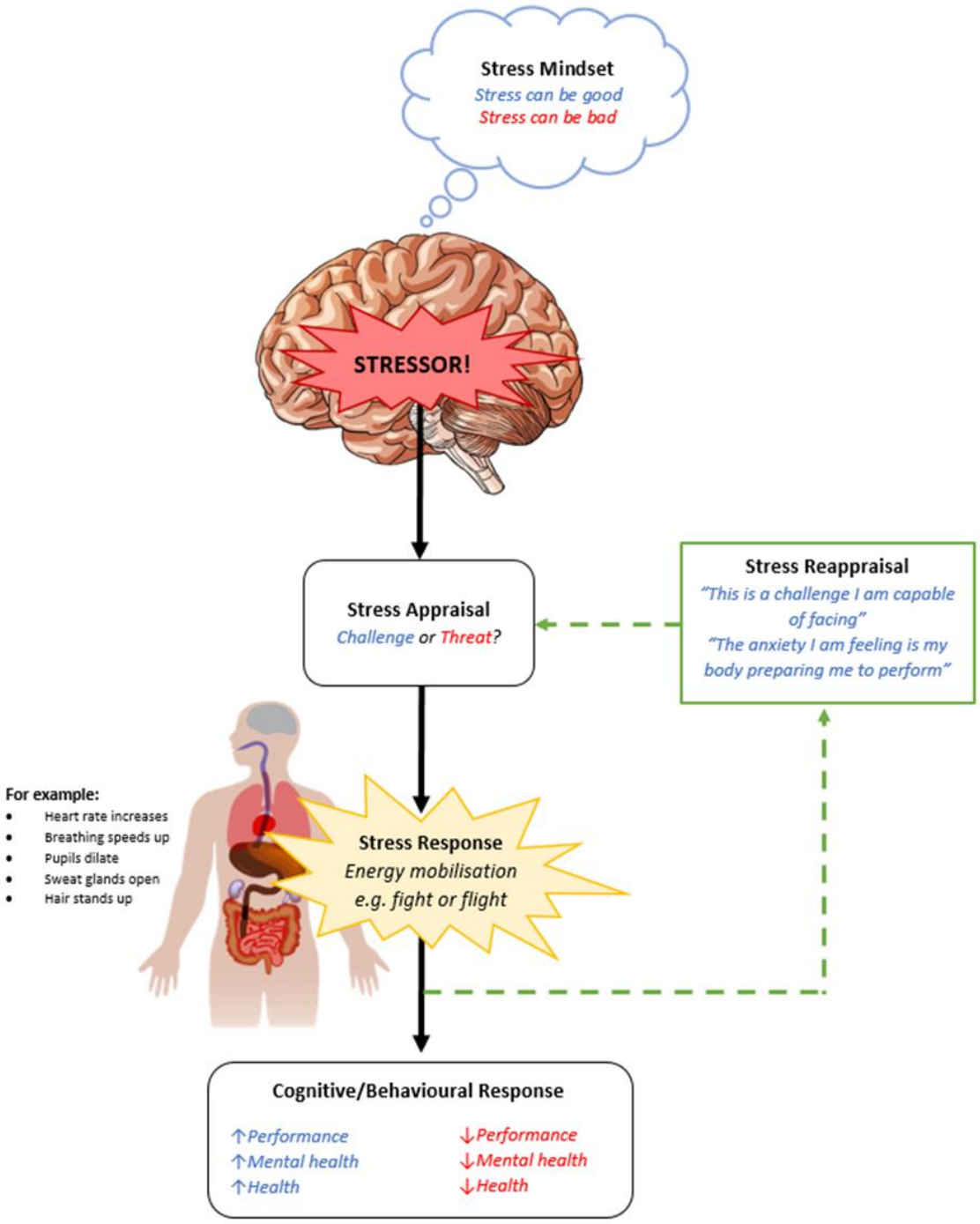
Jamieson et al. (2018) suggest that stress responses can be optimised by implementing short interventions which change appraisals of the stress response (stress reappraisal) and the nature of stress (stress mindsets). Figure 1 shows the conceptualisation of this stress optimisation model. Often the positive benefits of the acute stress response, such as energy mobilisation, are

overshadowed by the negative effects of chronic stress, within the literature, which can lead to a desire to avoid or minimise specific stressors within interventions (Crum et al., 2020). The stress optimisation model was developed based on the idea that many stress management programs focus on reducing or eliminating stressors, but do not acknowledge that some stressors cannot be eliminated (e.g., school) or that acute stress may encourage growth and opportunity (e.g., using the energy mobilised by the acute stress response to perform physically, occupationally, or academically) (Jamieson et al., 2018). Regulating beliefs about stress may lead to adaptive coping mechanisms and promote performance, health, and wellbeing (Jamieson et al., 2018).

Crum further discussed the benefits of stress optimisation interventions et al. (2020) from the perspective of emotion regulation strategies, such as situation selection, attentional deployment, cognitive change, and response modulation (Gross, 2015). Stress optimisation may allow individuals to seek out stressors, rather than avoid them, with the belief that they will promote growth or facilitate a beneficial outcome for the individual (situation selection) (Crum et al., 2020). This proposed model may allow individuals to divert attentional resources to their underlying goals rather than focus on the negative aspects of stress (attentional deployment) (Crum et al., 2020). Stress optimisation employs the cognitive reappraisal of stressors from threats to manageable challenges (cognitive change) and encourages individuals to capitalise on their stress response for performance or use techniques, such as deep breathing, to regulate their stress response (response modulation) (Crum et al., 2020). The stress optimisation model suggests that antecedent-focused strategies, such as stress reappraisal and stress mindsets, may have positive behavioural, cognitive, and psychological implications (Jamieson et al., 2018). However, this theoretical approach needs to be empirically tested, as to date, interventions have only focused on either stress mindsets or cognitive reappraisal separately.

Figure 1

Stress Optimisation Model



Note. The Stress Optimisation Model developed by Jamieson et al. (2018). Stress mindsets are the lens through which individuals view stress, while stress reappraisal is the change in beliefs about stressors or the stress response. These concepts can lead to changes in cognitive, emotional, or physical responses to stressors.

Stress Reappraisal

Stress can be reappraised to promote performance (Jamieson et al., 2018). Stress reappraisal relies on the Biopsychosocial (BPS) model of challenge and threat, which describes how stress responses are shaped. This model suggests that challenges occur when an individual perceives their resources to exceed the situational demands, unlike threats where the perceived demands exceed resources (Blascovich, 2008; Blascovich & Tomaka, 1996; Jamieson et al., 2013). The sympathetic activation related to acute stress may be an effective coping mechanism and promote performance (Jamieson et al., 2013). Based on the BPS model, it was suggested that acute stress responses could become more efficient by altering appraisals of arousal (stress reappraisal) where individuals are taught that, in stressful situations, their physiological arousal can be a resource to improve their performance. Multiple studies have used journal articles or short-form instructions to teach the importance of the body's stress response on performance to alter appraisals of arousal (Akinola et al., 2016; Jamieson et al., 2010; Jamieson et al., 2012). The reappraisal of stress has been associated with improved test performance, decreased attentional bias, adaptive cortisol responses, increased salivary alpha-amylase (a predictor of better task performance), and more efficient cardiovascular responses (Akinola et al., 2016; Jamieson et al., 2010; Jamieson et al., 2012). A recent systematic review and meta-analysis found that stress reappraisal interventions are effective in reducing perceived stress levels (Liu et al., 2019).

Cognitive reappraisal is a common emotion regulation strategy and component of cognitive-behavioural therapy (Ochsner & Gross, 2008; Jamieson et al., 2013). However, this strategy is more often focused on reducing sympathetic activation by modifying affective stimuli during passive tasks (e.g., altering negative automatic thoughts with rational thinking). Instead, stress reappraisal allows for individuals to utilise rather than reduce or eliminate the sympathetic activation (e.g., increased blood flow to the brain) during acute stress, to improve their performance in active tasks (Jamieson et al., 2013). In other words, stress reappraisal does not focus on reducing or eliminating specific

stressors (stressor reappraisal) but instead focuses on utilise the stress response as a coping tool. Therefore, stress reappraisal may be a promising approach within stress optimisation programs.

Stress Mindsets

Stress mindsets are the lens through which individuals view stress; that stress can be "enhancing" or "debilitating" (Crum et al., 2013). Stress mindsets focus on "domain-general", higher-level beliefs about the nature of stress rather than specific stressors or situational appraisals (Jamieson et al., 2018). Stress mindsets were conceptualised based on previous research on implicit mindset theories (Dweck, 2008; Wolcott et al., 2021). In particular, Dweck (2008) theorised that people have implicit beliefs about personal qualities, such as intelligence, where some people view the quality as fixed and unchangeable (fixed mindset), and others believe it can develop and grow (growth mindset). These beliefs can determine motivation and behaviour (e.g., growth mindsets can be associated with improved academic performance) and can be changed through short interventions (Dweck, 2008). Crum et al. (2013) first conceptualised stress mindsets and suggested that having a more stress-is-enhancing mindset was associated with beliefs that stress can be beneficial to health, performance, and wellbeing, which may lead to more adaptive coping strategies. Crum et al. (2013) further advocated that these implicit beliefs about the nature of stress could similarly be changed through short intervention and developed the Stress Mindset Measure (SMM), as a method of measuring this construct. Unlike stress reappraisal interventions, the efficacy of stress mindset interventions have not been systematically reviewed; but only briefly discussed within some reviews (Crum et al., 2020; Hagger et al., 2020; Jamieson et al., 2018; Laferton et al., 2020; Zion & Crum, 2018; Zion et al., 2019).

Consequently, a systematic review of current stress mindset interventions is warranted, as several studies suggest that mindsets can be primed. Crum et al. (2013) found that participants who watched short three-minute multimedia videos encouraging a *stress-is-enhancing* mindset developed more positive stress mindsets (increased SMM scores), with parallel improvements in mood and work performance (Crum et al., 2013). However, participants exposed to *stress-is-*

debilitating videos developed more negative stress mindsets (Crum et al., 2013). Several independent studies have utilised the SMM and found that more stress-is-enhancing mindsets could be primed through similar short multimedia presentations (Crum et al., 2017; Crum et al., 2018; Crum et al., 2013; Gold, 2019; Hogue, 2019). Further, having a more stress-is-enhancing mindset was associated with appraising stressors as challenges rather than threats as well as improved psychological and work performance outcomes (Crum et al., 2017; Crum et al., 2013; Kilby & Sherman, 2016). Jamieson et al. (2018) argued that only showing the positive effects of stress, to bias participants, may be ethically questionable, but also impractical due to the availability of information in the media and research about the negative effects of stress. Liu et al. (2017) found that the balanced framing of stress showed more adaptive physiological responses to acute stressors. As such, within the stress optimisation model, stress mindset training with a more nuanced and balanced view of stress may promote more stress-is-enhancing mindsets (Jamieson et al., 2018). This change in stress mindsets does not directly target performance but instead instils a change in meta-cognitive beliefs about the nature of stress (Jamieson et al., 2018).

Project Aim and Hypothesis

The current project was developed to test the efficacy of the novel stress optimisation model proposed by Jamieson et al. (2018). The overarching aim of this thesis was to utilise stress optimisation theory to promote more positive beliefs about stress during adolescence and promote mental health in this age group.

There is a lack of systematic investigation into stress mindset interventions, which informed the first aim of the project; to investigate whether beliefs about the nature of stress can be modified.

The second aim of this thesis was to critically examine the efficacy of the Stress N' Go education program (developed by Journault & Lupien, 2020). This stress education program is a rapid intervention designed to promote more stress-is-enhancing mindsets and mental well-being during adolescence. Stress N' Go involves four approximately five-minute videos using neuroscience-

informed education to teach students about their stress response (video one), stress mindsets (video two), adaptive coping strategies (video three), and stress reappraisal (video four). It was hypothesised that Stress N' Go would prime more stress-is-enhancing mindsets and may, in turn, promote mental health and wellbeing during adolescence. Student perceptions of the program from free-text responses were subsequently examined to gain more insight into the efficacy of the program.

Exploratory chapters were conducted to investigate the reliability and validity of the SMM in a cross-cultural cohort (Australian and Canadian samples) and whether COVID-19 had an impact on the stress and mental health of these adolescents.

Finally, the inclusion of nail cortisol as an emerging and potentially more inclusive measure of chronic stress compared to hair cortisol was examined as a future direction for this project, as research should consider the inclusion of stress physiology to examine the efficacy of future stress optimisation programs. Table 3 illustrates the more specific aims and hypotheses of each chapter included in this thesis.

Table 3

Chapter-Level Project Objectives

Chapter	Title	Study type	Aim	Hypothesis
1	*Turning Stress into Success*	Background	***Overarching aim:*** to utilise stress optimisation theory to prime more positive beliefs about stress during adolescence and promote mental health in this age group. *Aim 1:* to investigate whether beliefs about the nature of stress can be modified *Aim 2:* to critically examine the efficacy of the Stress N' Go education program	-
2	*Changing Stress Mindsets: A Systematic Review*	Systematic Review	To investigate whether stress mindsets can be changed through short interventions or manipulations.	-
3	*Promoting positive stress mindsets in Australian adolescents using the Stress N' Go intervention: A cluster randomised controlled trial*	Cluster randomised controlled trial	To test the effectiveness of the intervention at changing stress mindsets and promoting mental health in Australian adolescents	It was hypothesised that the Stress N' Go program would help Australian adolescents develop more stress-is-enhancing mindsets and promote mental health and wellbeing.
4	*A Mixed-Method Investigation of Student Experiences during Stress N' Go a Stress Education Program*	Mixed-Methods Study	To appraise the intervention based on feedback from the adolescents.	-
5	*A psychometric validation study assessing the reliability and validity of the Stress Mindset Measure - General among Canadian and Australian adolescents*	Psychometric Validation	To assess the reliability and validity of the primary outcome in Canadian and Australian adolescents at baseline.	It was hypothesised that the Stress Mindset Measure would be a reliable and valid measure of the implicit beliefs about stress held by Canadian and Australian adolescents.
6	*A cross-sectional study investigating Canadian and Australian adolescents' perceived experiences of COVID-19, gender differences, and mental health implications*	Cross-sectional Study	To situate the research within the context of a global pandemic (COVID-19) and to examine differences between adolescents living in Canada compared to Australia at baseline.	It was hypothesised that the global pandemic would be more stressful for students, particularly females, in stricter lockdown conditions.
7	*Human Nail Cortisol as a Retrospective Biomarker of Chronic Stress: A Systematic Review*	Systematic review	To review a prospective future measure of chronic stress for the project	-
8	*Can Stress Turn into Success?*	Discussion	To discuss the project's findings, limitations, and generalisability.	-

References

Akinola, M., Fridman, I., Mor, S., Morris, M. W., & Crum, A. J. (2016). Adaptive appraisals of anxiety moderate the association between cortisol reactivity and performance in salary negotiations. *PLOS One*, *11*(12), e0167977. https://doi.org/10.1371/journal.pone.0167977

Blascovich, J. (2008). Challenge, threat, and health. In J. Y. Shah & W. L. Gardner (Eds.), *Handbook of motivation science* (pp. 481–493). The Guilford Press.

Blascovich, J., & Tomaka, J. (1996). The biopsychosocial model of arousal regulation. *Advances in Experimental Social Psychology*, *28*, 1-51. https://doi.org/10.1016/S0065-2601(08)60235-X

Crum, A. J., Akinola, M., Martin, A., & Fath, S. (2017). The role of stress mindset in shaping cognitive, emotional, and physiological responses to challenging and threatening stress. *Anxiety, Stress & Coping*, *30*(4), 379-395. https://doi.org/10.1080/10615806.2016.1275585

Crum, A. J., Akinola, M., Turnwald, B. P., Kaptchuk, T. J., & Hall, K. T. (2018). Catechol-O-methyltransferase moderates effect of stress mindset on affect and cognition. *PLOS One*, *13*(4), e0195883. https://doi.org/10.1371/journal.pone.0195883

Crum, A. J., Jamieson, J. P., & Akinola, M. (2020). Optimizing stress: An integrated intervention for regulating stress responses. *Emotion*, *20*(1), 120-125. https://doi.org/10.1037/emo0000670

Crum, A. J., Salovey, P., & Achor, S. (2013). Rethinking stress: The role of mindsets in determining the stress response. *Journal of Personality and Social Psychology*, *104*(4), 716. https://doi.org/10.1037/a0031201

Dhabhar, F. S. (2018). The short-term stress response - mother nature's mechanism for enhancing protection and performance under conditions of threat, challenge, and opportunity. *Frontiers in Neuroendocrinology*, *49*, 175-192. https://doi.org/10.1016/j.yfrne.2018.03.004

Duan, L., Shao, X., Wang, Y., Huang, Y., Miao, J., Yang, X., & Zhu, G. (2020). An investigation of mental health status of children and adolescents in china during the outbreak of COVID-19. *Journal of Affective Disorders*, *275*, 112-118. https://doi.org/10.1016/j.jad.2020.06.029

Dweck, C. S. (2008). *Mindset: The new psychology of success*. Random House.

Folkman, S. (2008). The case for positive emotions in the stress process. *Anxiety, Stress & Coping*, *21*(1), 3-14. https://doi.org/10.1080/10615800701740457

Folkman, S., & Lazarus, R. S. (1984). *Stress, appraisal, and coping*. New York: Springer Publishing Company.

Giannopoulou, I., Efstathiou, V., Triantafyllou, G., Korkoliakou, P., & Douzenis, A. (2021). Adding stress to the stressed: Senior high school students' mental health amidst the COVID-19 nationwide lockdown in Greece. *Psychiatry Research*, *295*, 113560-113560. https://doi.org/10.1016/j.psychres.2020.113560

Gold, J. (2019). Overcoming students' limiting viewpoints via learner & stress mindset teaching interventions. *The European Journal of Social & Behavioural Sciences*, *24*(1), 2805-2821. http://dx.doi.org/10.15405/ejsbs.246

Gross, J. J. (2015). Emotion regulation: Current status and future prospects. *Psychological Inquiry*, *26*(1), 1-26. https://doi.org/10.1080/1047840X.2014.940781

Groth, N., Schnyder, N., Kaess, M., Markovic, A., Rietschel, L., Moser, S., ... & Schmidt, S. J. (2019). Coping as a mediator between locus of control, competence beliefs, and mental health: A systematic review and structural equation modelling meta-analysis. *Behaviour Research and Therapy*, *121*, 103442. https://doi.org/10.1016/j.brat.2019.103442

Hafstad, G. S., Sætren, S. S., Wentzel-Larsen, T., & Augusti, E.-M. (2021). Adolescents' symptoms of anxiety and depression before and during the Covid-19 outbreak – A prospective population-based study of teenagers in Norway. *The Lancet Regional Health - Europe*, *5*, 100093. https://doi.org/10.1016/j.lanepe.2021.100093

Hagger, M. S., Keech, J. J., & Hamilton, K. (2020). Managing stress during the coronavirus disease 2019 pandemic and beyond: Reappraisal and mindset approaches. *Stress and Health*, *36*(3), 396-401. https://doi.org/10.1002/smi.2969

Haugan, J. A., Frostad, P., & Mjaavatn, P. E. (2021). Stressors and vulnerability during upper secondary school: Subjective experiences of classroom climate and coping beliefs as

predicting factors of school stress in Norway. *Social Psychology of Education*, *24*(5), 1125-1144. https://doi.org/10.1007/s11218-021-09662-7

Headspace. (2020). *Insights: Youth mental health and wellbeing over time*. Headspace national youth mental health survey 2020. https://headspace.org.au/assets/Uploads/Insights-youth-mental-health-and-wellbeing-over-time-headspace-National-Youth-Mental-Health-Survey-2020.pdf

Heffer, T., & Willoughby, T. (2017). A count of coping strategies: A longitudinal study investigating an alternative method to understanding coping and adjustment. *PLOS One*, *12*(10), e0186057. https://doi.org/10.1371/journal.pone.0186057

Hogue, C. M. (2019). The protective impact of a mental skills training session and motivational priming on participants' psychophysiological responses to performance stress. *Psychology of Sport and Exercise*, *45*, 101574. https://doi.org/10.1016/j.psychsport.2019.101574

Jamieson, J. P., Crum, A. J., Goyer, J. P., Marotta, M. E., & Akinola, M. (2018). Optimizing stress responses with reappraisal and mindset interventions: an integrated model. *Anxiety, Stress & Coping*, *31*(3), 245-261. https://doi.org/10.1080/10615806.2018.1442615

Jamieson, J. P., Mendes, W. B., & Nock, M. K. (2013). Improving acute stress responses: The power of reappraisal. *Current Directions in Psychological Science*, *22*(1), 51-56. https://doi.org/10.1177/0963721412461500

Jamieson, J. P., Mendes, W. B., Blackstock, E., & Schmader, T. (2010). Turning the knots in your stomach into bows: Reappraising arousal improves performance on the GRE. *Journal of Experimental Social Psychology*, *46*(1), 208-212. https://doi.org/10.1016/j.jesp.2009.08.015

Jamieson, J. P., Nock, M. K., & Mendes, W. B. (2012). Mind over matter: reappraising arousal improves cardiovascular and cognitive responses to stress. *Journal of Experimental Psychology: General*, *141*(3), 417-422. https://doi.org/10.1037/a0025719

Journault, A., & Lupien, S. (2020). *Addendum to MATA's study: Stress mindset intervention*. https://doi.org/10.17605/OSF.IO/U4CMF

Juster, R.-P., McEwen, B. S., & Lupien, S. J. (2010). Allostatic load biomarkers of chronic stress and impact on health and cognition. *Neuroscience & Biobehavioral Reviews*, *35*(1), 2-16. https://doi.org/10.1016/j.neubiorev.2009.10.002

Kendall, P. C., Cummings, C. M., Villabø, M. A., Narayanan, M. K., Treadwell, K., Birmaher, B., Compton, S., Piacentini, J., Sherrill, J., Walkup, J., Gosch, E., Keeton, C., Ginsburg, G., Suveg, C., & Albano, A. M. (2016). Mediators of change in the child/adolescent anxiety multimodal treatment study. *Journal of Consulting and Clinical Psychology*, *84*(1), 1–14. https://doi.org/10.1037/a0039773

Kilby, C. J., & Sherman, K. A. (2016). Delineating the relationship between stress mindset and primary appraisals: preliminary findings. *SpringerPlus*, *5*, 336. https://doi.org/10.1186/s40064-016-1937-7

Laferton, J. A. C., Fischer, S., Ebert, D. D., Stenzel, N. M., & Zimmermann, J. (2020). The effects of stress beliefs on daily affective stress responses. *Annals of Behavioral Medicine*, *54*(4), 258-267. https://doi.org/10.1093/abm/kaz046

Lee, J. H., Seo, M., Lee, M., Park, S. Y., Lee, J. H., & Lee, S. M. (2017). Profiles of coping strategies in resilient adolescents. *Psychological Reports*, *120*(1), 49-69. https://doi.org/10.1177/0033294116677947

Liang, L., Ren, H., Cao, R., Hu, Y., Qin, Z., Li, C., & Mei, S. (2020). The effect of COVID-19 on youth mental health. *Psychiatric Quarterly*, *91*(3), 841-852. https://doi.org/10.1007/s11126-020-09744-3

Liu, J. J. W., Ein, N., Gervasio, J., & Vickers, K. (2019). The efficacy of stress reappraisal interventions on stress responsivity: A meta-analysis and systematic review of existing evidence. *PLOS One*, *14*(2), e0212854-e0212854. https://doi.org/10.1371/journal.pone.0212854

Liu, J. J., Vickers, K., Reed, M., & Hadad, M. (2017). Re-conceptualizing stress: Shifting views on the consequences of stress and its effects on stress reactivity. *PLOS One*, *12*(3), e0173188. https://doi.org/10.1371/journal.pone.0173188

Lupien, S. J., Juster, R.-P., Raymond, C., & Marin, M.-F. (2018). The effects of chronic stress on the human brain: From neurotoxicity, to vulnerability, to opportunity. *Frontiers in Neuroendocrinology*, *49*, 91-105. https://doi.org/10.1016/j.yfrne.2018.02.001

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

Ma, Z., Idris, S., Zhang, Y., Zewen, L., Wali, A., Ji, Y., Pan, Q., & Baloch, Z. (2021). The impact of COVID-19 pandemic outbreak on education and mental health of Chinese children aged 7-15 years: an online survey. *BMC Pediatrics*, *21*(1), 95-95. https://doi.org/10.1186/s12887-021-02550-1

Magson, N. R., Freeman, J. Y. A., Rapee, R. M., Richardson, C. E., Oar, E. L., & Fardouly, J. (2021). Risk and protective factors for prospective changes in adolescent mental health during the COVID-19 pandemic. *Journal of Youth and Adolescence*, *50*(1), 44-57. https://doi.org/10.1007/s10964-020-01332-9

McCrindle. (2021). *MyStrengths youth wellbeing report 2021*. https://s3.amazonaws.com/kajabi-storefronts-production/sites/163568/themes/2149125913/downloads/TnT1pVifTn62tOGicnyT_MyStrengths_Youth_Wellbeing_Report_2021.pdf

McEwen, B. S. (2017). Neurobiological and systemic effects of chronic stress. *Chronic Stress*, *1*, 2470547017692328. https://doi.org/10.1177/2470547017692328

Meda, N., Pardini, S., Slongo, I., Bodini, L., Zordan, M. A., Rigobello, P., Visioli, F., & Novara, C. (2021). Students' mental health problems before, during, and after COVID-19 lockdown in Italy. *Journal of Psychiatric Research*, *134*, 69-77. https://doi.org/10.1016/j.jpsychires.2020.12.045

Ochsner, K. N., & Gross, J. J. (2008). Cognitive emotion regulation: Insights from social cognitive and affective neuroscience. *Current Directions in Psychological Science*, *17*(2), 153-158. https://doi.org/10.1111/j.1467-8721.2008.00566.x

Ravens-Sieberer, U., Kaman, A., Otto, C., Adedeji, A., Devine, J., Erhart, M., Napp, A.-K., Becker, M., Blanck-Stellmacher, U., Löffler, C., Schlack, R., & Hurrelmann, K. (2020). Mental health and quality of life in children and adolescents during the COVID-19 pandemic-results of the copsy study. *Deutsches Arzteblatt International*, *117*(48), 828-829. https://doi.org/10.3238/arztebl.2020.0828

Rogers, A. A., Ha, T., & Ockey, S. (2021). Adolescents' perceived socio-emotional impact of COVID-19 and implications for mental health: Results from a U.S.-based mixed-methods study. *Journal of Adolescent Health*, *68*(1), 43-52. https://doi.org/10.1016/j.jadohealth.2020.09.039

Romeo, R. D. (2013). The teenage brain: The stress response and the adolescent brain. *Current Directions in Psychological Science*, *22*(2), 140-145. https://doi.org/10.1177/0963721413475445

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

Thorisdottir, I. E., Asgeirsdottir, B. B., Kristjansson, A. L., Valdimarsdottir, H. B., Jonsdottir Tolgyes, E. M., Sigfusson, J., Allegrante, J. P., Sigfusdottir, I. D., & Halldorsdottir, T. (2021). Depressive symptoms, mental wellbeing, and substance use among adolescents before and during the COVID-19 pandemic in Iceland: A longitudinal, population-based study. *The Lancet Psychiatry*, *8*(8), 663-672. https://doi.org/10.1016/S2215-0366(21)00156-5

Tiller, E., Fildes, J., Hall, S., Hicking, V., Greenland, N., Liyanarachchi, D., & Di Nicola, K. (2020). *Youth survey report 2020*. Mission Australia. https://www.missionaustralia.com.au/publications/youth-survey/1717-mission-australia-youth-survey-report-2020/file

Tsigos, C., Kyrou, I., Kassi, E., & Chrousos, G. P. (2020). Stress: Endocrine Physiology and Pathophysiology. In K. R. Feingold (Eds.) et. al., Endotext. MDText.com, Inc.

Wolcott, M. D., McLaughlin, J. E., Hann, A., Miklavec, A., Beck Dallaghan, G. L., Rhoney, D. H., & Zomorodi, M. (2021). A review to characterise and map the growth mindset theory in health professions education. *Medical Education*, *55*(4), 430-440. https://doi.org/10.1111/medu.14381

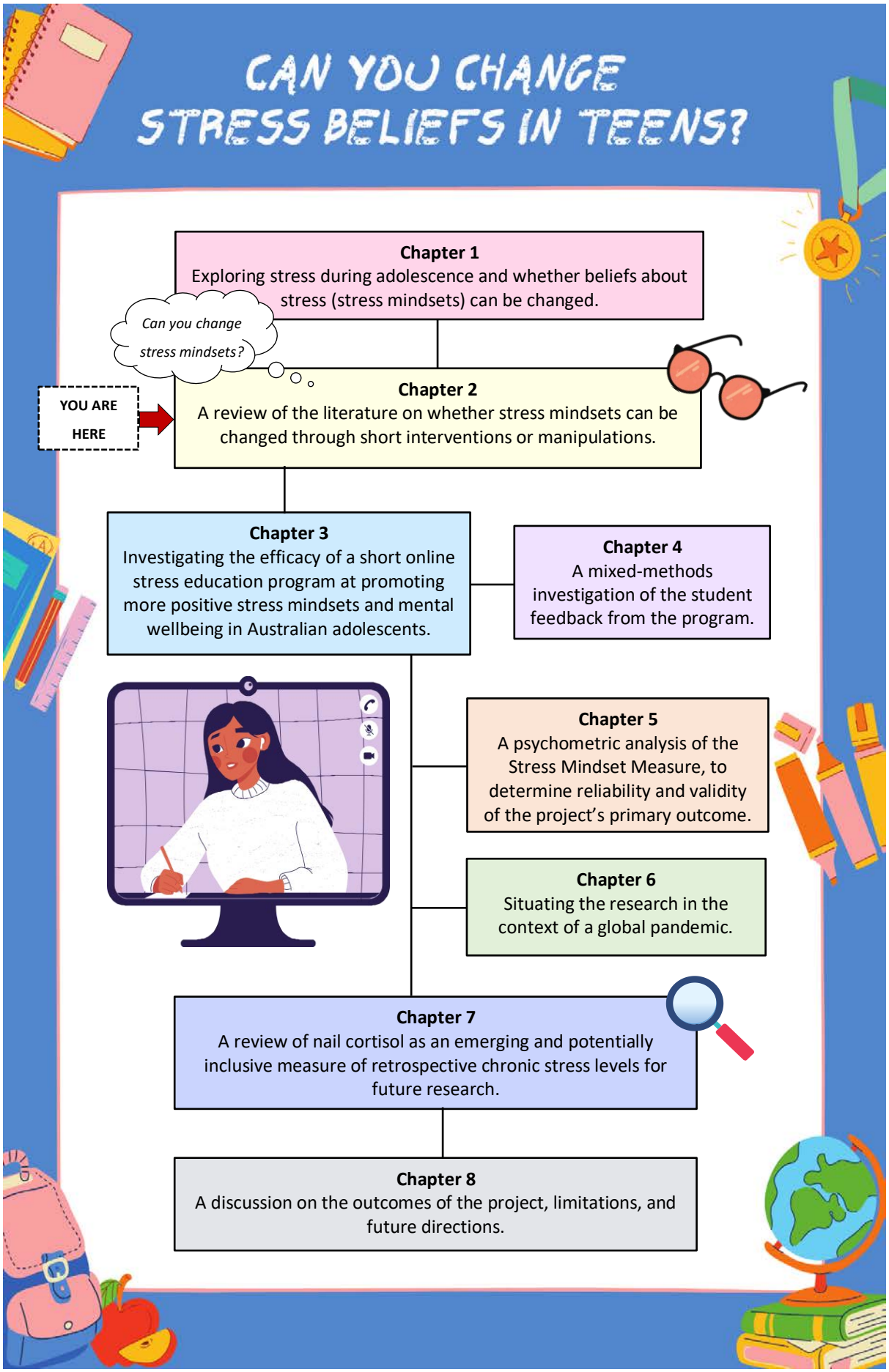
World Health Organisation. (2021). *Adolescent health*. World Health Organization. https://www.who.int/health-topics/adolescent-health#tab=tab_1

Yaribeygi, H., Panahi, Y., Sahraei, H., Johnston, T. P., & Sahebkar, A. (2017). The impact of stress on body function: A review. *EXCLI journal*, *16*, 1057-1072. https://doi.org/10.17179/excli2017-480

Zhou, S.-J., Zhang, L.-G., Wang, L.-L., Guo, Z.-C., Wang, J.-Q., Chen, J.-C., Liu, M., Chen, X., & Chen, J.-X. (2020). Prevalence and socio-demographic correlates of psychological health problems in Chinese adolescents during the outbreak of COVID-19. *European Child & Adolescent Psychiatry*, *29*(6), 749-758. https://doi.org/10.1007/s00787-020-01541-4

Zion, S. R., & Crum, A. J. (2018). Mindsets matter: A new framework for harnessing the placebo effect in modern medicine. *International Review of Neurobiology*, *138*, 137–160. https://doi.org/10.1016/bs.irn.2018.02.002

Zion, S. R., Schapira, L., & Crum, A. J. (2019). Targeting mindsets, not just tumors. *Trends in Cancer*, *5*(10), 573-576. https://doi.org/10.1016/j.trecan.2019.08.00


CAN YOU CHANGE STRESS BELIEFS IN TEENS?
Chapter 1
Exploring stress during adolescence and whether beliefs about stress (stress mindsets) can be changed.
Can you change stress mindsets?
YOU ARE HERE
Chapter 2
A review of the literature on whether stress mindsets can be changed through short interventions or manipulations.
Chapter 3
Investigating the efficacy of a short online stress education program at promoting more positive stress mindsets and mental wellbeing in Australian adolescents.
Chapter 4
A mixed-methods investigation of the student feedback from the program.
Chapter 5
A psychometric analysis of the Stress Mindset Measure, to determine reliability and validity of the project's primary outcome.
Chapter 6
Situating the research in the context of a global pandemic.
Chapter 7
A review of nail cortisol as an emerging and potentially inclusive measure of retrospective chronic stress levels for future research.
Chapter 8
A discussion on the outcomes of the project, limitations, and future directions.

TARGET JOURNAL: Frontiers of Psychology

Chapter 2

Changing Stress Mindsets: A Systematic Review

Riana Marie[123], Sabine Finlay[124], Beena Suvarna[124], Brett McDermott[3], Joseph V Moxon[3], and Zoltan Sarnyai[124*]

[1]Laboratory of Psychiatric Neuroscience, Centre for Molecular Therapeutics, [2] Australian Institute of Tropical Health and Medicine, James Cook University, Townsville, Queensland, Australia

[3]College of Medicine and Dentistry, James Cook University, Townsville, Queensland, Australia

[4]College of Public Health, Medical, and Veterinary Sciences, James Cook University, Townsville, Queensland, Australia

[*]Corresponding author:

Professor Zoltán Sarnyai, M.D., Ph.D.

Phone: +61747816992

Email: zoltan.sarnyai@jcu.edu.au

Address: College of Public Health, Medical, and Veterinary Sciences, James Cook University, 1 James Cook Drive, Townsville QLD 4811 AUSTRALIA

Abstract

Stress mindsets are the implicit way people view stress and can be viewed as either “enhancing” or “debilitating”. A *stress-is-enhancing* mindset has been associated with better work performance and psychological wellbeing; whereas a *stress-is-debilitating* mindset has been associated with increased perceived stress and poor mental health outcomes. As stress is often viewed negatively within society, this systematic review aimed to investigate whether stress mindsets can be changed using short interventions or manipulations with either a stress mindset or mental health focus. A systematic literature search identified 12 studies investigating changes in stress mindsets after a stress or health-related experimental manipulation (databases: Medline Ovid, Scopus, Web of Science, PsycINFO, and Google Scholar). Findings from these studies suggest that adults can be primed to view stress as more “enhancing” using stress mindset or resilience skills training via multimedia presentations, memory recall, mental imagery, or virtual reality. Limited data regarding long-term effects is available. These findings suggest that stress mindsets can be changed through intervention or manipulation, but further investigations are warranted to examine the length of these priming effects and whether they can have long-term changes to performance and mental wellbeing.

Keywords: Stress Mindset, Stress Mindset Measure, Stress Beliefs, Mindsets, Positive Stress

Changing Stress Mindsets: A Systematic Review

Stress is the psychological and/or physical response to threats or demands (Lazarus & Folkman, 1984). The acute physiological stress response mobilises energy to promote survival, performance, and potential stress-related growth (McEwen, 2008; Park & Helgeson, 2006). Chronic stress has been associated with poor mental and physical health outcomes (McEwen, 2017; Yaribeygi et al., 2017). Further, the perception that stress has adverse effects on health has been linked to an increased risk of premature death (Keller et al., 2012), suggesting that beliefs about stress may influence health perceptions and behaviour.

Stress Mindsets

Mindsets are the implicit mental frame or heuristics that individuals use to organise and encode information and guide thoughts and behaviour (Crum et al., 2013; Dweck, 2008; Dweck & Yeager, 2019). Stress mindsets are the lens through which an individual views stress (Crum et al., 2013). Depending on the individual's perspective, stress can have either enhancing or debilitating effects (Crum et al., 2013). Crum et al. (2013) proposed that stress mindsets may be an additional meta-cognitive variable involved in the stress response. Researchers have theorised that mindsets can affect beliefs related to growth and intelligence (Dweck, 2008; Wolcott et al., 2021). Based on implicit mindset theory, Crum et al. (2013) suggested that stress mindsets may alter the way people cognitively and behaviourally experience stress, which may consequently be linked to health and performance outcomes. For example, individuals who innately viewed stress as "enhancing" may engage in more proactive coping strategies such as support seeking or problem-solving; whereas individuals who view stress as "debilitating" may engage in non-productive coping strategies such as avoidance and rumination.

The Stress Mindset Measure

Crum et al. (2013) developed the Stress Mindset Measure (SMM) to quantify whether a person believes that the effects of stress are enhancing or debilitating. The SMM items were generated using focus groups of university staff and students and had two versions: a scale

associated with *general* beliefs about stress (SMM-G) and a scale associated with beliefs about stress related to a *specific* stressor (SMM-S). The initial items were refined through pilot samples until the final 8-item scales were developed (see Table S1 in the supplementary materials for the SMM items). The items focus on learning and growth, health and vitality, and performance and productivity. A five-point Likert scale from 0 "Strongly disagree" to 4 "Strongly agree" was used, where participant global scores were the average of all items. Higher scores indicate a more positive *stress-is-enhancing* belief (scores above 2 suggest a more enhancing stress mindset while below two is seen as more debilitating). The scale showed good reliability and validity (Crum et al., 2013), which was further supported in two psychometric reviews of translations (Greek and Japanese) of the scale (Iwamoto et al., 2019; Karampas et al., 2020).

Changing Stress Mindsets

Researchers have suggested that mindsets can be malleable through short intervention or experimental manipulation (Dweck, 2008). Crum et al. (2013) investigated whether scientific education and multimedia interventions could prime a stress-is-enhancing mindset and promote adaptive performance and wellbeing. Several literature reviews have discussed the historical context and potential of stress mindsets within health and performance (Crum et al., 2020; Hagger et al., 2020; Herman et al., 2020; Jamieson et al., 2018; Laferton et al., 2020; Zion & Crum, 2018; Zion et al., 2019). However, to date, there are currently no reviews systematically appraising the efficacy of *experimental manipulations* at changing stress mindsets. This review focused specifically on interventions, which quantitatively measured a change in stress mindsets, primarily using the SMM, for more heterogeneity within the qualitative comparisons. These interventions may have the potential to help individuals cope with stress and could be highly applicable in educational or clinical settings as a tool for coping with stress. Therefore, the aim of this systematic review was to assess whether stress mindsets can be changed through short experimental manipulations through a systematic evaluation of available evidence.

Method

Protocol

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Page, Moher, et al., 2021). A qualitative and quantitative synthesis was performed on studies reporting either stress-mindset or health-related programs measuring stress mindset scores pre- and post-manipulation.

Eligibility Criteria

This review included full-text peer-reviewed English language journal articles. Dissertations, conference proceedings, editorials, and literature reviews were excluded. There were no restrictions imposed on publication dates or status. Only studies assessing human participants were included. There were no limitations on participant demographics, such as age, sex, or ethnicity. Studies were eligible for inclusion in the qualitative synthesis if they examined an intervention or experimental manipulation, while, measuring stress mindsets at baseline and post-intervention.

Information Sources

Electronic databases were last searched on the 3rd of May 2021. All sources from before this date were included in this screening process. The searched databases included Medline (Ovid), ProQuest (PsycINFO), Scopus, Web of Science, and Google Scholar.

Search Strategy

The following search term was entered independently by two reviewers (RM and SF) into the selected databases: “stress mindset*” (*indicates truncation for plurals). This search term remained consistent for all databases using all fields. Using Web of Science, all articles that cited Crum et al. (2013) were also included in the search.

Selection Process

Two independent reviewers (RM and SF) assessed the eligibility of the studies based initially on the titles and abstracts of each journal article. After this screening process, full-text articles

deemed relevant were subsequently reviewed and, if eligible, included in the synthesis and analyses. Consensus was reached by discussion in cases of disagreement.

Data Items

The variables of interest in this review included: (1) Stress Mindset Training Interventions, (2) Non-specific manipulations (e.g., general mental health, resilience, etc.), (3) SMM global scores, and (4) participant demographics (age, sex, and ethnicity/race).

Critical Appraisal of Studies

Two independent reviewers (RM and BS) assessed the study quality, using the Joanna Briggs Institute (JBI) critical appraisal tool for quasi-randomised studies and randomised control trials (Tufanaru et al., 2020), and cross-sectional studies (Moola et al., 2020), to evaluate the risk of bias. These studies were assessed before any contact with authors for missing information. Studies clearly reporting >50% of the checklist items were considered to be at a "low" risk of bias. Any discrepancies between reviewers were resolved through discussion until consensus was achieved.

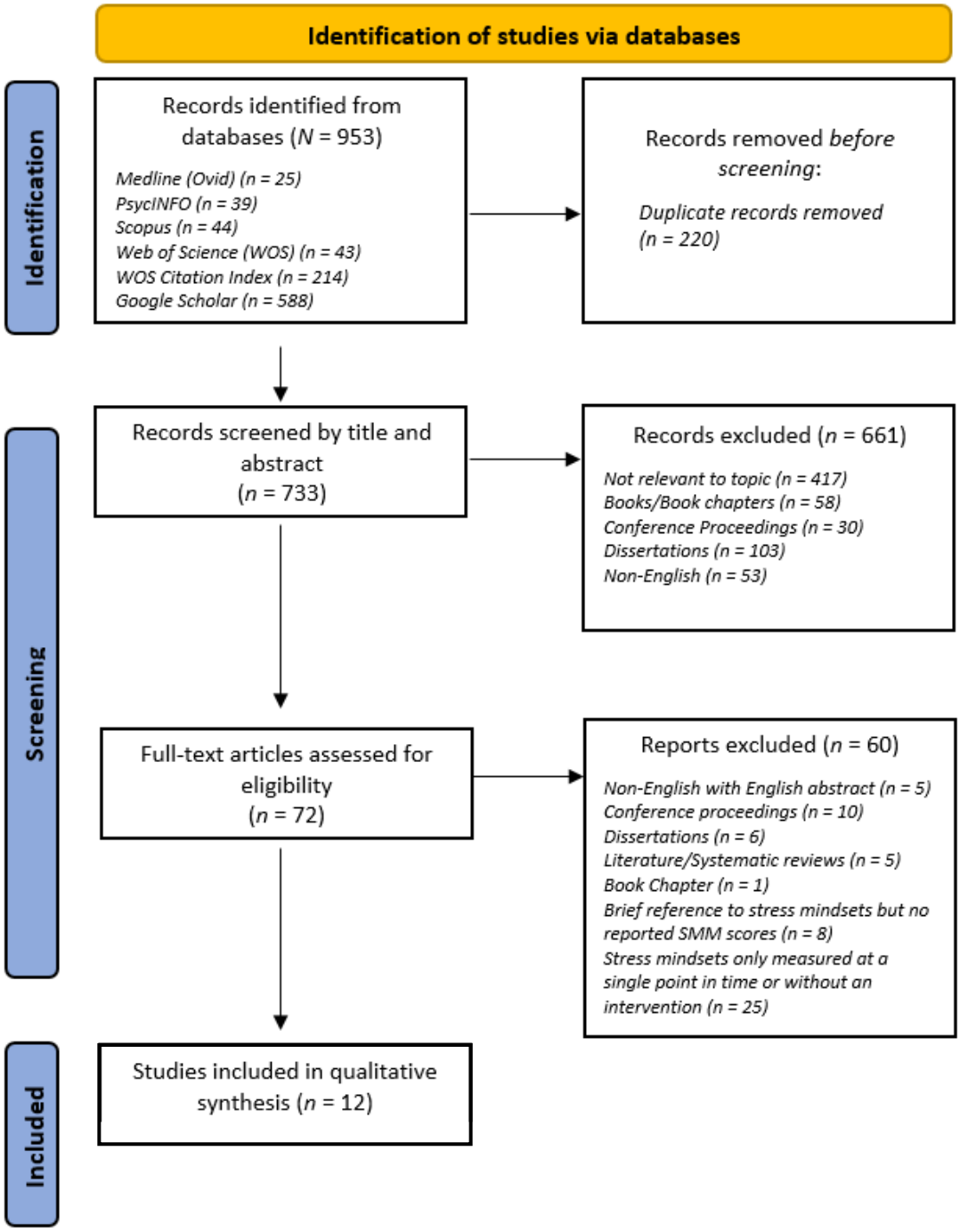
Results

Study Selection

The electronic database search found a total of 739 studies: Medline (Ovid) = 25, PsycINFO = 39, Scopus = 44, Web of Science = 43, and Google Scholar = 588. Articles (N = 214) specifically citing Crum et al. (2013) were also identified using the Web of Science citation database. These search results were combined and a total of 953 records were screened. Titles and abstracts from 733 studies were screened for relevancy. Duplicates (*n* = 220) and non-relevant studies (*n* = 661) were removed and the full text of 72 articles were screened. A total of 12 eligible journal articles were extracted for qualitative analysis. See Figure 2 for the PRISMA flow diagram for the full article screening process.

Figure 2

PRISMA 2020 flow diagram for new systematic reviews which included searches of databases only



Note. From: Page, McKenzie, et al. (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews.

Study Characteristics

Characteristics of the 12 studies included in the review are shown in Table 4. The studies were published between 2013 and 2021. The total cumulative sample size for the included studies was 3255 participants, gender was balanced for about 84% of the studies, and all eligible studies recruited adult participants. Studies recruited college (university) students (84%), employed adults (25%), and people with a mental health risk (15%). One study specifically investigated middle to older-aged adults (Crane et al., 2020). Half of the studies were conducted in the United States of America and the rest were from Australia, Israel, Japan, Korea, and Europe. Roughly 50% of studies reported specific ethnic profiles of their participants, with all reporting mostly white/Caucasian origins. The majority (75%) of the reviewed studies utilised the SMM-G developed by Crum et al. (2013). One study used the SMM-S to measure performance stress (Hogue, 2019) and another study separated the eight SMM items into ten items (Park & Hahm, 2019). Finally, one study used the Stress Control Mindset Measure (SCMM; Keech et al., 2021). The studies, which reported reliability coefficients for the SMM, all showed acceptable internal consistency (Cronbach's alpha = .77 to .95) for their respective scales. Summary of outcomes and extracted inferential statistics can be found in Table S5 within the supplementary materials.

Table 4

Study Characteristics

Author	Manipulation	N	Sample Type	Baseline Age (years, SD)	Gender	Ethnicity	Scale	Reliability
Crum et al. (2013) ***Study 1***	Validation study (no manipulation)	388	Finance employees USA	38.49 (8.40)	54% male	72% White/Caucasian 16% Asian 6% Hispanic 2% Black/African American 4% Other	SMM	SMM-G α = .86 SMM-S α = .80
Crum et al. (2013) ***Study 2****	Stress mindset skills training	388	Finance employees USA	38.49 (8.40)	54% male	72% White/Caucasian 16% Asian 6% Hispanic 2% Black/African American 4% Other	SMM	Test-retest: *r* = .66
Crum et al. (2013) ***Study 3***	Stress mindset skills training	63	College Students USA	19.00 (N/R)	62% female	N/R	SMM	N/R

Crum et al. (2017)	Stress mindset skills training	113	College students USA	24.10 (5.10)	66% female	40% White 32% Asian 15% Black 10% Native American 3% Other	SMM	α = .85 pre α = .94 post
Ben-Avi et al. (2018) ***Study 1***	No manipulation	348	Employees USA	37.40 (9.60)	48% female	N/R	SMM	α = .90
Ben-Avi et al. (2018) ***Study 2a***	Stress mindset memory recall manipulation	65	Business students IL	35.00 (11.00)	51% female	N/R	SMM	α = .88
Ben-Avi et al. (2018) ***Study 2b***	Stress mindset memory recall manipulation	207	Employees IL	29.18 (8.70)	50% female	N/R	SMM	N/A
Ben-Avi et al. (2018) ***Study 3***	Stress mindset memory recall manipulation	124	Employees IL	31.42 (10.17)	52% female	N/R	SMM	N/A
Ben-Avi et al. (2018) ***Study 4***	Stress mindset memory recall manipulation	292	Employees USA	36.04 (9.55)	51% female	78% White/Caucasian 7% Black/African American 7% Hispanic 6% Asian 2% Other	SMM	N/A
Crum et al. (2018)	Stress mindset skills training	107	College students USA	24.10 (5.10)	65% female	38% Caucasian 30% Asian 18% Black 14% Other	SMM	N/R
Gold (2019)	Growth mindset and stress mindset education	53	Japanese ESL students JP	N/R	N/R	N/R	SMM	N/R
Hogue (2019)	Mental skills training (including stress mindset skills)	59	College students USA	20.25 (3.15)	100% male	58% Caucasian, 22% African American 15% Pacific Islander/Asian 3% Other	SMM-S	α = .77 pre α = .85 post
Maarsingh et al. (2019)	"StressJam" biofeedback virtual reality game with stress mindset toolkit	111 HS 64 PS NL	Healthy sample (HS) Patient Sample (PS)	43.00 (10.50) HS 40.60 (11.50) PS	62% female HS 52% female PS	N/R	SMM	N/R
Park and Hahm (2019)	Stress mindset skills education	479	College students KR	18 – 24+[a]	60% male	N/R	SMM-10	α = .94 pre α = .94 post
Crane et al. (2020)	Stress resilience program	144	Corporate and community middle to older aged adults AUS	58.63 (N/R) Community 53.56 (N/R) Corporate 54.61 (N/R) Control	52% female	N/A	SMM	α = .80 to .84
Wegmann et al. (2020)	Health education	423	College students USA	20.77 (N/R)	64% female	62% White 19% Asian 9% Hispanic/Latino 5% Black or African American 5% Other	SMM	α = .80 pre α = .87 post
Wols et al. (2020)	Mental health game promotion	129	Young adults with elevated mental health symptoms EU	21.22 (3.20)	74% female	N/R	SMM	α = .78 pre α = .84 post
Keech et al. (2021)	Mental imagery stress mindset intervention	150	College students AUS	19.11 (1.94)	64% female	N/R	SCMM	α = .93 pre α = .95 post α = .95 follow-up

Note. *indicates the same sample of participants as the previous study. "N" is the study sample size. Location of study acronyms: United States of America (USA), Israel (IL), Japan (JP), Korea (KR), Australia (AUS), Netherlands (NL), and Europe in general (EU). Baseline age is presented as mean (standard deviation) unless reported otherwise. [a]Only general age range categories were provided. "SMM" = Stress Mindset Measure. "SCMM" = Stress Control Mindset Measure. "SMM-10" = adapted Stress Mindset Measure. "α" = Cronbach's alpha for internal consistency. "*r*" = Pearson's *r* correlation. "Pre" and "post" stand for pre and post-intervention respectively. "N/R" is data not reported and "N/A" stands for not applicable.

Study Quality

Approximately 75% of the studies used a quasi-randomised/experimental study design (Ben-Avi et al., 2018; Crum et al., 2018; Crum et al., 2017; Crum et al., 2013; Gold, 2019; Hogue, 2019; Maarsingh et al., 2019; Park and Hahm, 2020; Wols et al., 2020). Of these studies, 89% showed a low risk of bias (see Tables S2, S3, and S4 in the supplementary material) and only one showed a high risk of bias due to a lack of clear methodological reporting and sound data analysis (Gold, 2019). Only four of these quasi-randomised studies utilised a control group (Ben-Avi et al., 2018; Crum et al., 2013; Hogue, 2019; Wols et al., 2020). Two studies used a randomised control trial design but did not report whether outcome assessors were blinded to the treatment allocation (Crane et al., 2020; Keech et al., 2021). Finally, one study used a cross-sectional design where the only area of risk was the need for further consideration of confounding factors (Wegmann et al., 2020). All studies were critically reviewed within the qualitative synthesis.

Baseline SMM Scores

Normative data from the studies that recorded baseline levels of a stress mindset score are found in Table 5. There was a large amount of heterogeneity in scale selection, as scales ranged from 0 – 4, 1 – 5, 1 – 6, and 1 – 7. Crum et al. (2013) found that participants were more inclined to perceive stress as "debilitating" before manipulation. This is further supported by the majority of studies reporting SMM means within the lower spectrum of their scale range (Crum et al., 2018;

Crum et al., 2013; Hogue, 2019; Keetch et al., 2021; Maarsingh et al., 2019; Park & Hahm, 2019; Wegmann et al., 2020; Wols et al., 2020). All manipulations, except for Wegmann et al. (2020), found a significant increase in stress-is-enhancing mindsets post-intervention. Only two studies found a stable increase in stress mindsets after two weeks (Ketch et al., 2021) and four to five months (Crane et al., 2020) post-intervention.

Table 5

Baseline and Post-Intervention Change in Stress Mindsets

Author	Scale	Group	Baseline		Spectrum	Intervention Length	Post-Intervention			Follow up			Change
			M	*SD*			*T*	*M*	*SD*	*T*	*M*	*SD*	
Crum et al. (2013)	0 - 4	C	1.62	0.67	↓	Three 3-minute videos over 1 week	2-3 d	1.6	N/R	-	-	-	$p > .05$ (NC)
		SIE	"	"	"		"	1.9	N/R	-	-	-	$p < .01$ (↑)
		SID	"	"	"		"	1.15	N/R	-	-	-	$p < .001$ (↓)
Crum et al. (2017)	0 - 4	SIE	N/R	N/R	N/R	3-minute video	PM	2.48	N/R	-	-	-	$p < .001$ (↑)
		SID	N/R	N/R	N/R		"	1.13	N/R	-	-	-	$p < .001$ (↓)
Ben-Avi et al. (2018)	1 - 5	SIE	3.22	1.13	↑	Online survey	PM	3.43	0.52	-	-	-	$p < .001$ (↑)
		SID	"	"	"		"	2.53	0.68	-	-	-	$p < .001$ (↓)
Crum et al. (2018)	0 - 4	SIE	1.81	0.63	↓	3-minute video	PM	N/R	N/R	-	-	-	$p < .001$ (↑)
		SID	"	"	"			N/R	N/R	-	-	-	$p < .001$ (↓)
Gold (2019)	N/R	N/R	N/R	N/R	N/R	4 mindset sessions (1 stress mindset) over the course of a semester	N/R	N/R	N/R	-	-	-	N/R

Hogue (2019)	0 – 4 (SIE items)	C	1.72	0.69	↓	15-minute presentation	PM	1.80	0.91	-	-	-	$p > .05$ (NC)
		Mental Skills	1.92	0.62	↓		"	2.45	0.52	-	-	-	$p < .01$ (↑)
Maarsingh et al. (2019)	0 - 4	C	2.11	0.66	↑	1 hour	PM	2.31	0.68	-	-	-	$p < .001$ (↑)
		Patient	1.59	0.49	↓	Three 1hr sessions	"	2.14	0.58	-	-	-	$p < .001$ (↑)
Park and Hahm (2019)	1 - 7	-	3.378	N/R	↓	Three sessions over 3 weeks	2 d	4.152	N/R	-	-	-	$p < .001$ (↑)
Crane et al. (2020)*	1 - 5	C	3.05	N/R	↑	Two 40 minute sessions (intervention & debrief) Two 20 minute calls post-intervention	PM	3.11	N/R	4-5 mth	3.16	N/R	$p > .05$ (NC)
		Corporate	3.09	0.03	↑	" +5 weekly reflective writing tasks	"	3.24	0.06	"	3.15	N/R	$p < .05$ (↑)
		Community	2.96	0.03	↓	"	"	3.32	0.07	"	3.31	0.08	$p < .001$ (↑)
Wegmann et al. (2020)	N/R	-	1.85	0.63	-	Health education courses (no emphasis on stress)	9 wks from baseline	1.92	0.72	-	-	-	$p > .05$ (NC)
Wols et al. (2020)	0 - 4	Entertainment Group (C)	1.57	0.63	↓	Two 1-minute trailers + 60min experiment time	PM	1.45	0.67	-	-	-	$p > .05$ (NC)
		Mental Health Group	1.54	0.56	↓	"	"	1.68	0.61	-	-	-	$p < .05$ (↑)
Keech et al. (2021)*	1 - 6	C	3.27	0.10	↓	1 session including series of videos and writing task	PM	3.28	0.10	2 wks	3.22	0.10	$p > .05$ (NC)
		Intervention	3.35	0.10	↓		"	4.27	0.10	"	4.02	0.10	$p < .001$ (↑)

Note. Data is presented as baseline means and standard deviations. "T" = time. *Standard error was reported. "C" = Control. "SIE" = Stress-is-enhancing manipulation. "SID" = Stress-is-debilitating manipulation. " = Same as above. ↑ = Significant increase in scores. ↓ = Significant decrease in scores. "NC" = No change. "N/R" stands for data not reported and "-" Was used when the category was not applicable. "PM" = Immediately post- manipulation.

Stress Mindset Training

Stress mindset manipulations were reported in nine studies (Ben-Avi et al., 2018; Crum et al., 2017; Crum et al., 2018; Crum et al., 2013; Gold, 2019; Hogue, 2019; Keech et al., 2021; Maarsingh et al., 2019; Park & Hahm, 2019) and all of these studies found that participants could be primed to have more stress-is-enhancing mindsets. In the first investigation of stress mindsets, Crum et al. (2013) used short educational videos biased towards the positive (stress-is-enhancing) or negative (stress-is-debilitating effects of stress. The original stress mindset training content designed by Crum et al. (2013) can be found at: https://mbl.stanford.edu/materials-measures/stress-mindset-manipulation-videos. Participants in the stress-is-enhancing manipulation (*n* = 163) reported a significantly more positive stress mindset over time, improved psychological symptoms, and better work performance. However, participants in the stress-is-debilitating manipulation (*n* = 164) showed significantly more stress-is-debilitating mindsets but no changes in psychological or work outcomes. There were no significant changes in the stress mindsets of control participants (*n* = 61) who were shown no video content.

Crum et al. (2013) later replicated these findings using the same stress mindset manipulation videos in two different studies (Crum et al., 2017; Crum et al., 2018). University students (*n* = 113) in the stress-is-enhancing condition reported more positive affect and increased bias towards happy faces when given positive feedback (a condition to encourage appraising a stressful task as a challenge) during a Trier Social Stress Test (TSST) (Crum et al., 2017). Participants with a stress-is-enhancing mindset showed increased levels of the neurotrophic hormone, dehydroepiandrosterone sulfate (DHEA-S), relative to the stress-is-debilitating manipulation group and baseline values. Conversely, participants with a stress-is-enhancing mindset showed no significant reduction in negative affect or change cortisol levels in response to the TSST. From the same university study pool (*n* = 107), participants were genotyped to examine which variation of the catechol-O-methyltransferase (COMT) gene they expressed (Crum et al., 2018). The low activity form of this enzyme was hypothesised to be partially associated with increased stress reactivity (Crum et al.,

2018; Hernaus et al., 2013). Participants with low activity COMT gene, primed to have a stress-is-enhancing mindset, reported significantly more positive affect post-TSST. However, participants with the high activity enzyme did not respond to stress mindset manipulation.

One study used a stress mindset manipulation recall task (Ben-Avi et al., 2018). Business students, who were asked to recall a memory associated with the positive effects of stress, had a significantly more stress-is-enhancing mindset compared to the stress-is-debilitating condition who had to recall a negative stress-related event. However, no baseline scores were recorded in this experiment. In additional investigations of employees and independent of their mood, individuals with a primed stress-is-enhancing mindset evaluated an employee with a heavy workload (from a vignette) as less burnt-out and more promotable, as well as assigned lower ratings to their presenteeism (decreased productivity due to health concerns) and reduced physical symptoms of strain. Further, a primed stress-is-enhancing mindset reduced intentions to help the employee when they were perceived as experiencing fewer physical symptoms of stress.

Positive stress mindset education was also incorporated into one study's cognitive restructuring-based mental skills training session (Hogue, 2019). This study examined protective responses to performance stress. Male university students were randomly assigned into a control condition (n = 16), mental skills training group (n = 27), or achievement goal perspective theory (AGPT)-based educational lecture group (n = 16). The mental skills training group was presented with information about task-orientated achievement in addition to a brief education about stress mindsets. The SMM-S items were divided into the four positive and four negative stress mindset items and reported separately. The mental skills group showed significantly more stress-is-enhancing mindsets post-intervention compared to baseline, the control group, and the AGPT group. However, the mental skills group also showed significantly more stress-is-debilitating mindsets post-intervention. This experimental intervention did not reduce cortisol responses toward a stressor (ego-involving juggling task) but did show elevated responses in DHEA-S. Further, stress was evaluated as more of a challenge rather than a threat after the mental skills training.

Interestingly, one study used a virtual reality biofeedback game called “Stressjam” with the primary objective to prime more stress-is-enhancing mindsets (Maarsingh et al., 2019). The game used a heart rate variability sensor on the participant's chest so that the game was connected in real-time to their stress response. To progress through the game, they had to utilise more adaptive stress responses (e.g., open a gate by reducing stress levels) and a rethinking stress mindset toolkit. Healthy participants (*n* = 111) reported significantly more stress-is-enhancing mindsets after playing Stressjam for 1 hour. Patients (*n* = 64) from a mental health facility showed a significant linear increase in stress mindsets after three sessions.

Another study developed a stress mindset intervention to target limiting views of stress and promote more stress-is-enhancing mindsets in students (*n* = 53) (Gold, 2019). Before stress mindset education, 98% of students believed stress was negative. However, post-intervention, a greater percentage (74%) of students reported viewing stress as more positive. However, no inferential statistics were reported in this study limiting the ability to interpret findings. Similarly, one study used an online stress mindset training program that ran over a couple of weeks where university students (*n* = 479) were introduced to the concept of stress mindsets (Park & Hahm, 2019). These students also reported more stress-is-enhancing mindsets post-intervention. The same study also examined a subsample (*n* = 30) of participants’ electroencephalography (EEG) responses after a stressor (a coercive interview using aggressive language), before and after the online program. Only participants who showed a significant change towards a more stress-is-enhancing mindset were included in the post-intervention EEG analysis (*n* = 20). The EEG results suggest that people with a primed stress-is-enhancing mindset may show less arousal to a stressor (based on reduced beta activity and increased alpha activity).

Finally, a randomised control trial investigated a stress mindset intervention; post-intervention, and at a two-week follow-up (Keech et al., 2021). The intervention used stress mindset education and mental imagery exercises, such as imagining the potential positive consequences and experiences of stress in their life. Although stress mindset scores decreased over time, participants in

the intervention group (*n* = 69) showed more "stress-can be-enhancing" mindsets post-intervention and at the two-week follow-up, compared to pre-intervention and the control group (*n* = 70). Further, the intervention appeared to have a stronger effect on participants who perceived greater distress. Participants stratified into a high baseline perceived distress subgroup within the intervention group, reported reduced distress, higher positive affect, higher proactive behaviour, higher academic performance, and lower negative affect at follow-up compared to the control group.

Non-specific Programs

Stress mindset changes were also investigated outside of stress mindset-specific training methods, including mental health promotion (Wols et al., 2020), stress resilience (Crane et al., 2020), and health education (Wegmann et al., 2020). In young adults (*n* = 129), stress mindsets did not predict participants willingness to select a game promoted for mental health (*n* = 77) compared to the same game promoted for entertainment (*n* = 52) (Wols et al., 2020). However, participants who chose to play the game when it was promoted for mental health reported more stress-is-enhancing mindsets after playing the game, suggesting that the promotion of the mental health benefits of a game may incite more positive beliefs about stress after gameplay. Further, middle to older-aged participants from the community and corporate businesses were recruited into a nested clustered-randomised control trial investigating guided self-reflection to promote stress resilience (Crane et al., 2020). The self-reflective resilience training program involved discussions about resilience, stress perception, and adaptive self-reflection. The community samples (*n* = 51) reported significantly more stress-is-enhancing mindsets post-intervention and at follow-up (4 to 5 months after training) compared to pre-intervention and the controls. Conversely, the corporate sample reported more stress-is-enhancing mindsets post-intervention but not compared to follow-up or the controls. Greater engagement was related to increases in stress-is-enhancing mindsets in the community and corporate samples and having a more stress-is-enhancing mindset partially mediated resilience outcomes. Finally, a more indirect investigation of stress mindsets was conducted on college students enrolled in health education courses (with no emphasis on stress management) associated

with physical activity and nutrition (Wegmann et al., 2020). Students showed no significant changes in stress mindsets as they progressed with their health education courses. However, students with high levels of neuroticism, low levels of conscientiousness, and low levels of openness held less stress-is-debilitating beliefs as they progressed in their health education courses. Therefore, although general mental health and stress resilience programs appear to promote more stress-is-enhancing mindsets, programs that have no emphasis on stress education, appear to be less effective.

Discussion

This systematic review aimed to investigate studies that used experimental manipulations to prime more stress-is-enhancing mindsets at baseline and post-intervention. Overall, the qualitative synthesis suggests that participants can be primed to have more stress-is-enhancing or stress-is-debilitating mindsets.

Is Stress Viewed Negatively within Society?

At baseline, participants appeared to hold a more stress-is-debilitating mindset. The bias towards negativity within media and society may incite the more stress-is-debilitating mindsets observed at baseline (Soroka & McAdams, 2015). This belief that the nature of stress is inherently debilitating suggests that there is a need for interventions to create a more balanced perspective of stress. Acute stress can promote survival and performance through mechanisms, such as increased alertness and vigilance (McEwen, 2008). Recognising these benefits in addition to the negative effects of stress may help individuals feel more competent at coping with controllable stressors. Crum et al. (2013) experimentally manipulated individuals to have more “debilitating” stress mindsets using research emphasising the negative effects of stress. The ability to promote more negative stress mindsets through simple research examples and videos further supports the likely bias that individuals experience regarding the nature of stress within society. Although chronic stress can have negative effects, holding this belief alone may undermine the potential positive effects that some people may experience from acute stress, for instance, athletes, musicians, or school students.

Can Stress Mindsets be Changed?

stress-is-enhancing mindsets appeared to be primed through short interventions educating participants about their mindsets and stress response. Stress mindset psychoeducation can be conducted using multimedia presentations (Crum et al., 2017; Crum et al., 2018; Crum et al., 2013; Gold, 2019; Hogue, 2019), memory recall tasks (Ben-Avi et al., 2018), novel mental imagery (Keech et al., 2021), online education (Park & Hahm, 2019), and virtual biofeedback reality games (Maarsingh et al., 2019). There is also evidence to suggest that mindsets can be positively modified using more general mental health-related manipulations, such as stress resilience training (Crane et al., 2020) and game trailers promoting mental health (Wols et al., 2020).

One study measuring the positive and negative SMM items separately found that while stress-is-enhancing mindsets increased, stress-is-debilitating mindsets also increased (Hogue, 2019). It is unclear why this may have occurred, but it could be due to methodological variations, such as the intervention being more primarily focused on goal orientation than stress mindsets, the focus on performance stress rather than stress in general, or the use of a male cohort. This could also suggest that a more nuanced view of stress mindsets should be measured, such as the one promoted by Keech, Orbell et al. (2021) that stress “can be” enhancing rather than stress “is” enhancing. A balanced view of stress (that it can have both positive and negative effects) is more ethical and realistic, as not all stressors are controllable and as such it is suggested that stress mindset interventions reflect this nuanced perspective (Jamieson et al., 2018).

The only study that found no direct change in stress mindsets did not directly implement an intervention or control group but instead observed students enrolled in health education (Wegmann et al., 2020). Importantly, this study excluded students involved in stress management or mental health programs, which suggests that changing stress mindsets is only possible through stress-related interventions rather than any type of intervention. Therefore, findings from this study were not causal and need to be examined experimentally to determine whether health education would be a sufficient method of changing mindsets or due to the lack of stress-related education may be a useful

active control in future stress mindset manipulations. However, it is possible that the more specific stress mindset skills training may have a stronger effect compared to general health interventions. Based on the findings from this observational study, stress mindsets may be influenced by personality traits, which warrants further investigations.

The majority of the reviewed studies recruited university/college students. The developmental stability of stress mindsets would be worth examining to compare stress mindsets in early life to older adulthood. Implementing stress mindset interventions earlier in development may help children and adolescents learn to manage controllable stressors earlier in life. This may help prevent later difficulties in coping with stress for some individuals. Second to students were employee samples. It would be important to consider the efficacy of stress mindset programs on professions that experience considerable stress and higher burnout rates, such as health, military, or business professionals (Lubbadeh, 2020).

Future directions could also examine more diverse ethnic groups, as these interventions were largely implemented within white/Caucasian origins, which may limit the generalisability of the reported outcomes. Individuals from certain cultures and socioeconomic backgrounds can experience greater stress and consequently poorer mental health outcomes (Milas et al., 2019) and therefore stress mindset programs could be a potentially universal and rapid method of helping individuals cope with stress.

Long-term Changes in Stress Mindsets

Only two studies investigated longitudinal changes in stress mindsets beyond post-intervention (Crane et al., 2020; Keech et al., 2021). Both investigations were randomised control trials. The change in stress mindsets appeared to remain significant between follow-ups at two weeks (Keech et al., 2021) and four to five months (Crane et al., 2020) compared to pre-intervention. There was a decline between stress mindset scores post-intervention and follow-up. A lack of stability may suggest further reinforcement or practice is needed to help maintain these metacognitive beliefs about stress, especially if individuals are experiencing biases from outside

sources highlighting only the negative effects of stress. Future longitudinal investigations are warranted to determine the stability of primed stress mindsets as well as whether these primed mindsets have indirect causal effects on performance and psychological outcomes. It would be beneficial to compare whether different delivery methods (e.g., mental imagery or educational videos) may have varied effects on the stability of these meta-cognitive changes.

The Role of Stress Mindsets in Stress Appraisal

Two studies found that stress mindsets were associated with stress appraisal (Crum et al., 2017; Crum et al., 2013). Lazarus and Folkman (1984) suggested that stressors could be appraised as threats (situations with negative effects) or challenges (situations that are positive or promote growth). Having a more stress-is-enhancing mindset was related to viewing an acute stressor as a challenge instead of a threat. This reappraisal was also supported in a cross-sectional study investigating stress appraisal (Kilby & Sherman, 2016). Therefore, this may provide evidence for the influence of implicit mindsets on an individual's willingness to cognitively reappraise their environment. An integrated model of stress optimisation has been suggested that combines the concepts of stress mindsets and stress reappraisal (viewing stressful situations as challenges rather than threats) (Crum et al., 2020; Jamieson et al., 2018). This model may be a novel method of promoting more adaptive responses to stress, as it targets both meta-cognitive processes associated with beliefs about the nature of stress and perceptions/behaviours about specific stressors.

The Effect of Stress Mindsets on Performance

In the current review, work and academic performance were only investigated by two intervention studies, which showed promising results (Crum et al., 2013; Keech et al., 2021). However, observational research found having a more stress-is-enhancing mindset was associated with an increased desire for feedback on performance during a stressful task (Crum et al., 2013) Individuals with a stress-is-debilitating mindset had improved performance in critical reasoning tasks when they believed they were using a well-known branded product (e.g., Kaplan) compared to a fictitious brand; however, a stress-is-enhancing mindset harmed cognitive performance when the

brand was well-known. This suggests that stress mindsets may moderate performance brand placebo effects (Garvey et al., 2016).

Other studies have focused on the relationship between stress mindsets and work performance in business employees, preschool teachers, engineers, police officers, and military personnel (Ben-Avi et al., 2018; Casper et al., 2017; Chen & Fang, 2019a; Chen & Fang, 2019b; Chen & Hou, 2021; Crum et al., 2013; Hammond et al., 2020; Huettermann & Bruch, 2019; Iwamoto et al., 2020; Keech et al., 2020; Kim et al., 2020; Smith et al., 2020). For example, people with a more stress-is-enhancing mindset engaged in more approach-coping efforts during high workload anticipation. Workload anticipation was associated with enhanced vigour and task performance for employees with a more stress-is-enhancing mindset (Casper et al., 2017). stress-is-enhancing mindsets were associated with lower job stress, and job turnover, and increased job satisfaction and engagement (Chen & Fang, 2019a; Chen & Fang, 2019b; Hammond et al., 2020; Huettermann & Bruch, 2019; Kim et al., 2020). From an intrapersonal perspective, employees with a stress-is-enhancing mindset perceived individuals with high workloads to be less burnt-out, more promotable, and experience fewer somatic symptoms (Ben-Avi et al., 2018). Therefore, stress mindsets appear to influence work performance on an interpersonal and intrapersonal level. However, further experimental investigations into the effect of stress mindsets on performance using more objective measures besides self-report measures are warranted.

The Effects of Stress Mindsets on Mental Health

Stress mindsets have also been examined as direct and indirect factors influencing psychological outcomes (Chen & Qu, 2021; Chen & Hou, 2021; Crum et al., 2017; Crum et al., 2013; Horiuchi et al., 2018; Huebschmann & Sheets, 2020; Iwamoto et al., 2020; Jiang et al., 2020; Jiang et al., 2019; Johnson & Moore, 2020; Keech et al., 2020; Keech et al., 2018; Klussman et al., 2020; Nguyen et al., 2020; Park et al., 2018). stress-is-enhancing mindsets have also been positively associated with mood, positive affect, and psychological wellbeing (Chen & Qu, 2021; Crum et al., 2017; Crum et al., 2013; Keech et al., 2018). Similarly, stress-is-enhancing mindsets have been shown

to attenuate perceived distress, risk of mental illness, and improve relationship support (Jiang et al., 2019; Keech et al., 2020; Nguyen et al., 2020; Park et al., 2018). However, more stress-is-debilitating mindsets can be predictive of increased distress, conflict, burnout, and poor mental health (Chen & Hou, 2021; Huebschmann & Sheets, 2020; Iwamoto et al., 2020; Jiang et al., 2020; Johnson & Moore, 2020; Keech et al., 2018). Therefore, more stress-is-enhancing mindsets may have protective effects on mental wellbeing. Interestingly, having a more stress-is-enhancing mindset may reduce empathetic responses to others experiencing burnout, such as job strain (Ben-Avi et al., 2018). Although stress mindsets may be beneficial intrapersonally, the interpersonal effects of these implicit theories should be examined. Further, the majority of these investigations linking stress mindsets to performance or mental health have been cross-sectional, which stresses the need for more experimental research investigating the effects of priming stress mindsets through intervention.

The Influence of Stress Mindsets on Physiological Responses

stress-is-enhancing mindsets have been investigated to determine if they may influence physiological responses (Crum et al., 2017; Crum et al., 2018; Hogue, 2019; Maarsingh et al., 2019; Park & Hahm, 2019). Two studies examined cortisol responses after an acute stress response (e.g., a TSST or ego-involving climate) (Crum et al., 2017; Hogue, 2019). Cortisol responses were not buffered by having a more stress-is-enhancing mindset. Previous investigations have suggested that stress mindsets might provide more adaptive cortisol responses, but these reported outcomes were not based on statistically significant results (p = or > .05) (Crum et al., 2013). Considering an acute stress response was induced, it would be logical that stress mindsets did not affect cortisol reactively, as, in healthy participants, its short-term reactivity is important for metabolising the energy needed for performance (Lee et al., 2015). The effect of stress mindset changes on chronic measures of cortisol may also provide more insight into whether having a stress-is-enhancing mindset may result in an adaptive physiological response to stressful situations (Lee et al., 2015). Alternatively, two papers showed that DHEA-S secretion increased with a more stress-is-enhancing mindset (Crum et al., 2017; Hogue, 2019). DHEA-S is an anabolic and immune-enhancing steroid that may buffer the negative

effects of cortisol (Maninger et al., 2009). Elevated DHEA-S: cortisol ratios have also been associated with enhanced military performance, which may suggest that elevated DHEA-S may be predictive of performance under stress (Morgan et al., 2004).

Individuals with the COMT genetic variation associated with heightened stress reactivity may also benefit from having a more stress-is-enhancing mindset. One study found that individuals with greater susceptibility to increased subjective stress levels, who were primed to have more positive beliefs about stress, showed increased positive affect during an acute stress response (Crum et al., 2018). In a different study, stress-is-enhancing mindsets were also associated with less arousal in EEG responses during acute stress (Park & Hahm, 2019). Therefore, a stress-is-enhancing mindset may have protective physiological effects. However, more rigorous investigations are warranted to fully understand this relationship.

Finally, one study used a biofeedback virtual reality game based on heart rate variability (Maarsingh et al., 2019). Heart rate variability was used as a self-regulatory tool to help participants learn about their acute physiological stress response and how they can control it to perform within a game. This method of implicitly training more positive mindsets through video games may be useful as an engaging reinforcement tool in future investigations to allow a participant to learn how to manage their physiological stress responses. Overall, future research is needed to examine more comprehensive physiological investigations, such as heart rate variability and chronic stress measures, in addition to the psychological outcomes to understand how beliefs about stress may influence health outcomes.

Limitations

The focus of this systematic review was to review intervention studies investigating changes specifically in “stress mindsets” (as described by Crum et al., 2013), as this would allow for more homogenous comparisons within the synthesis. However, these limited search terms may not have found studies suggesting the possible presence of a metacognitive process about stress prior to Crum et al. (2013). The qualitative analysis would be strengthened by expanding the search terms to

include the use of synonyms and keyword mapping for “mindset” to reach a broader range of studies. The quality of some of the reviewed studies was limited by the lack of control groups used within the experimental investigations. The majority of the studies only investigated changes in stress mindset from baseline to post-intervention. Six studies used a form of a control group; however, one study did not measure stress mindsets post-manipulation for their experiment (Ben-Avi et al., 2018). Three studies only reported differences in stress-is-enhancing compared to stress-is-debilitating manipulations but did not have a control condition. Two studies reported non-significant findings ($p > .05$), as marginally significant results, which affected the interpretability of particular outcomes (Crum et al., 2018; Crum et al., 2013). Consequently, this review only reported statistically significant outcomes. There also was some heterogeneity within experimental methods and in the measurement of stress mindsets. Another limitation within this systematic review was the lack of diverse demographic samples. Most of the participants were adult college students of white/Caucasian origins, which may limit the generalisability of the reported outcomes. Investigations into a range of age groups, especially children and adolescents, and how culture may play a role in stress mindsets are critical future directions for this area of research to assess its applicability in a diverse range of backgrounds.

Conclusion

Overall, this review provides evidence to suggest that stress mindsets are malleable through intervention. Individuals can be primed to view stress as “enhancing” using short manipulations based on the positive effects of stress on performance, health, and wellbeing. Stress mindsets can also be altered using memory recall, mental imagery, or game-related tasks. Stress resilience and mental health programs also appear to promote more stress-is-enhancing mindsets. Previous investigations and the reviewed manipulations suggest that stress mindsets are associated with performance and psychological wellbeing. Stress mindset training interventions appear to offer rapid and non-invasive methods of altering meta-cognitive beliefs about stress. However, more research is needed to strengthen the relationship between stress mindset interventions and health and

performance before educational or clinical application. Nevertheless, promoting more positive implicit beliefs about stress may be beneficial, especially within the context of the pandemic when individuals are facing a shared global stressor. The longitudinal stability and protective emotional and biological effects of priming more positive stress mindsets need further investigations.

Conflict of Interest

The authors declare that they have no competing interests.

Authors' Contributions

The paper was drafted by RM. Database searches and data extraction was performed by RM and SF. Critical appraisal was performed by RM and BS. All authors edited and approved the final manuscript.

Funding

The Australian Government Research Training Program Scholarship and College of Medicine and Dentistry Top-up and Doctoral Thesis Writing Scholarships supported the Australian study.

Acknowledgments

The authors would like to acknowledge James Cook University (Australian Institute of Tropical Health and Medicine and the College of Medicine and Dentistry) for their facilities and the guidance of staff members. The authors would also like to thank the contacted authors within the review for their assistance with data extraction.

References

Ben-Avi, N., Toker, S., & Heller, D. (2018). “If stress is good for me, it's probably good for you too”: Stress mindset and judgment of others' strain. *Journal of Experimental Social Psychology*, *74*, 98-110. https://doi.org/http://dx.doi.org/10.1016/j.jesp.2017.09.002

Casper, A., Sonnentag, S., & Tremmel, S. (2017). Mindset matters: The role of employees’ stress mindset for day-specific reactions to workload anticipation. *European Journal of Work and Organizational Psychology*, *26*(6), 798-810. https://doi.org/10.1080/1359432x.2017.1374947

Chen, H.-L., & Fang, S.-C. (2019a). Interaction effect of leader-member exchange and stress mindset on challenge stressor and job performance relationship. *Research Journal of Business and Management*, *6*(4), 281-290. https://doi.org/10.17261/Pressacademia.2019.1158

Chen, H.-L., & Fang, S.-C. (2019b). Job stressors and job performance: Modeling of moderating mediation effects of stress mindset. *Research Journal of Business and Management*, *6*(1), 35-45. https://doi.org/10.17261/Pressacademia.2019.1020

Chen, L., & Qu, L. (2021). From stressful experiences to depression in Chinese migrant children: The roles of stress mindset and coping. *Frontiers in Psychology*, *12*, 868.

Chen, Z., & Hou, L. (2021). An actor-partner interdependence model of work challenge stressors and work-family outcomes: the moderating roles of dual-career couples’ stress mindsets. *Journal of Business and Psychology*, 1-15. https://doi.org/10.1007/s10869-020-09724-1

Crane, M. F., Kho, M., Kangas, M., Griffin, B., Karin, E., Earl, J. K., & Harris, C. B. (2020). Strengthening resilience in over 50’s: A nested clustered-randomized controlled trial of adaptive systematic self-reflection. *Anxiety, Stress, & Coping*, *33*(6), 623-641. https://doi.org/10.1080/10615806.2020.1768375

Crum, A. J., Akinola, M., Martin, A., & Fath, S. (2017). The role of stress mindset in shaping cognitive, emotional, and physiological responses to challenging and threatening stress. *Anxiety, Stress, & Coping*, *30*(4), 379-395. https://doi.org/10.1080/10615806.2016.1275585

Crum, A. J., Akinola, M., Turnwald, B. P., Kaptchuk, T. J., & Hall, K. T. (2018). Catechol-O-methyltransferase moderates effect of stress mindset on affect and cognition. *PLOS One*, *13*(4), e0195883. https://doi.org/10.1371/journal.pone.0195883

Crum, A. J., Jamieson, J. P., & Akinola, M. (2020). Optimizing stress: An integrated intervention for regulating stress responses. *Emotion*, *20*(1), 120-125. https://doi.org/10.1037/emo0000670

Crum, A. J., Salovey, P., & Achor, S. (2013). Rethinking stress: The role of mindsets in determining the stress response. *Journal of Personality and Social Psychology*, *104*(4), 716. https://doi.org/10.1037/a0031201

Dweck, C. S. (2008). *Mindset: The new psychology of success*. Random House.

Dweck, C. S., & Yeager, D. S. (2019). Mindsets: A view from two eras. *Perspectives on Psychological Science*, *14*(3), 481-496. https://doi.org/10.1177/1745691618804166

Garvey, A. M., Germann, F., & Bolton, L. E. (2016). Performance brand placebos: How brands improve performance and consumers take the credit. *Journal of Consumer Research*, *42*(6), 931-951. http://dx.doi.org/10.1093/jcr/ucv094

Gold, J. (2019). Overcoming students' limiting viewpoints via learner & stress mindset teaching interventions. *The European Journal of Social & Behavioural Sciences*, *24*(1), 2805-2821. https://doi.org/10.15405/ejsbs.246

Hagger, M. S., Keech, J. J., & Hamilton, K. (2020). Managing stress during the coronavirus disease 2019 pandemic and beyond: Reappraisal and mindset approaches. *Stress and Health*, *36*(3), 396-401. https://doi.org/10.1002/smi.2969

Hammond, M. M., Murphy, C., & Demsky, C. A. (2020). Stress mindset and the work–family interface. *International Journal of Manpower*, *42*(1). 150-166. https://doi.org/10.1108/ijm-05-2018-0161

Herman, K. C., Reinke, W. M., & Eddy, C. L. (2020). Advances in understanding and intervening in teacher stress and coping: The coping-competence-context theory. *Journal of School Psychology*, *78*, 69-74. https://doi.org/10.1016/j.jsp.2020.01.001

Hernaus, D., Collip, D., Lataster, J., Ceccarini, J., Kenis, G., Booij, L., Pruessner, J., Van Laere, K., van Winkel, R., van Os, J., & Myin-Germeys, I. (2013). COMT Val158Met genotype selectively alters prefrontal [18F]fallypride displacement and subjective feelings of stress in response to a psychosocial stress challenge. *PLOS One*, *8*(6), e65662. https://doi.org/10.1371/journal.pone.0065662

Hogue, C. M. (2019). The protective impact of a mental skills training session and motivational priming on participants' psychophysiological responses to performance stress. *Psychology of Sport and Exercise*, *45*, 101574. https://doi.org/10.1016/j.psychsport.2019.101574

Horiuchi, S., Tsuda, A., Aoki, S., Yoneda, K., & Sawaguchi, Y. (2018). Coping as a mediator of the relationship between stress mindset and psychological stress response: A pilot study. *Psychology Research and Behavior Management*, *11*, 47. https://doi.org/10.2147/PRBM.S150400

Huebschmann, N. A., & Sheets, E. S. (2020). The right mindset: stress mindset moderates the association between perceived stress and depressive symptoms. *Anxiety, Stress, & Coping*, *33*(3), 248-255. https://doi.org/10.1080/10615806.2020.1736900

Huettermann, H., & Bruch, H. (2019). Mutual gains? health-related HRM, collective well-being and organizational performance. *Journal of Management Studies*, *56*(6), 1045-1072. https://doi.org/10.1111/joms.12446

Iwamoto, K., Takehashi, H., & Taka, F. (2019). Reliability and validity of a Japanese translation of the Stress Mindset Measure (SMM-J). *Japanese Journal of Psychology*, *90*(6), 592-602. https://doi.org/http://dx.doi.org/10.4992/jjpsy.90.18229

Iwamoto, K., Takehashi, H., Ozaki, Y., & Narita, N. (2020). Investigating effects of intelligence and stress mindsets on system engineer's mental health and learning motivations. *Japanese Journal of Motivational Studies: IMSAR Annual Report*, *9*(2), 9.

Jamieson, J. P., Crum, A. J., Goyer, J. P., Marotta, M. E., & Akinola, M. (2018). Optimizing stress responses with reappraisal and mindset interventions: an integrated model. *Anxiety, Stress, & Coping*, *31*(3), 245-261. https://doi.org/10.1080/10615806.2018.1442615

Jiang, Y., Ming, H., Tian, Y., Huang, S. L., Sun, L., Li, H. J., & Zhang, H. C. (2020). Cumulative risk and subjective well-being among rural-to-urban migrant adolescents in China: Differential moderating roles of stress mindset and resilience. *Journal of Happiness Studies*, *21*(7), 2429-2449. https://doi.org/10.1007/s10902-019-00187-7

Jiang, Y., Zhang, J., Ming, H., Huang, S. L., & Lin, D. H. (2019). Stressful life events and well-being among rural-to-urban migrant adolescents: The moderating role of the stress mindset and differences between genders. *Journal of Adolescence*, *74*, 24-32. https://doi.org/10.1016/j.adolescence.2019.05.005

Johnson, S. J., & Moore, T. M. (2020). The role of impulsivity and stress mind-set in understanding the mindfulness–intimate partner aggression relationship. *Journal of Interpersonal Violence*, 0886260520917506. https://doi.org/10.1177/0886260520917506

Karampas, K., Pezirkianidis, C., & Stalikas, A. (2020). Psychometric properties of the Stress Mindset Measure (SMM) in a Greek sample. *Psychology*, *11*(08), 1185. https://doi.org/10.4236/psych.2020.118079

Keech, J. J., Cole, K. L., Hagger, M. S., & Hamilton, K. (2020). The association between stress mindset and physical and psychological wellbeing: Testing a stress beliefs model in police officers. *Psychology & Health*, *35*(11), 1306-1325. https://doi.org/10.1080/08870446.2020.1743841

Keech, J. J., Hagger, M. S., & Hamilton, K. (2021). Changing stress mindsets with a novel imagery intervention: A randomized controlled trial. *Emotion*, *21*(1), 123-136. https://doi.org/10.1037/emo0000678

Keech, J. J., Hagger, M. S., O'Callaghan, F. V., & Hamilton, K. (2018). The infuence of university students' stress mindsets on health and performance outcomes. *Annals of Behavioral Medicine*, *52*(12), 1046-1059. https://doi.org/10.1093/abm/kay008

Keech, J. J., Orbell, S., Hagger, M. S., O'Callaghan, F. V., & Hamilton, K. (2021). Psychometric properties of the stress control mindset measure in university students from Australia and the UK. *Brain and Behavior*, *11*(2), e01963. https://doi.org/10.1002/brb3.1963

Keller, A., Litzelman, K., Wisk, L. E., Maddox, T., Cheng, E. R., Creswell, P. D., & Witt, W. P. (2012). Does the perception that stress affects health matter? The association with health and mortality. *Health Psychology*, *31*(5), 677-684. https://doi.org/10.1037/a0026743

Kilby, C. J., & Sherman, K. A. (2016). Delineating the relationship between stress mindset and primary appraisals: Preliminary findings. *Springerplus*, *5*(1), 1-8. https://doi.org/10.1186/s40064-016-1937-7

Kim, J., Shin, Y., Tsukayama, E., & Park, D. (2020). Stress mindset predicts job turnover among preschool teachers. *Journal of School Psychology*, *78*, 13-22. https://doi.org/10.1016/j.jsp.2019.11.002

Klussman, K., Lindeman, M. I. H., Nichols, A. L., & Langer, J. (2020). Fostering stress resilience among business students: The role of stress mindset and self-connection. *Psychological Reports*, 0033294120937440. https://doi.org/10.1177/0033294120937440

Laferton, J. A. C., Fischer, S., Ebert, D. D., Stenzel, N. M., & Zimmermann, J. (2020). The effects of stress beliefs on daily affective stress responses. *Annals of Behavioral Medicine*, *54*(4), 258-267. https://doi.org/10.1093/abm/kaz046

Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping*. Springer publishing company.

Lee, D. Y., Kim, E., & Choi, M. H. (2015). Technical and clinical aspects of cortisol as a biochemical marker of chronic stress. *BMB Reports*, *48*(4), 209-216. https://doi.org/10.5483/bmbrep.2015.48.4.275

Lubbadeh, T. (2020). Job burnout: a general literature review. *International Review of Management and Marketing*, *10*(3), 7. https://doi.org/10.32479/irmm.9398

Maarsingh, B. M., Bos, J., Van Tuijn, C. F. J., & Renard, S. B. (2019). Changing stress mindset through Stressjam: A virtual reality game using biofeedback. *Games for Health*, *8*(5), 326-331. https://doi.org/http://dx.doi.org/10.1089/g4h.2018.0145

Maninger, N., Wolkowitz, O. M., Reus, V. I., Epel, E. S., & Mellon, S. H. (2009). Neurobiological and neuropsychiatric effects of dehydroepiandrosterone (DHEA) and DHEA sulfate (DHEAS). *Frontiers in Neuroendocrinology*, *30*(1), 65-91. https://doi.org/10.1016/j.yfrne.2008.11.002

McEwen, B. S. (2008). Central effects of stress hormones in health and disease: Understanding the protective and damaging effects of stress and stress mediators. *European Journal of Pharmacology*, *583*(2), 174-185. https://doi.org/10.1016/j.ejphar.2007.11.071

McEwen, B. S. (2017). Neurobiological and Systemic Effects of Chronic Stress. *Chronic Stress*, *1*, 2470547017692328. https://doi.org/10.1177/2470547017692328

Milas, G., Klarić, I. M., Malnar, A., Šupe-Domić, D., & Slavich, G. M. (2019). Socioeconomic status, social-cultural values, life stress, and health behaviors in a national sample of adolescents. *Stress and Health*, *35*(2), 860 217–224. https://doi.org/10.1002/smi.2854

Moola, S., Munn, Z., Tufanaru, C., Aromataris, E., Sears, K., Sfetcu, R., Currie, M., Qureshi, R., Mattis, P., Lisy, K., & Mu, P.-F. (2020). *Chapter 7: Systematic reviews of etiology and risk* (M. Z. E. Aromataris E, Ed. Vol. 5). JBI.

Morgan, C. A., 3rd, Southwick, S., Hazlett, G., Rasmusson, A., Hoyt, G., Zimolo, Z., & Charney, D. (2004). Relationships among plasma dehydroepiandrosterone sulfate and cortisol levels, symptoms of dissociation, and objective performance in humans exposed to acute stress. *Archives Of General Psychiatry*, *61*(8), 819-825. https://doi.org/10.1001/archpsyc.61.8.819

Nguyen, T. T. T., Neff, L. A., & Williamson, H. C. (2020). The role of stress mindset in support provision. *Personal Relationships*, *27*(1), 138-155. https://doi.org/http://dx.doi.org/10.1111/pere.12302

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., & Brennan, S. E. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, *372*. https://doi.org/10.1136/bmj.n71

Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., Stewart, L. A., Thomas, J., Tricco, A. C., Welch, V. A., Whiting, P., & McKenzie, J. E. (2021). PRISMA 2020 explanation and elaboration: Updated guidance and exemplars for reporting systematic reviews. *BMJ*, *372*, n160. https://doi.org/10.1136/bmj.n160

Park, C. L., & Helgeson, V. S. (2006). Introduction to the special section: Growth following highly stressful life events--current status and future directions. *Journal of Consulting and Clinical Psychology*, *74*(5), 791-796. https://doi.org/10.1037/0022-006x.74.5.791

Park, D., Yu, A., Metz, S. E., Tsukayama, E., Crum, A. J., & Duckworth, A. L. (2018). Beliefs about stress attenuate the relation among adverse life events, perceived distress, and self-control. *Child Development*, *89*(6), 2059-2069. https://doi.org/http://dx.doi.org/10.1111/cdev.12946

Park, H., & Hahm, S. (2019). Changes in stress mindset and EEG through E-healthcare based education. *IEEE Access*, 7, 20163-20171, Article 8629068. https://doi.org/10.1109/ACCESS.2019.2895655

Smith, E. N., Young, M. D., & Crum, A. J. (2020). Stress, mindsets, and success in navy SEALs special warfare training. *Frontiers in Psychology*, *10*, 2962. https://doi.org/10.3389/fpsyg.2019.02962

Soroka, S., & McAdams, S. (2015). News, Politics, and Negativity. *Political Communication*, *32*(1), 1-22. https://doi.org/10.1080/10584609.2014.881942

Tufanaru, C., Munn, Z., Aromataris, E., Campbell, J., & Hopp, L. (2020). *Chapter 3: Systematic Reviews of Effectiveness* (M. Z. E. Aromataris E, Ed.). JBI.

Wegmann, J., Marshall, J., Tsai, C. Y., & Dionne, S. (2020). Health education and changing stress mindsets: The moderating role of personality. *American Journal of Health Education*, *51*(4), 244-256. https://doi.org/10.1080/19325037.2020.1767002

Wolcott, M. D., McLaughlin, J. E., Hann, A., Miklavec, A., Beck Dallaghan, G. L., Rhoney, D. H., & Zomorodi, M. (2021). A review to characterise and map the growth mindset theory in health professions education. *Medical Education*, *55*(4), 430-440. https://doi.org/10.1111/medu.14381

Wols, A., Poppelaars, M., Lichtwarck-Aschoff, A., & Granic, I. (2020). The role of motivation to change and mindsets in a game promoted for mental health. *Entertainment Computing*, *35*, 100371. https://doi.org/10.1016/j.entcom.2020.100371

Yaribeygi, H., Panahi, Y., Sahraei, H., Johnston, T. P., & Sahebkar, A. (2017). The impact of stress on body function: A review. *EXCLI journal*, *16*, 1057-1072. https://doi.org/10.17179/excli2017-480

Zion, S. R., & Crum, A. J. (2018). Mindsets Matter: A New Framework for Harnessing the Placebo Effect in Modern Medicine. *International Review of Neurobiology*, *138*, 137–160. https://doi.org/10.1016/bs.irn.2018.02.002

Zion, S. R., Schapira, L., & Crum, A. J. (2019). Targeting mindsets, not just tumors. *Trends in Cancer*, *5*(10), 573-576. https://doi.org/10.1016/j.trecan.2019.08.00

Supplementary Materials

Table S1

Stress Mindset Measure – General (Specific)

Items
Please rate the extent to which you agree or disagree with the following statements
1. The effects of (this) stress are negative and should be avoided. (Reverse scored)
2. Experiencing (this) stress facilitates my learning and growth.
3. Experiencing (this) stress depletes my health and vitality. (Reverse scored)
4. Experiencing (this) stress enhances my performance and productivity.
5. Experiencing (this) stress inhibits my learning and growth. (Reverse scored).
6. Experiencing (this) stress improves my health and vitality.
7. Experiencing (this) stress debilitates my performance and productivity. (Reverse scored)
8. The effects of (this) stress are positive and should be utilised.

Table S2

Critical Appraisal of Studies based on JBI Checklist for Quasi-Randomised Studies

Study	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Total (%)**
Crum et al. (2013)	1	1	1	1	1	1	1	1	1	9 (100)
Crum et al. (2017)	1	0	1	0	1	1	1	1	1	7 (78)
Ben-Avi et al. (2018)	1	0	1	1	1	1	1	1	1	8 (89)
Crum et al. (2018)	1	1	1	0	1	1	1	1	1	8 (89)
Gold (2019)	1	1	0	0	1	1	1	0	0	5 (50)
Hogue (2019)	1	0	1	1	1	1	1	1	1	8 (89)
Maarsingh et al. (2019)	1	0	1	0	1	1	1	1	0	6 (67)
Park and Hahm (2019)	1	1	1	0	1	1	1	1	0	7 (78)

Wols et al. (2020)	1	1	1	1	1	1	1	1	1	9 (100)

Note. 1 = Yes and 0 = Unclear/No. Total risk reported as frequency (percentage).

Domains:

Q1. Is it clear in the study what is the 'cause' and what is the 'effect' (i.e. there is no confusion about which variable comes first)?

Q2. Were the participants included in any comparisons similar?

Q3. Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?

Q4. Was there a control group?

Q5. Were there multiple measurements of the outcome both pre and post the intervention/exposure?

Q6. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?

Q7. Were the outcomes of participants included in any comparisons measured in the same way?

Q8. Were outcomes measured in a reliable way?

Q9. Was appropriate statistical analysis used?

Table S3

Critical Appraisal of Studies based on JBI Checklist for Randomised Control Trials

Study	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**	**Q13**	**Total (%)**
Keech et al. (2021)	1	1	1	1	1	1	1	1	1	1	1	1	1	12 (92)
Crane et al. (2020)	1	0	1	0	0	0	1	1	1	1	1	1	1	9 (69)

Note. 1 = Yes and 0 = Unclear/No. Total risk reported as frequency (percentage).

Domains:

Q1. Was true randomization used for assignment of participants to treatment groups?

Q2. Was allocation to treatment groups concealed?

Q3. Were treatment groups similar at the baseline?

Q4. Were participants blind to treatment assignment?

Q5. Were those delivering treatment blind to treatment assignment?

Q6. Were outcome assessors blind to treatment assignment?

Q7. Were treatment groups treated identically other than the intervention of interest?

Q8. Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?

Q9. Were participants analysed in the groups to which they were randomized?

Q10. Were outcomes measured in the same way for treatment groups?

Q11. Were outcomes measured in a reliable way?

Q12. Was appropriate statistical analysis used?

Q13. Was the trial design appropriate, and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?

Table S4

Critical Appraisal of Studies based on JBI Checklist for Analytical Cross-sectional Studies

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Total (%)
Wegmann et al. (2020)	1	1	1	1	0	0	1	1	6 (75)

Note. 1 = Yes and 0 = Unclear/No. Total risk reported as frequency (percentage).

Domains:

Q1. Were the criteria for inclusion in the sample clearly defined?

Q2. Were the study subjects and the setting described in detail?

Q3. Was the exposure measured in a valid and reliable way?

Q4. Were objective, standard criteria used for measurement of the condition?

Q5. Were confounding factors identified?

Q6. Were strategies to deal with confounding factors stated?

Q7. Were the outcomes measured in a valid and reliable way?

Q8. Was appropriate statistical analysis used?

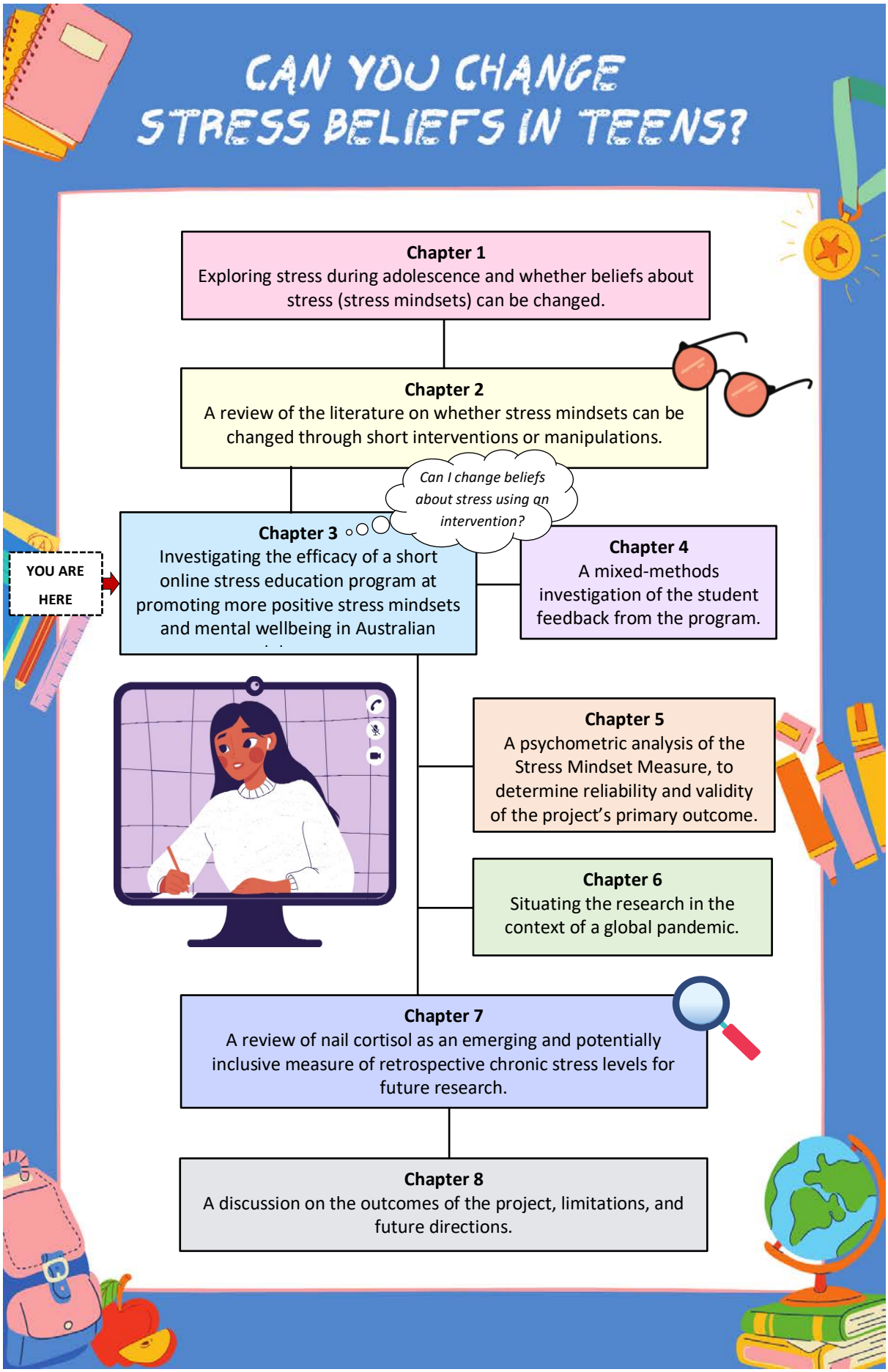
Table S5

Study Outcomes

Author	N	Primary Statistical Outcomes	Author Findings
Crum et al. (2013) ***Study 1***	388	*Confirmatory Factor Analysis* [1]Single factor structure *Stepwise regression* [2]β = -.19, $p < .01$, $R^2 = .40$, $\Delta R^2 = .03$ [3]β =.13, $p < .01$, $R^2 = .27$, $\Delta R^2 = .02$	The SMM-G and SMM-S were developed using focus groups and validated as a distinct stress construct[1] that has a meaningful relationship to health[2] and wellbeing[3].
Crum et al. (2013) ***Study 2****	388	*ANOVA* *Group (enhancing, debilitating, control) X Time (pre- and post-intervention)* [1]$F(1, 261) = 27.39$, $p < .001$, $\eta^2 = .17$ [2]$F(1, 269) = 3.20$, $p = .04$, $\eta^2 = .02$ [3]$F(1, 293) = 5.10$, $p = .01$, $\eta^2 = .04$	Stress mindsets can be altered by short video interventions. Videos promoting the effects of positive stress appear to facilitate more stress-is-enhancing mindsets[1], improved mood[2], and better work performance[3].
Crum et al. (2013) ***Study 3***	63	*Stepwise regression* [1]B (SE) = .42 (.19), β = .23, p < .05, $R^2 = .17$, $\Delta R^2 = .09$ *Hierarchical regression model* [2]β = .21, $t(58) = 1.80$, $p = .07$	Positive stress mindsets may increase desire for performance feedback[1] The authors report a trend suggesting the stress mindsets promote more adaptive cortisol reactivity[2] during brief stressful experiences, but this should be further investigated as the effect was non-significant.
Crum et al. (2017)	113	*ANOVA* *Time (baseline, pre-speech, post-speech) X Mindset (enhancing, debilitating) X Feedback (positive "challenge", negative "threat").* [1]$F(2, 202) = 3.63$, $p = .020$, $\eta^2 = .035$ [2]$F(1, 107) = 37.99$, $p < .001$, $\eta^2 = .271$ [3]$F(1, 61) = 4.07$, $p = .048$, $\eta^2 = .068$ [4]$F(1.22, 67.13) = 0.367$, $p = .694$, $\eta^2 = .002$ *Mindset (enhancing, debilitating) X Feedback (positive "challenge", negative "threat").* [5]$F(1, 46) = 4.40$, $p = .042$, $\eta^2 = .091$ [6]$F(1, 105) = 4.64$, $p = .033$, $\eta^2 = .044$	Participants with a stress-is-enhancing mindset reported greater positive affect (particularly after positive "challenge" feedback)[1] and increased DHEA-S levels[3] (but not cortisol[4]) post-stressor. Regardless of stress mindset, those who experienced negative feedback (threat appraisal) showed increased negative affect[2]. A stress-is-enhancing mindset and challenge appraisal increased attentional bias towards happy faces[5]. Participants who receive positive "challenge" feedback encouraged cognitive flexibility[6].
Ben-Avi et al. (2018) ***Study 1***	348	*Regression analyses* [1]β =−0.11, $t(341) = 2.21$, $p = 0.028$, 95% *CI* [−0.21, −0.01], $\Delta R^2 = .18$ *Mediation analyses* [2]Unstandardized indirect effect =0.02, *SE* = 0.01, 95% *CI* [0.003, 0.049]	Independent of demographics, mood, wellbeing, and perceived workload, employees with a stress-is-enhancing mindset were less likely to regard a target with a high workload as experiencing job strain (burnout)[1] and more likely to have increased estimates about the promotability of the target[2].
Ben-Avi et al. (2018) ***Study 2a***	65	*Independent samples t-test* [1]$t(63) = 6.05$, $p < 0.001$, $d = 1.33$	Participants who described a stressful event that had affected them in an enhancing way were primed to have a more stress-is-enhancing mindset compared to participants who had to describe an event that negatively affected them[1].
Ben-Avi et al. (2018) ***Study 2b***	207	*Multivariate analysis of covariance* [1]$F(1, 205) = 7.45$, $p = 0.007$, $\eta^2 = 0.03$ [2]$F(1, 205) = 4.78$, $p = 0.030$, $\eta^2 = 0.02$	Participants with a primed stress-is-enhancing mindset assigned lower ratings to a target with a high workload (study 1) presenteeism level (decreased productivity due to health concerns)[1] and somatic symptoms[2] compared to the stress-is-debilitating group, even after controlling for age.
Ben-Avi et al. (2018) ***Study 3***	124	*ANOVA* [1]$F(2, 120) = 3.23$, $p = 0.043$, $\eta^2 = 0.05$ *Mediation analyses*	Supporting previous studies and independent of perceived mood, participants with a primed stress-is-enhancing mindset evaluated a target with a high workload as less burned-out[1] and more promotable[2] compared to the stress-is-debilitating group.

		[2]unstandardized indirect effect estimate = 0.06, *SE* = 0.05, 95% *CI* [0.002, 0.193]	However, there were no significant differences between the control group and the primed mindset groups.
Ben-Avi et al. (2018) ***Study 4***	292	*ANOVA* [1]*F* (1, 289) = 11.04, *p* = 0.001, η^2 =0.04 [2]*F* (1, 289) = 5.12, *p* = 0.024, η^2 =0.02 [3]*F* (1, 289) = 2.05, *p* = 0.154, η^2 =0.01 *Mediation analyses* [4]unstandardized indirect effect estimate = −0.04, *SE* = 0.03, 95% *CI* [−0.132,−0.002]	Supported previous findings that participants primed with stress-is-enhancing mindsets assigned lower ratings of burnout[1] and somatic symptoms[2] to target with high workload, independent of participant mood. Presenteeism was also rated lower by the stress-is-enhancing group, but this was not significant after adjusting for mood[3]. Intention to help[4] the target was reduced with judgments that the target was experiencing lower job strain (somatic symptoms).
Crum et al. (2018)	107	*ANOVA* *[1]F(1,96) = 92.9, p < .001, η2 = .492* *[2]F(6.4,133.9) = 3.06, p = .007, η2 = .127*	stress-is-enhancing mindsets were greater post-stress mindset manipulation[1], which may be partially explained by genetic variation at polymorphism such as COMT rs4680[2].
Gold (2019)	53	[12]74%	A large percentage[1] of students agreed that stress was harmful. After a stress mindset program, a large percentage of students demonstrated a positive stress mindset[2].
Hogue (2019)	59	ANOVA [1]*F*(2, 55) = 6.82, *p* < .005, η^2 = 0.199 [2] *t*(1, 26) = 4.23, *p* < .001 [3]*t*(1,13) = 2.86, *p* = .009 [4]*t*(1,13) = 2.86, *p* = .013	stress-is-enhancing mindsets were significantly greater after a mental skills training session and relative to a control group[12]. The mental skills training increased the production of DHEA-S, which is known to mitigate negative cortisol effects[34].
Maarsingh et al. (2019)	111 HS 64 PS	*Paired-samples t-test* [1]*t*(111) = 4.38, *p* < 0.001 [2]*F*(1,63) = 66.57, *p* < 0.001	The biofeedback virtual reality game "StressJam" promoted more positive mindsets after 1 hour of game time in healthy participants[1] and after 3 sessions in mental health patients[2].
Park and Hahm (2019)	479	*Paired-samples t-test* [1]t = −9.366, p < .001	Stress mindsets (stress mindset questionnaire) were improved through health care education[1] and were associated with more adaptive EEG responses to stress.
Crane et al. (2020)	144	*Generalised Estimation Equation (GEE) models* [1]*B* = .32, 95% *CI* [0.12; 0.53], *p* = .003 [2]*B* = .26, 95% *CI* [0.02; 0.51], *p* = .037 [3]*p* = .016	A stress resilience intervention showed increased stress-is-enhancing mindsets post-intervention[1] and at follow-up[2] for a community sample of middle to older aged adults compared to the control group. There were significant differences between pre- and post-intervention[3] for a sample of corporate middle to older aged adults.
Wegmann et al. (2020)	423	*Linear growth models* [1]*γ* = .16, *p* < .01, simple slope = .21, *p* < .01 [2]*γ* = −.17, *p* = .01, simple slope = .20, *p* < .01 [3]*γ* = −.15, *p* = .04, simple slope = .17, *p* = .01	Students enrolled in health education courses with high levels of neuroticism[1], low levels of conscientiousness[2], and low levels of openness[3] had increased SMM-G scores later in their course semester.
Wols et al. (2020)	129	*Paired-samples t-test* *[1]t(76) = −2.15, p = .04*	Participants who chose to watch a mental health-related trailer before playing a game reported a decrease in stress-is-debilitating mindsets after gameplay[1].
Keech et al. (2021)	150	*ANOVA* [1]F(1.59, 217.64) = 51.44, p < .001, η_p^2 = .273 [2]*p* < .001, η_p^2 = .26 [3]*p* < .001, η_p^2 = .18	A novel mental imagery stress mindset intervention promoted[1] more stress-is-enhancing mindsets post-intervention[2] and at the two-week follow-up[3].

Note. ANOVA stands for analysis of variance. Matching superscript joins inferential statistics with respective outcomes within the study.


CAN YOU CHANGE STRESS BELIEFS IN TEENS?
Chapter 1
Exploring stress during adolescence and whether beliefs about stress (stress mindsets) can be changed.
Chapter 2
A review of the literature on whether stress mindsets can be changed through short interventions or manipulations.
Can I change beliefs about stress using an intervention?
YOU ARE HERE
Chapter 3
Investigating the efficacy of a short online stress education program at promoting more positive stress mindsets and mental wellbeing in Australian
Chapter 4
A mixed-methods investigation of the student feedback from the program.
Chapter 5
A psychometric analysis of the Stress Mindset Measure, to determine reliability and validity of the project's primary outcome.
Chapter 6
Situating the research in the context of a global pandemic.
Chapter 7
A review of nail cortisol as an emerging and potentially inclusive measure of retrospective chronic stress levels for future research.
Chapter 8
A discussion on the outcomes of the project, limitations, and future directions.

TARGET JOURNAL: Psychological Science

Chapter 3

Promoting positive stress mindsets in Australian adolescents using an online neuroscience-informed stress education program: A cluster randomised controlled trial

Riana Marie[123], Sabine Finlay[124], Audrey-Ann Journault[56], Rebecca Cernik[57], Paul Welch[3], Sonia Lupien[57], Brett McDermott[3], Joseph V Moxon[3], and Zoltan Sarnyai[124*]

[1] Laboratory of Psychiatric Neuroscience, Centre for Molecular Therapeutics, [2] Australian Institute of Tropical Health and Medicine, James Cook University, Townsville, Queensland, Australia

[3] College of Medicine and Dentistry, James Cook University, Townsville, Queensland, Australia

[4] College of Public Health, Medical, and Veterinary Sciences, James Cook University, Townsville, Queensland, Australia

[5] Centre for Studies on Human Stress, [6] Psychology Department, [7] Psychiatry Department, University of Montreal, Canada

[*]Corresponding author:

Professor Zoltán Sarnyai, M.D., Ph.D.

Phone: +61747816992

Email: zoltan.sarnyai@jcu.edu.au

Address: College of Public Health, Medical and Veterinary Sciences

James Cook University, 1 James Cook Drive, Townsville QLD 4811 AUSTRALIA

Abstract

This pre-post study aimed to examine the efficacy of the Stress N' Go online video capsules at facilitating *stress-is-enhancing* mindsets (implicit metacognitive views of stress) in Australian adolescents. Adolescents (*N* = 236, 59% female), aged 13 to 18 years old, were randomly assigned to the "Stress N' Go" intervention group or the "Destination: Brain" control group (neuroscience content with no emphasis on stress) and were asked to watch four approximately five-minute videos across two weeks within the school class setting. Stress mindsets were measured one-week pre- and post-intervention using the Stress Mindset Measure – General (SMM-G). Mental health outcomes were assessed concurrently with the SMM-G using self-report scales. The Stress N' Go intervention facilitated more stress-is-enhancing mindsets in Australian adolescents compared to the control intervention (β = 0.16, *p* = .030, 95% *CI*: 0.02, 0.29). However, there were no positive changes in mental health outcomes post-intervention, possibly due to the brief study period. Further research is warranted to investigate whether stress mindsets can predict longitudinal mental health outcomes.

Keywords: Stress mindset, Stress reappraisal, Stress optimisation, Mental health, Adolescents

Promoting positive stress mindsets in Australian adolescents using an online neuroscience-informed stress education program: A cluster randomised controlled trial

Adolescence is a period of social, emotional, and physical changes with heightened stress reactivity (Romeo, 2013). In 2020, approximately one in three Australians aged 12 to 25 years old reported experiencing symptoms of anxiety and depression (Headspace, 2020). In 2020, coping with stress and school work was of significant concern to young Australians (McCrindle, 2021; Tiller et al., 2020). Stress is the body's biological response to physical and/or psychological challenges (Lazarus & Folkman, 1984). The human stress response relies on the interaction of multiple mediators including the sympathetic–adrenal–medullary (SAM) axis and the hypothalamic-pituitary-adrenal (HPA) axis (Juster et al., 2010; Sapolsky et al., 2000). The SAM axis regulates the "fight or flight" response by releasing adrenaline and noradrenaline and the HPA axis is responsible for maintaining homeostasis and mobilising energy within the body by releasing glucocorticoids (cortisol) (Juster et al., 2010; Sapolsky et al., 2000). Although chronic and unrelenting stress can lead to damaging effects on mental and physical health, the human stress response can be adaptive (i.e. the "fight or flight" response) (McEwen, 2017; Wingfield & Sapolsky, 2003).

Individuals who perceived that stress had negative effects on their health; however, had an increased risk of premature death (Keller et al., 2012), which suggests that beliefs about stress may be linked to health behaviours. Consequently, stress mindsets are the lens or heuristics through which people view stress, as either having enhancing effects or debilitating effects. Stress mindsets were conceptualised based on implicit mindset theories, where fixed or flexible (growth) beliefs about characteristics, such as intelligence, can influence cognition and behaviour (Dweck, 2008; Wolcott et al., 2021). A mindset draws attention to environmental information congruent with one's beliefs, which then can influence appraisals and in turn behaviour (Kilby, 2015). Like beliefs, stress mindsets appear to be stable, likely due to this cognitive bias of attending to information congruent to an individual's beliefs (Kilby, 2015). Mindsets can be modified through short intervention (Dweck, 2008). Based on these findings, Crum et al. (2013) found that a manipulated *stress is enhancing*

mindset has been associated with improved mood, work performance, and potentially adaptive cortisol responses (Crum et al., 2013). By priming more positive stress mindsets, a person's perception and appraisal of stress may be altered which may, in turn, promote effective coping strategies (Crum et al., 2013). However, with society emphasising the negative effects of chronic stress,

According to the transactional model of stress and coping by Lazarus and Folkman (1984), people or situations (stressors) can be cognitively appraised as threats (stressors with negative consequences) or challenges (stressors with positive/growth-related consequences). Stress can be reappraised by appraising the stress response (sympathetic arousal) as a challenge instead of a threat (Jamieson et al., 2018). Stress reappraisal is based on the Biopsychosocial (BPS) model of challenge and threat, which examines how cognitive appraisal can influence physiological and behavioural performance (Blascovich, 2008; Blascovich & Tomaka, 1996). The reappraisal of stress has been associated with improved test performance, decreased attentional bias, increased salivary alpha-amylase (a stress biomarker predictive of task performance), and more efficient cardiovascular responses (Jamieson et al., 2010; Jamieson et al., 2012).

Jamieson et al. (2018) suggest that stress responses can be optimised by implementing short interventions which alter how an individual appraises stress (cognitive reappraisal of stress) as well as their implicit beliefs about stress (stress mindsets). Crum et al. (2020) later published further justification for this model, extending it to also include emotion regulation strategies (Gross, 2015). The stress optimisation model was developed based on the idea that many stress management programs focus on reducing or eliminating stressors but overlook that some stressors cannot be eliminated (e.g., school) and that some stressors may encourage growth and opportunity (e.g., using the energy mobilised by the adaptive stress response to perform physically, occupationally, or academically) (Jamieson et al., 2018). The stress optimisation model suggests that antecedent focused strategies, such as stress mindsets and stress reappraisal, may have positive behavioural, cognitive, and psychological implications. These outcomes have been investigated using rapid

education intervention methods (e.g., videos, journal articles, or short-form instructions) (Ben-Avi et al., 2018; Crum et al., 2013; Jamieson et al., 2010; Jamieson et al., 2012).

This stress optimisation model formed the basis of the Stress N' Go intervention, a series of short video capsules that teach students how to 1) recognise the physiological stress response, 2) understand the usefulness of the physiological stress response in life, 3) reappraise negative stress mindsets, and 4) learn that it is possible to use the physiological stress response to one's advantage, such as turning unavoidable but controllable stressors, such as school and study performance, into challenges rather than threats. This study aimed to examine the efficacy of the Stress N' Go online video capsules at promoting stress-is-enhancing mindsets in Australian adolescents and positive mental health outcomes. The primary outcome was the change in stress mindsets, pre- and post-intervention, using the Stress Mindset Measure – General (Crum et al., 2013). Further analyses were conducted to investigate whether primed stress-is-enhancing mindsets would lead to more positive mental health outcomes such as reduced anxiety, co-rumination, depression, and improved mental wellbeing. It was hypothesised based on previous stress mindset research (Crum et al., 2013; Jamieson et al., 2018), that the Stress N' Go intervention would result in positive changes in stress mindsets that may promote mental health and wellbeing in Australian adolescents.

Method

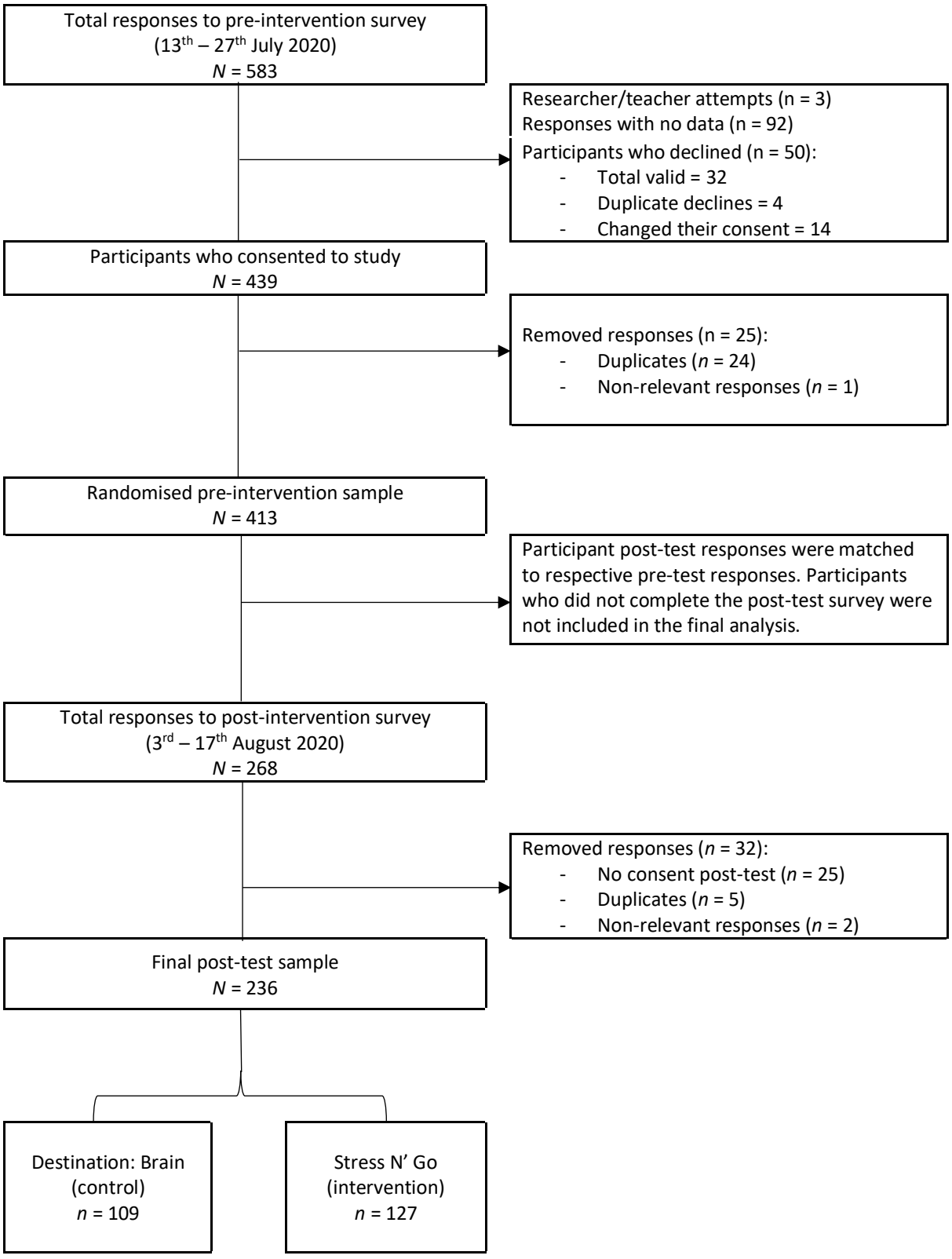
Participants

To be eligible for inclusion in the current study, participants had to be in Grades 8 to 12 (approximately 13 to 18 years of age). Participants from a private high school in North Queensland, Australia were recruited using convenience sampling in July 2020. Participants were informed about the purpose of the study, the risks and benefits, and informed consent was obtained online before entry into the intervention. Online parental consent was also obtained for students under 16 years of age. Only students who had data at baseline (T1) and post-intervention (T2) were retained in the final sample. A total of 236 participants were included in the final sample. Of these participants, 109 had received the control condition and 127 in the Stress N' Go Intervention. Participants with partial

responses (e.g., only completed a few scales) were still eligible to participate in the study. See Figure 4 for a flow diagram illustrating the final sample size. This study was approved by the James Cook University Human Research Ethics Committee on the 24th of July, 2019 (ethics number: H7727).

Figure 4

Sample Size Flow Diagram



Note. Non-relevant data included responses that were erroneous or not comprehendible.

Materials

Stress Mindsets

The primary outcome was the change in stress mindsets between T1 and T2, which were measured using the Stress Mindset Measure – General (SMM-G: Crum et al., 2013). The Stress Mindset Measure – General (SMM-G; Crum et al. (2013)), is a recently developed 8-item measure of beliefs about stress. Scores can range from 0 "strongly disagree" to 4 "strongly agree", with higher scores indicating more positive stress mindsets (scores ≥2 fall on the more stress-is-enhancing spectrum and scores <2 fall on the stress-is-debilitating spectrum). Examples of these items include "*The effects of stress are negative and should be avoided*" (Item 1) and "*The effects of stress are positive and should be utilised*" (Item 8). Mean scores were calculated after items (1,3,5, and 7) were reverse scored. This scale showed acceptable internal consistency (T1: α = .70 and T2: α = .72) in the present study and good construct and criterion validity within the literature (Crum et al., 2013). Although there is a study supporting a 3-item short form suitable for youth (Park et al., 2018), there was no official youth adapted version of the scale available at the time of study and as such, this study selected to use the consistently validated full-scale adult SMM.

Mental Health Measures

Perceived Stress. The Perceived Stress Scale for Children (PSS-C; White, 2014), is a 14-item measure of subjective stress. An example of an item from this scale is "*In the past week, how often did you feel rushed or hurried?*" (Item 2). Item scores could range from 0 "never" to 3 "often". Items 3, 6, 7, 10, 11, 13, and 14 were reversed scored. The sum of the items (0 – 39, item 1 is not included due to being a practice question) was calculated for the current study. Higher scores indicate greater perceived stress levels. This scale showed good internal consistency (T1: α = .82 and T2: α = .74) in the present study. However, there is a lack of validation studies within the literature.

Anxiety. The Childhood Anxiety Sensitivity Index (CASI; Silverman et al., 1991), is an 18-item scale measuring an individual's sensitivity to anxiety (innate beliefs that anxiety can have harmful

consequences). Scores range from 1 “not at all” to 3 “a lot”. The sum of all the items was calculated (18 – 54), with higher scores suggesting an increased sensitivity to anxiety. An example of an item from this scale is “*I don’t want other people to know when I feel afraid*”. This scale showed good internal consistency (T1: α = .90 and T2: α = .91) and evidence of good construct validity (Silverman et al., 1991). The State-Trait Anxiety Inventory for Children – State Subscale (STAIC-S; Spielberger, 1973), is a 20-item measure of momentary anxiety with scores ranging from 1 “very [emotion e.g., *“worried”*]” to 3 “not [emotion e.g., *worried*]” and items 2, 4, 5, 7, 9, 11, 15, 16, 18, and 19 were reversed scored. The sum of all items (20 – 60) was calculated, with higher scores suggesting increased levels of momentary anxiety. This scale is psychometrically sound (Thomas & Cassady, 2021) and in the present study showed good internal consistency (T1: α = .92 and T2: α = .92). The Children's Test Anxiety Scale (CTAS; Wren & Benson, 2004), is a 25-item scale that measures the level of performance anxiety a participant might experience during a test. For example, participants are asked to rate how they feel, think, and react when they take a test (e.g., “…*my heart beats fast*” [item 1]). Scores can range from 1 “almost never” to 4 “almost always”. The sum of all items (25 – 100) was calculated with higher scores indicating increased levels of test anxiety. There is evidence of construct validity (Wren & Benson, 2004) and, in the present study, the scale showed good internal consistency (T1: α = .94 and T2: α = .95).

Co-Rumination. The Co-Rumination Questionnaire (CRQ; Arroyo, 2013; Rose, 2002), is a short form (9-item) scale of the original Co-Rumination Questionnaire (27-items), which measures how often a participant dwells on negative situations with their friends. Scores can range from 1 “not true at all” to 5 “very true” and an example of an item includes “*We spend most of our time together talking about problems that my friend or I have*” (Item 1). The sum of all items (9 – 45) was calculated, with higher scores suggesting that participants engaged in a greater amount of co-rumination with their friends. Criterion validity was supported in the literature (Davidson et al., 2014) and in the current study, this scale showed good internal consistency (T1: α = .90 and T2: α = .92).

Depression. The Patient Health Questionnaire - 9 for Adolescents (PHQ-9A; Kroenke et al., 2001), adapted for youth by Johnson et al. (2002)), is a 9-item scale that was used to measure depression severity within the Australian sample. Participants are asked the frequency they experience certain symptoms such as "*Little interest or pleasure in doing things*" (Item 1). Scores can range from 0 "not at all" to 3 "nearly every day" (score range; 0 – 27), with higher scores suggesting that the participant may be experiencing a greater number of depression symptoms. Diagnostic validity was supported (Jonson et al., 2002). In the current study, this scale showed good internal consistency (T1: α = .82 and T2: α = .74).

Mental Wellbeing. The EPOCH Measure of Adolescent Wellbeing (Kern et al., 2016) is a 20-item measure of five positive psychological characteristics: Engagement ("I *get completely absorbed in what I am doing*" [Item 7]), Perseverance ("*I finish whatever I begin*" [Item 2]), Optimism ("*I am optimistic about my future*" [Item 3]), Connectedness ("*I have friends that I really care about*" [Item 16]), and Happiness ("*I feel happy*" [Item 4]). The EPOCH is measured on a scale of 1 "almost never/not at all like me" to 5 "almost always/very much like me" (score range: 20 – 100). Higher average scores on each domain indicated increased mental wellbeing. It should be noted that item 1 on the mental wellbeing scale (EPOCH) was missing, due to human error during the data collection process. This scale showed good internal consistency (T1: α = .94 and T2: α = .94) in the current sample. Content and criterion validity was supported in the literature (Kern et al., 2016).

Stress N' Go Education Program

The Stress N' Go videos were designed, based on the stress optimisation model proposed by Jamieson et al. (2018), to teach students about the positive and negative aspects of stress, and how stress can be used to improve mental health and performance. Content from this program also integrated some additional stress education concepts from a previous stress management program by the Centre for Studies on Human Stress (CSHS) called "DeStress for Success" (Lupien et al., 2013). For example, the NUTS model teaches students about the main determinants of HPA axis activation.

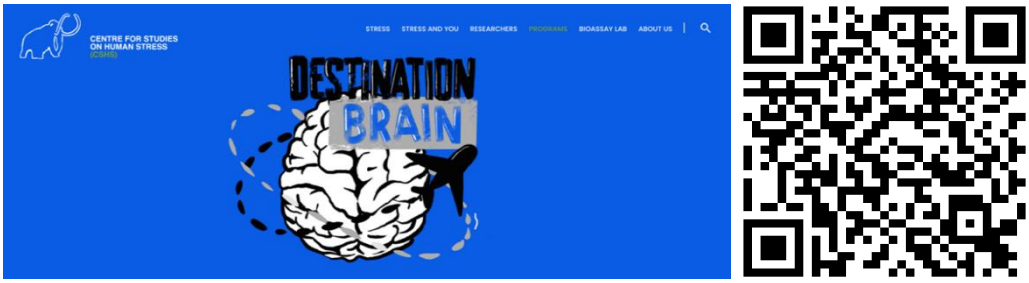
This model describes new (N) or unpredictable (U) situations, where an individual may feel their ego or personality is threatened (T) or that they sense (S) low control over the situation.

The first Stress N' Go video introduces the rationale for the program, education about the stress response, and the NUTS model. The second video presents a balanced view of the human stress response, which aligns with the stress mindset skills. The third videos suggest some adaptive coping strategies for the participants (e.g., support seeking, exercise, deep breathing). Finally, the fourth video presents how stress can be turned into success and promote growth/performance (stress reappraisal). To control for any potential placebo effects, an active control was run in conjunction with the Stress N' Go program called "Destination: Brain". Destination: Brain was developed by the CSHS (Journault et al., 2020) as a basic neuroscience educational program with no emphasis on stress. Four approximately five-minute videos educated adolescents on the structure and function of the brain. All participants were informed that they would be involved in a "stress optimisation" project. (see Figure 5 for the intervention videos)

Figure 5

QR Code Link to Stress N' Go Videos

QR Code Link to Destination Brain Videos



Procedure

This trial was a single-centre, double-blind, active control, parallel-group study with balanced class-group randomisation (1:1) conducted in Australia (see Figure 6 for study design). This study was conducted, based on the protocol developed by Journault & Lupien (2020), using face-to-face delivery integrated into the school curriculum. It should be noted that the delivery of this program was during the coronavirus (COVID-19) pandemic, but the Stress N' Go program was not made in response to the pandemic. The conception for these videos began in 2019. At the time of testing, Queensland encouraged sanitary measures such as social distancing, mask-wearing, hand sanitization, and limited the number of people attending indoor/outdoor gatherings but schools and businesses were open (Queensland Government, 2021).

In the current study, the school research officer randomly allocated students via their class groups (one condition per homeroom class) into either the control or intervention based on a randomly generated list of class groups. The researcher [RM] was blind to this 1:1 simple class block allocation. The study ran for approximately four weeks. Across two weeks, students were asked by their teachers to watch four videos (two per week) for each group during class and answer several short logbook questions after each video. A week before and after watching these intervention videos, the students were given a Qualtrics link consisting of demographic questions, implementation questions, and self-report psychological scales (Qualtrics, Provo, UT; July 2020 version). The psychological scales were presented in a randomised order. The researcher (RM) was blind to the intervention groups from recruitment until after statistical analysis was performed.

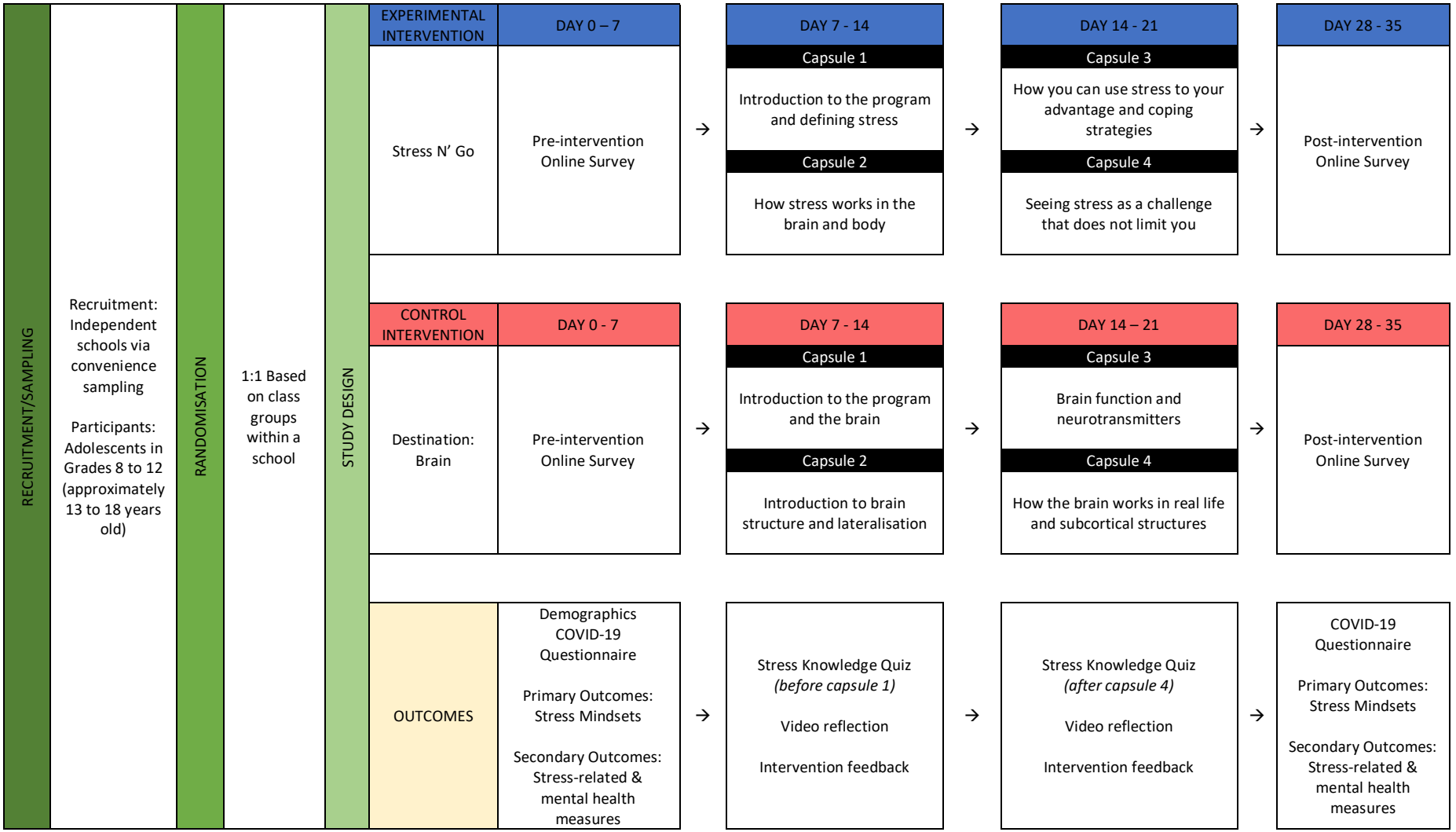
Mental Health Risk

All participants (from the original pre-test cohort and final sample), 16 years old and above, who scored equal to or above 10 (the clinical cut-off score) on the PHQ-9A, were notified via email that they may be experiencing some concerns with their mood and wellbeing and were recommended to speak to a mental health professional or school psychologist to obtain a current clinical assessment. If the participant was below 16 years of age, parents were notified about the

result. At T1 and T2, 26.8% and 25.5% of participants scored equal to or above the clinical cut-off score of the PHQ-9A respectively, which is similar to existing norms for this age group and year (Headspace, 2020).

Figure 6

Study Design



Sample Size

An a priori G*Power analysis was performed using an estimated effect size (η^2=0.17) informed by the change in stress mindsets from the previous stress-is-enhancing manipulation program implemented by Crum et al. (2013). Alpha-value was set at .05 (two-tailed) for a single primary outcome. Sample size was estimated based on a power of 80%. According to this calculation, a sample size of 44 per group was required. Assuming an attrition rate of 20%, this calculation is increased to approximately 53 participants in the control group and 53 participants in the experimental group (*N* = 106).

Statistical Analysis

Quantitative data were analysed using *R* software. Installed packages included *knitr* (Xie, 2021)*, dplyr* (Wickham et al., 2021), *psych* (Revelle, 2020)*, summarytools* (Comtois, 2021), *ggpubr* (Kassambara, 2020), *nlme* (Pinheiro et al., 2020), *EMAtools* (Kleiman, 2017), *Hmisc* (Harrell & Dupont, 2021)*, MASS* (Venables & Ripley, 2002), *ggplot2* (Wickham, 2016), *Rmisc (Hope, 2013*), and *naniar* (Tierney et al., 2020).

Outliers were assessed via visual inspection (demographics) and scale limits (psychological measures). Only two data points in the demographics were removed as outliers. Missing data accounted for 16.5% of the entire dataset. At item-level, only participants who answered at minimum ¾ of items on a scale were given global scores for the respective scale (*n* = 3 participant responses were removed). Missing data at the item-level, for participants missing items <¾, was treated using prorated scale scores (average of the number of available items*number of scale items). The demographic/implementation variables showed major deviations in skewness (*x* > +2/-2) and kurtosis (*x* > +7/-7) (Byrne, 2010; Hair et al., 2010); while the global psychological scale scores remained within the acceptable skewness/kurtosis range (Q-Q plots visually corroborated these distributions). Therefore, the demographic/implementation variables were assumed to be non-normally distributed data, and the psychological measures were assumed to be normally distributed data.

Demographic data (e.g., age, gender, socioeconomic status, race/ethnicity) and post-implementation survey data (e.g., number of videos watched) were compared between groups to determine potential. Mann-Whitney *U* tests were run for the continuous demographic data and nominal data was compared using the Chi-Square test (for cell counts >5) and Fisher's exact test (for cell counts <5). Therefore, data were reported using medians [*Med*] (interquartile [*IQR*] range) and frequencies (percentage). The predictors in this study were intervention (between-subjects design) and time (within-subjects design). There were two levels for intervention: the Stress N' Go intervention and Destination: Brain control. There were also two levels for time: T1 (outcomes assessed one-week pre-intervention) and T2 (outcomes assessed one-week post-intervention). Random-intercept unadjusted linear mixed-effects (LME) modelling was used to investigate any significant interaction effects between interventions (Stress N' Go and Destination: Brain) and time (T1 and T2) on the change in stress mindsets and later exploratory analyses on mental health outcomes. LME models were selected as they adjust for missing data in repeated measures (McDermott et al., 2021). In all models, intervention and time (as a factorial variable) were treated as fixed effects and participants as random effects. Model fit was assessed through inspection of standardised residual distribution and Q-Q norm plots. Data were reported as means, beta (β) coefficient estimates, 95% confidence intervals (*CI*), and a significance threshold of *p* values < .05.

Results

Sample Characteristics

Adolescents (N = 236, 59% female) in the final sample were aged between 13 and 18 years old (M_{age} = 15.11 years, SD_{age} = 1.49 years, see Table 6). The majority (92%) reported being from regional North Queensland, Australia, being "quite comfortable" financially (52%), and living with an average of four people in their household. Participants mostly identified their origins as white/Caucasian. Overall, demographic factors were balanced between intervention groups. See Table S6 in the Supplementary materials for responses from the participants related to their experience of COVID-19 at the time of testing.

Table 6

Baseline Characteristics of Participants in Each Intervention

Variable	Cohort (N=236)	Destination: Brain Control (N=109)	Stress N' Go Intervention (N=127)	*p*-value[a]
Age (years)	15 (2)	15 (2)	15 (2)	.552
N (Missing)	236 (0)	109 (0)	127 (0)	
Sex				.111
Male	96 (40.7%)	38 (34.9%)	58 (45.7%)	
Female	139 (58.9%)	70 (64.2%)	69 (54.3%)	
Other/non-specific	1 (0.4%)	1 (0.9%)	0 (0%)	
N (Missing)	236 (0)	109 (0)	127 (0)	
Education Level				.189
Grade 8	44 (18.6%)	15 (13.8%)	29 (22.8%)	
Grade 9	72 (30.5%)	39 (35.8%)	33 (26.0%)	
Grade 10	24 (10.2%)	13 (11.9%)	11 (8.7%)	
Grade 11	52 (22.0%)	25 (22.9%)	27 (21.3%)	
Grade 12	44 (18.6%)	17 (15.6%)	27 (21.3%)	
N (Missing)	236 (0)	109 (0)	127 (0)	
Residence (Modified Monash Model 2019)				.698
Metropolitan	0 (0%)	0 (0%)	0 (0%)	
Regional centres	217 (92.0%)	98 (89.9%)	119 (93.7%)	
Large rural towns	0 (0%)	0 (0%)	0 (0%)	
Medium rural towns	2 (0.9%)	1 (0.9%)	1 (0.8%)	
Small rural towns	3 (1.3%)	2 (1.8%)	1 (0.8%)	
Remote communities	3 (1.3%)	2 (1.8%)	1 (0.8%)	
Very remote communities	9 (3.8%)	4 (3.7%)	5 (3.9%)	
Overseas	2 (0.9%)	2 (1.8%)	0 (0%)	
N (Missing)	236 (0)	109 (0)	127 (0)	
Indigenous Status				.820
Non-indigenous	230 (97.5%)	106 (97.2%)	124 (97.6%)	
Australian Aboriginal	5 (2.1%)	2 (1.8%)	3 (2.4%)	
Torres Strait Islander	1 (0.4%)	1 (0.9%)	0 (0%)	
Australian Aboriginal and Torres Strait Islander	0 (0%)	0 (0%)	0 (0%)	
N (Missing)	236 (0)	109 (0)	127 (0)	
Race/Ethnicity				.689
White or Caucasian	161 (68.5%)	73 (67.0%)	88 (69.3%)	
Australian Aboriginal or Torres Strait Islander	3 (1.3%)	2 (1.8%)	1 (0.8%)	
Asian	36 (15.3%)	15 (13.8%)	21 (16.5%)	
African	3 (1.3%)	1 (0.9%)	2 (1.6%)	
Multiracial/Other	32 (13.6%)	18 (16.5%)	14 (11.0%)	
N (Missing)	235 (1)	109 (0)	126 (1)	
Household Size				
Average size	4 (1)	4 (1)	4 (1)	.293
N (Missing)	230 (6)	106 (3)	124 (2)	
Pets	1 (2.75)	2 (3)	1 (2)	.413
N (Missing)	230 (6)	106 (3)	124 (3)	
Living off-campus	230 (97.46)	106 (97.2%)	124 (97.6%)	1
Living on-campus (Boarding school)	6 (2.5%)	3 (2.8%)	3 (2.4%)	
N (Missing)	236 (0)			

Socioeconomic Status				.112
Very comfortable	59 (25.1%)	32 (29.4%)	27 (21.3%)	
Quite comfortable	121 (51.5%)	49 (45.0%)	72 (56%)	
Moderately comfortable	49 (20.9%)	26 (23.9%)	23 (18.1%)	
Not very comfortable	6 (2.6%)	1 (0.9%)	5 (3.9%)	
Extremely uncomfortable	0 (0%)	0 (0%)	0 (0%)	
N (Missing)	235 (1)	108 (1)	127 (0)	

Note. Continuous data are presented as median (interquartile range) and nominal variables are presented as frequency and per cent. "*N*" is the total sample size for each variable and "(Missing)" is the total number of missing responses from incomplete data.

[a]*p*-value refers to comparisons between intervention groups using the Mann–Whitney *U* test (continuous variables), or Chi-Square χ^2 test (nominal variables with cell count >5) and Fisher's Exact Test (nominal variables with cell count <5).

Post-Implementation Measures

Most of the students in the Stress N' go program agreed that the Stress N' Go videos helped them to live better with their stress (61%) post-intervention (see Table 7). Most students in the control group disagreed that the videos helped them live better with stress (65%). The majority (78%) of students in both intervention groups watched greater than two out of four videos.

Table 7

Post-intervention Implementation Measures

Variable	Cohort (*N*=236)	Destination: Brain Control (*N*=109)	Stress N' Go Intervention (*N*=127)	*p*-value[a]
Do you feel that these capsules helped you to live better with your stress?				<.001***
No	113 (49.8%)	71 (65.1%)	42 (33.1%)	
Yes	114 (50.2%)	36 (33.0%)	78 (61.4%)	
N (Missing)	227 (9)	2 (1.8%)	120 (7)	
How many of the videos did you watch				.076
≤50%	45 (19.1%)	15 (13.8%)	30 (23.6%)	
>50%	184 (78.0%)	91 (83.5%)	93 (73.2%)	
N (Missing)	229 (7)	106 (3)	123 (4)	

Note. Nominal variables are presented as frequency and per cent. "*N*" is the total sample size for each variable and "(Missing)" is the total number of missing responses from incomplete data.

[a]*p*-value refers to comparisons between intervention groups using Chi-Square χ^2 test (nominal variables with cell count >5).

[***]$p < .001$

Scale Descriptive Statistics

See Table 8 for descriptive statistics and sample size data for each outcome.

Table 8

Mean (95% Confidence Interval) Global Scores for Stress Mindset and Mental Health Scales

Outcome	Destination: Brain				Stress N' Go			
	T1	*n*	T2	*n*	T1	*n*	T2	*n*
SMM-G *(Stress mindsets)*	1.85 ± 0.10	101	1.97 ± 0.10	91	1.77 ± 0.11	107	2.06 ± 0.13	94
PSS-C *(Perceived stress)*	13.75 ± 1.48	99	15.54 ± 1.22	94	14.48 ± 1.30	106	16.34 ± 1.27	92
CASI *(Anxiety sensitivity)*	30.86 ± 1.60	100	30.00 ± 1.58	93	30.87 ± 1.41	107	30.50 ± 1.62	93
Physical	11.12 ± 0.71	100	10.89 ± 0.71	93	10.94 ± 0.66	107	10.83 ± 0.72	93
Social	6.69 ± 0.33	100	6.43 ± 0.36	93	6.75 ± 0.29	107	6.55 ± 0.36	93
Mental	6.15 ± 0.44	100	5.95 ± 0.38	93	6.34 ± 0.40	107	6.44 ± 0.48	93
Control	6.90 ± 0.42	100	6.73 ± 0.44	93	6.85 ± 0.39	107	6.68 ± 0.41	93
STAI-Cs *(State anxiety)*	33.31 ± 1.46	98	33.84 ± 1.58	89	33.73 ± 1.32	107	35.00 ± 1.70	92
CTAS *(Test anxiety)*	57.03 ± 3.54	99	54.51 ± 3.28	91	56.90 ± 3.09	108	57.97 ± 3.68	96
Autonomic Reactions	14.21 ± 1.08	99	13.51 ± 0.94	91	14.05 ± 0.94	108	14.96 ± 1.14	96
Off Task Behaviours	16.90 ± 1.10	99	16.27 ± 1.03	91	16.58 ± 0.88	108	17.13 ± 1.01	96
Thoughts	25.92 ± 1.77	99	24.75 ± 1.73	91	26.28 ± 1.65	108	25.89 ± 1.85	96
CRQ *(Co-Rumination)*	27.73 ± 1.62	100	27.67 ± 1.58	88	27.28 ± 1.51	107	27.39 ± 1.68	92
PHQ-9A *(Depression)*	7.20 ± 1.26	100	7.46 ± 1.28	91	7.41 ± 1.22	102	8.22 ± 1.43	92
EPOCH *(Mental wellbeing)*	66.73 ± 2.65	100	66.30 ± 2.97	90	64.54 ± 3.05	109	64.44 ± 3.20	89
Engagement	3.06 ± 0.17	100	3.06 ± 0.18	90	3.07 ± 0.19	109	3.16 ± 0.19	89
Perseverance	3.52 ± 0.17	100	3.50 ± 0.18	90	3.45 ± 0.18	109	3.34 ± 0.20	89
Optimism	3.29 ± 0.19	100	3.35 ± 0.20	90	3.14 ± 0.19	109	3.22 ± 0.21	89
Connectedness	4.19 ± 0.17	100	4.00 ± 0.19	90	4.03 ± 0.18	109	3.97 ± 0.21	89
Happiness	3.68 ± 0.20	100	3.65 ± 0.19	90	3.47 ± 0.20	109	3.42 ± 0.22	89

Note. Descriptive statistics were reported as mean ± 95% confidence interval. Sample size (*n*) was provided for each scale. These are the same sample sizes used in the final analyses. [a]N/R refers to data that was not recorded.

Primary Outcome: Stress Mindsets

An LME model for the change in SMM-G found a significant interaction between intervention and time (β = 0.16, *p* = .030, 95% *CI*: 0.02, 0.29; see Table 9, Figure 7). There was also a significant main fixed effect on time (β = 0.12, *p* = .022, 95% *CI*: 0.02, 0.21) but not intervention (β = -0.09, *p* = .233, 95% *CI*: -0.24, 0.06). The Destination: Brain and Stress N' Go intervention groups both showed increased SMM-G scores at T2. However, this effect was significantly greater for the Stress N' Go intervention group.

Secondary Outcomes: Mental Health and Wellbeing

An LME model for the change in PSS-C (perceived stress) found no significant interaction between intervention and time (β = -0.03, *p* = .972, 95% *CI*: -1.76, 1.70; see Table 9, Figure 8). However, there was a significant main fixed effect on time (β = 1.89, *p* = .003, 95% *CI*: 0.67, 3.12) but not intervention (β = 0.75, *p* = .408, 95% *CI*: -1.04, 2.55). Participants in both groups reported increased levels of perceived stress at T2. No significant changes between intervention and time were found for anxiety sensitivity (CASI), state anxiety (STAI-Cs), test anxiety (CTAS), co-rumination (CRQ), depression (PHQ9-A), or mental wellbeing (EPOCH) (see Table 9).

Table 9

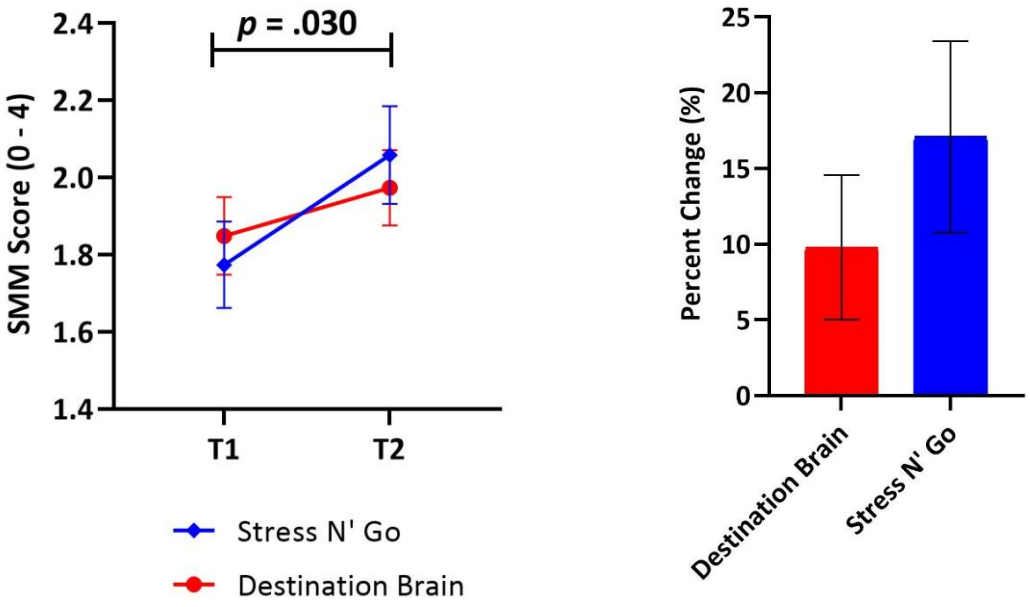
Unadjusted Interaction Effects from Linear Mixed-Effects Models Comparing the Change in Stress Mindsets and Mental Health Scales

Outcome	Unadjusted analyses	
	β (95% CI)	*p*-value
SMM-G *(Stress mindset)*	0.16 (0.02, 0.29)	.030*
PSS-C *(Perceived stress)*	-0.03 (-1.76, 1.70)	.972
CASI *(Anxiety sensitivity)*	0.55 (-1.63, 2.73)	.620
STAI-Cs *(State anxiety)*	0.28 (-1.79, 2.35)	.791
CTAS *(Test anxiety)*	3.94 (-0.70, 8.59)	.096
CRQ *(Co-Rumination)*	0.07 (-2.17, 2.31)	.949
PHQ-9A *(Depression)*	0.44 (-1.28, 2.16)	.614
EPOCH *(Mental wellbeing)*	1.51 (-2.72, 5.76)	.482

Note. Beta (β) coefficients refer to the interaction of intervention and time (using Destination: Brain control intervention at T1 as a reference). **p*-values relate to the interaction between interventions (Destination: Brain and Stress N' Go) and time (T1 to T2).

Figure 7

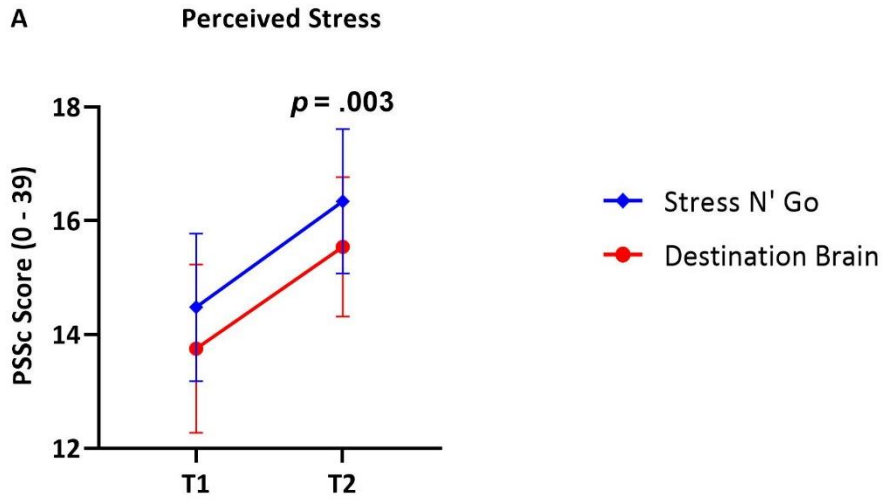
Change and Percent Change in Stress Mindset across Time and Intervention



Note. A. Participants in both groups showed a significant change in more positive stress mindsets post-intervention (p = .022). However, the Stress N' Go intervention showed a stronger positive mean change in stress mindsets from T1 to T2 compared to Destination: Brain control (p = .030). Data presented as mean ± 95% confidence intervals. B. Participants in the Stress N' Go intervention showed a stronger positive per cent change in stress mindsets from T1 to T2 compared to Destination: Brain control. Data presented as per cent (%) change (T2-T1/T1*100) in stress mindset mean ± 95% confidence intervals.

Figure 8

Changes in Perceived Stress over Time



Note. A. Participants perceived greater levels of stress at T2 for both interventions. Data presented as mean ± 95% confidence intervals. B. Participants in the Stress N' Go intervention reported greater subjective autonomic reactions towards test anxiety across time and compared to the control group who reported lower levels. Data presented as mean ± 95% confidence intervals.

Currently, what is your biggest stressor?

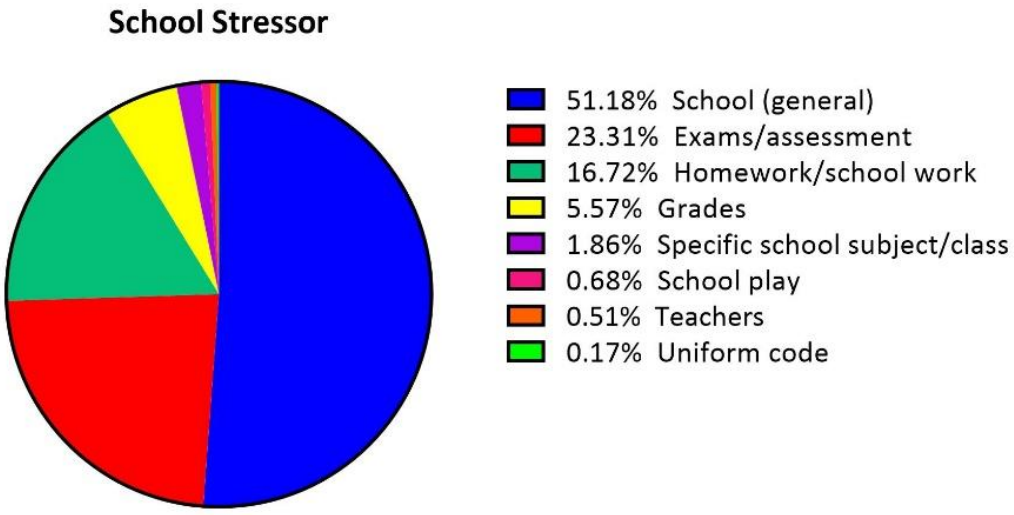
Using *NVivo* 12.6 Plus software, summative content analysis was conducted to assess the frequency of responses to a free-text question: *"Currently, what are your 3 biggest stressors?"* (In order of perceived importance). This analysis found that students [*N* = 236, Entries (missing data): 1410 (98)] considered "school" to be their biggest current stressor. This finding was consistent across time, intervention, and order of importance. School was referred to by students within about 45% of the entries, which was followed by future uncertainty (≈8%) and family (≈8%) as significant stressors (see Figure 7A for a word cloud visualising frequency of reported stressors). An exploratory analysis stratifying the "school" theme into subsections found that about 51% of responses referenced "school" in general, about 23% were associated with exams or assessment, and 17% were related to homework or schoolwork (see Figure 7B for the stratification of the school theme).

Figure 9

Content Analysis of Current Stressors based on Frequency of References to Theme

A

B



Note. A. Word cloud visualising the most frequently used words within the participant (*N* = 236) responses. B. Pie chart showing stratification of “school” thematic code. Data presented as the percentage of references within the coded subsection.

Discussion

This study aimed to examine the efficacy of the Stress N' Go online video capsules at promoting positive stress-is-enhancing mindsets to help students view the nature of acute stress as more positive and help reappraise their stress response to unavoidable but controllable stressors, such as school and study performance.

The Effect of Stress N' Go on Adolescent Stress Mindsets

The hypothesis that the Stress N' Go intervention would promote a greater improvement in positive stress mindsets, than a non-targeted control intervention, was supported. Participants in both groups showed significant increases in stress mindsets at follow-up, compared to entry levels. However, the magnitude of this change was significantly greater in the Stress N' Go intervention compared to Destination: Brain. Further, the majority of students in the Stress N' Go intervention also reported that the program had helped them cope with their stress. These findings are in agreement with the recent implementation of the Stress N' Go intervention in Montreal (Journault et al., 2021, personal communication), which showed that significantly more positive stress mindsets were reported post-Stress N' Go compared to Destination: Brain across adolescents from 73 private and public schools. Similarly, these findings were also supported by previous research utilising short stress-is-enhancing interventions designed to prime stress-is-enhancing mindsets (Ben-Avi et al., 2018; Crum et al., 2013; Jamieson et al., 2010; Jamieson et al., 2012).

It should be noted, however, that the effect size observed in the current trial was smaller than that reported in previous trials. Although the Stress N' Go intervention promoted a positive change in stress mindsets, this smaller effect may reflect unclear factors. For example, demand characteristics, as both groups were told that they would be participating in a "stress optimisation" study and there may have been some discussion between the control and intervention groups, as the intervention was implemented within a single school. It is also possible that the adult SMM may not have been appropriate for a youth sample or there may have been a dose effect, as only about three-quarters of the students watched the intervention videos.

The Effect of Stress N' Go on Adolescent Mental Health Outcomes

The hypothesis that the Stress N' Go intervention would promote mental health and wellbeing was not supported. Overall, there were no significant positive effects on the mental health outcomes of the adolescents in any group. Changes in behaviour, such as coping strategies, and mental health often require long-term approaches (Arango et al., 2018; Bishop, 2018), which were unlikely to be captured during this brief study. Jamieson et al. (2018) suggest that a change in stress mindsets does not directly target health and performance, but instead a change in meta-level beliefs about the nature of stress (Jamieson et al., 2018). By reappraising stress and encouraging more positive stress mindsets, participants may be more likely to select active coping strategies (e.g., support seeking, problem-solving, or exercise) in the future when facing unavoidable stressors (Crum et al., 2013). Therefore, the Stress N' Go intervention would benefit from longitudinal investigations to examine if a change in implicit stress mindsets can result in future positive cognitive/behavioural outcomes.

Adolescents in both groups reported increased perceived stress post-intervention. Based on the confidence intervals, this effect lacked precision. However, this finding may be associated with the study commencing the first week after school holidays and concluding closer to school assessment dates. School assessment is an unavoidable stressor during adolescence. Students reported in a free-text response that their major stressor across time and intervention was "school". These findings align with the MyStrengths Youth Wellbeing Report, which found that schoolwork was the leading cause of stress and worries in Australian high school students, particularly for independent/private students, between 2020 and 2021 (McCrindle, 2021). Consequently, the Stress N' Go intervention was designed to help change implicit ideas about the stress response rather than minimise stressors.

The intervention was also run during the COVID-19 pandemic, which may have had some effects on the students' stress levels. COVID-19 has been associated with poor mental health outcomes in adolescents (Magson et al., 2021; Racine et al., 2020) and increased discussions in the

media related to the pandemic. However, the location of testing was in a regional Queensland town where there were <30 confirmed cases of the virus at the time of testing (Queensland Government, 2021). Students answered some self-report questions and suggested that they were not attributing much of their stress levels to COVID-19 (see Table S6). These students were still attending school and living in an area with minimal pandemic restrictions. However, more empirical investigations are warranted to fully quantify the effect of COVID-19 on student stress levels.

Limitations

Students from the control and intervention groups may have discussed both interventions with each other. Being told that the project was a "stress optimisation" project to help with stress levels may have biased the findings due to demand characteristics. The SMM was the adult version of the scale, which may not have been appropriate for this youth cohort. The measures used were all self-report, as such social desirability cannot be eliminated, and these screening measures may not provide a comprehensive understanding of the effects of the Stress N' Go intervention, particularly related to changes in arousal or the stress response. There was also no follow-up, which would have been beneficial to clarify if the lack of mental health benefits from Stress N' Go was related to a need for later reinforcement and practice of the intervention techniques. The recruited school was a private school where the majority of students identified as white/Caucasian and were quite comfortable financially, which may have affected the generalisability of these findings to a wider Australian adolescent population. Human error resulted in one missing item for the EPOCH scale. This methodological error, therefore, affected the interpretability of the EPOCH scale.

Future Directions

A larger multi-centre study may provide stronger support for the Stress N' Go intervention, as observed within the Montreal cohort (Journault et al, 2021). Even one school being provided with the control and a separate school being provided with the intervention may have helped reduce the possibility of findings being confounded by students discussing the contents of the videos with each other. Although there is no specific youth version of the scale, a study validated three items of the

scale to be appropriate for use within an adolescent cohort (Park et al., 2018). A follow-up during a more stressful period (e.g., examinations) may be valuable to observe whether the intervention retained any positive effects during a period of arousal. To gain insight into the effects of Stress N' Go on sympathetic arousal, physiological stress markers, including autonomic nervous system activity (e.g., heart rate, heart rate variability, skin temperature, and systolic blood pressure) and neuroendocrine biomarkers, such as cortisol (major stress hormone) or dehydroepiandrosterone sulfate (DHEA-S). DHEA-S is a steroid that has been associated with protective stress responses and performance (Do Vale et al., 2011; Morgan et al., 2004). These measures would provide a more comprehensive profile of the effect of stress mindsets during the human stress response. Crum et al. (2013) found that a stress-is-enhancing mindset, lowered cortisol levels in individuals with high reactivity to stress. DHEA-S secretion increased with a more stress-is-enhancing mindset (Crum et al., 2017; Hogue, 2019). Similar to previous studies investigating stress reappraisal methods (Jamieson et al., 2010; Jamieson et al., 2012), performance on school assessment would also be worth investigating, as it could promote the inclusion of short stress optimisation interventions within school curriculums. Finally, Crum et al. (2020) suggested that these programs could be extended to include emotional regulation strategies (Gross, 2015). Therefore, an additional Stress N' Go video could be developed to help adolescents learn to identify and regulate emotions.

Conclusion

In summary, adolescents face stressors, related to school and their future, that are unavoidable. The Stress N' Go intervention involved short online videos educating adolescents on their stress response and how to employ effective coping strategies by showing that stress can be positive. Adolescents, who watched the Stress N' Go intervention videos, reported more positive stress mindsets compared to the control group. However, this intervention had no immediate benefits on mental health outcomes. Therefore, with further research, changing stress mindsets using the Stress N' Go intervention may be a novel education strategy to facilitate proactive coping

during stressful periods, with the online format allowing for more inclusivity from urban to more remote locations.

Conflict of Interest

The authors declare that they have no competing interests. The Destination: Brain and Stress N' Go interventions are freely available for use from the Centre for Studies on Human Stress (https://humanstress.ca/programs/stress-n-go/).

Disclosure

The protocol used in the current study was adapted from Journault et al. (2021) and a detailed description of the original protocol can be found at https://osf.io/u4cmf. All the video capsules (intervention and control) were created in French by the Centre for Studies on Human Stress (CSHS) in 2020 and translated for use in the current study. The creation of these videos by the CSHS was inspired by the work and in collaboration with Jeremy Jamieson (personal communication).

Authors' Contributions

The protocol for the studies was developed by AAJ, SL, and RC at the CSHS. The data was collected by RM. Data collection was aided by PW. Data analysis was performed by RM and content analysis was aided by SF. The paper was written by RM and edited by all authors. All authors read and approved the final manuscript.

Funding

The Australian Government Research Training Program Scholarship and College of Medicine and Dentistry Top-up Scholarship supported the Australian study.

Open Practices Statement

The experiment reported in this article was not formally preregistered. Neither the data nor the materials have been made available on a permanent third-party archive and cannot be shared as informed consent was not attained from the participants of this study.

Acknowledgments

The authors would like to express their thanks to the students, families, and teachers who generously gave their time to this project. The authors would like to acknowledge James Cook University (Australian Institute of Tropical Health and Medicine and the College of Medicine and

Dentistry) for their facilities and the guidance of staff members. This includes Emeritus Professor Rhondda Jones, Professor Sarah Larkins, Professor Cate Nagle, and Helen Griffiths for their ethical and methodological guidance as well as Dr Michele Redman-MacLaren for advice on content analysis. Finally, the authors would like to acknowledge the significant assistance of Sandrine Charbonneau who aided in the development of the French versions of the Destination: Brain and Stress N' Go intervention videos.

References

Arango, C., Díaz-Caneja, C. M., McGorry, P. D., Rapoport, J., Sommer, I. E., Vorstman, J. A., McDaid, D., Marín, O., Serrano-Drozdowskyj, E., & Freedman, R. (2018). Preventive strategies for mental health. *The Lancet Psychiatry*, *5*(7), 591-604. https://doi.org/10.1016/S2215-0366(18)30057-9

Arroyo, A. (2013). *Fat talk among female friends: Do friends' responses buffer the relationship between fat talk and health-related outcomes?* [Dissertation, The University of Arizona]. UA Campus Repository. https://repository.arizona.edu/handle/10150/297031

Ben-Avi, N., Toker, S., & Heller, D. (2018). "If stress is good for me, it's probably good for you too": Stress mindset and judgment of others' strain. *Journal of Experimental Social Psychology*, *74*, 98-110. https://doi.org/10.1016/j.jesp.2017.09.002

Bishop, F. M. (2018). Self-guided Change: The most common form of long-term, maintained health behavior change. *Health Psychology Open*, *5*(1), 2055102917751576. https://doi.org/10.1177/2055102917751576

Blascovich, J. (2008). Challenge, threat, and health. In J. Y. Shah & W. L. Gardner (Eds.), *Handbook of motivation science* (pp. 481–493). The Guilford Press.

Blascovich, J., & Tomaka, J. (1996). The biopsychosocial model of arousal regulation. *Advances in Experimental Social Psychology*, *28*, 1-51. https://doi.org/10.1016/S0065-2601(08)60235-X

Byrne, B. M. (2010). *Structural equation modeling with AMOS: Basic concepts, applications, and programming* (2nd Edition). In: New York: Routledge. https://doi.org/10.4324/9781315757421

Comtois, D. (2021). *Summarytools: Tools to quickly and neatly summarize data*. R package

Crum, A. J., Akinola, M., Martin, A., & Fath, S. (2017). The role of stress mindset in shaping cognitive, emotional, and physiological responses to challenging and threatening stress. *Anxiety, Stress & Coping*, *30*(4), 379-395. https://doi.org/10.1080/10615806.2016.1275585

Crum, A. J., Jamieson, J. P., & Akinola, M. (2020). Optimizing stress: An integrated intervention for regulating stress responses. *Emotion, 20*(1), 120-125. https://doi.org/10.1037/emo0000670

Crum, A. J., Salovey, P., & Achor, S. (2013). Rethinking stress: The role of mindsets in determining the stress response. *Journal of Personality and Social Psychology*, *104*(4), 716. https://doi.org/10.1037/a0031201

Davidson, C. L., Grant, D. M., Byrd-Craven, J., Mills, A. C., Judah, M. R., & Lechner, W. V. (2014). Psychometric properties of the Co-Rumination Questionnaire. *Personality and Individual Differences*, *70*, 171-175.

Do Vale, S., Martins, J. M., Fagundes, M. J., & do Carmo, I. (2011). Plasma dehydroepiandrosteronesulphate is related to personality and stress response. *Neuroendocrinology Letters*, *25*(4), 283-296.

Dweck, C. S. (2008). *Mindset: The new psychology of success*. Random House.

Gross, J. J. (2015). Emotion regulation: Current status and future prospects. *Psychological Inquiry*, *26*(1), 1-26. https://doi.org/10.1080/1047840X.2014.940781

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis: International version.* New Jersey, Pearson.

Harrell, F., & Dupont, C. (2021). *Hmisc: Harrell miscellaneous*. R package version 4.5-0. https://CRAN.R-project.org/package=Hmisc

Headspace. (2020). *Insights: youth mental health and wellbeing over time*. Headspace. Retrieved from https://headspace.org.au/assets/Uploads/Insights-youth-mental-health-and-wellbeing-over-time-headspace-National-Youth-Mental-Health-Survey-2020.pdf

Hogue, C. M. (2019). The protective impact of a mental skills training session and motivational priming on participants' psychophysiological responses to performance stress. *Psychology of Sport and Exercise*, *45*, 101574. https://doi.org/10.1016/j.psychsport.2019.101574

Hope, R. (2013). *Rmisc: Ryan miscellaneous.* R package version 1.5. https://CRAN.R-project.org/package=Rmisc

Jamieson, J. P., Crum, A. J., Goyer, J. P., Marotta, M. E., & Akinola, M. (2018). Optimizing stress responses with reappraisal and mindset interventions: an integrated model. *Anxiety, Stress, & Coping*, *31*(3), 245-261. https://doi.org/10.1080/10615806.2018.1442615

Jamieson, J. P., Mendes, W. B., Blackstock, E., & Schmader, T. (2010). Turning the knots in your stomach into bows: Reappraising arousal improves performance on the GRE. *Journal of Experimental Social Psychology*, *46*(1), 208-212. https://doi.org/10.1016/j.jesp.2009.08.015

Jamieson, J. P., Nock, M. K., & Mendes, W. B. (2012). Mind over matter: Reappraising arousal improves cardiovascular and cognitive responses to stress. *Journal of Experimental Psychology: General*, *141*(3), 417–422. https://doi.org/10.1037/a0025719

Johnson, J. G., Harris, E. S., Spitzer, R. L., & Williams, J. B. (2002). The patient health questionnaire for adolescents: Validation of an instrument for the assessment of mental disorders among adolescent primary care patients. *Journal of Adolescent Health*, *30*(3), 196-204. https://doi.org/10.1016/s1054-139x(01)00333-0

Journault, A., & Lupien, S. (2020). *Addendum to MATA's study: Stress mindset intervention*. https://doi.org/10.17605/OSF.IO/U4CMF

Journault, Charbonneau, Cernik, Jamieson, & Lupien. (2020). *Stress N' Go*. Centre for Studies on Human Stress. https://humanstress.ca/programs/stress-n-go/

Juster, R.-P., McEwen, B. S., & Lupien, S. J. (2010). Allostatic load biomarkers of chronic stress and impact on health and cognition. *Neuroscience & Biobehavioral Reviews*, *35*(1), 2-16. https://doi.org/10.1016/j.neubiorev.2009.10.002

Kassambara, A. (2020). *ggpubr: 'ggplot2' based publication ready plots.* R package version 0.4.0. https://CRAN.R-project.org/package=ggpubr

Keller, A., Litzelman, K., Wisk, L. E., Maddox, T., Cheng, E. R., Creswell, P. D., & Witt, W. P. (2012). Does the perception that stress affects health matter? The association with health and mortality. *Health Psychology*, *31*(5), 677-684. https://doi.org/10.1037/a0026743

Kern, M. L., Benson, L., Steinberg, E. A., & Steinberg, L. (2016). The EPOCH measure of adolescent well-being. *Psychological Assessment*, *28*(5), 586. https://doi.org/10.1037/pas0000201

Kilby, C. J. (2015). *On the validity of stress mindset* (Doctoral dissertation), Department of Psychology, Macquarie University. https://www.researchonline.mq.edu.au/vital/access/services/Download/mq:44802/SOURCE1?view=true

Kleiman, E. (2017*). EMAtools: Data management tools for real-time monitoringe/ecological momentary assessment data.* R package version 0.1.3. https://CRAN.R-project.org/package=EMAtools

Kroenke, K., Spitzer, R. L., & Williams, J. B. W. (2001). The PHQ-9: Validity of a brief depression severity measure. *Journal of General Internal Medicine*, *16*(9), 606-613. https://doi.org/10.1046/j.1525-1497.2001.016009606.x

Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping*. Springer Publishing Company.

European Journal of Personality, *1*(3), 141-169. https://doi.org/10.1002/per.2410010304

Lupien, S. J., Ouellet-Morin, I., Trépanier, L., Juster, R. P., Marin, M. F., Francois, N., Sindi, S., Wan, N., Findlay, H., Durand, N., Cooper, L., Schramek, T., Andrews, J., Corbo, V., Dedovic, K., Lai, B., & Plusquellec, P. (2013). The DeStress for Success program: Effects of a stress education program on cortisol levels and depressive symptomatology in adolescents making the transition to high school. *Neuroscience*, *249*, 74–87. https://doi.org/10.1016/j.neuroscience.2013.01.057

Magson, N. R., Freeman, J. Y. A., Rapee, R. M., Richardson, C. E., Oar, E. L., & Fardouly, J. (2021). Risk and protective factors for prospective changes in adolescent mental health during the COVID-19 pandemic. *Journal of Youth and Adolescence*, *50*(1), 44-57. https://doi.org/10.1007/s10964-020-01332-9

McCrindle. (2021). *MyStrengths youth wellbeing report 2021.* https://s3.amazonaws.com/kajabi-storefronts-

production/sites/163568/themes/2149125913/downloads/TnT1pVifTn62tOGicnyT_MyStrengths_Youth_Wellbeing_Report_2021.pdf

McDermott, M. M., Spring, B., Tian, L., Treat-Jacobson, D., Ferrucci, L., Lloyd-Jones, D., Zhao, L., Polonsky, T., Kibbe, M. R., Bazzano, L., Guralnik, J. M., Forman, D. E., Rego, A., Zhang, D., Domanchuk, K., Leeuwenburgh, C., Sufit, R., Smith, B., Manini, T., Criqui, M. H., & Rejeski, W. J. (2021). Effect of low-intensity vs high-intensity home-based walking exercise on walk distance in patients with peripheral artery disease: The LITE randomized clinical trial. *JAMA*, *325*(13), 1266-1276. https://doi.org/10.1001/jama.2021.2536

McEwen, B. S. (2017). Neurobiological and systemic effects of chronic stress. *Chronic Stress*, *1*, 2470547017692328. https://doi.org/10.1177/2470547017692328

Morgan, C. A., Southwick, S., Hazlett, G., Rasmusson, A., Hoyt, G., Zimolo, Z., & Charney, D. (2004). Relationships among plasma dehydroepiandrosterone sulfate and cortisol levels, symptoms of dissociation, and objective performance in humans exposed to acute stress. *Archives of General Psychiatry*, *61*(8), 819–825. https://doi.org/10.1001/archpsyc.61.8.819

Park, D., Yu, A., Metz, S. E., Tsukayama, E., Crum, A. J., & Duckworth, A. L. (2018). Beliefs about stress attenuate the relation among adverse life events, perceived distress, and self-control. *Child Development*, *89*(6), 2059-2069. https://doi.org/http://dx.doi.org/10.1111/cdev.12946

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., & R Core Team (2020). *_nlme: Linear and nonlinear mixed effects models.* R package version 3.1-149, https://CRAN.R-project.org/package=nlme.

Qualtrics. (July 2020). The output for this paper was generated using Qualtrics software, July 2020 Version of the Qualtrics Research Suite. Copyright © 2021 Qualtrics. Qualtrics and all other Qualtrics product or service names are registered trademarks or trademarks of Qualtrics, Provo, UT, USA. http://www.qualtrics.com

Queensland Government. (2021). *Queensland COVID-19 statistics*. https://www.qld.gov.au/health/conditions/health-alerts/coronavirus-covid-19/current-status/statistics#casesummary

Racine, N., Cooke, J. E., Eirich, R., Korczak, D. J., McArthur, B., & Madigan, S. (2020). Child and adolescent mental illness during COVID-19: A rapid review. *Psychiatry Research*, *292*, 113307-113307. https://doi.org/10.1016/j.psychres.2020.113307

Revelle, W. (2020). *psych: Procedures for personality and psychological research*. R package software. https://CRAN.R-project.org/package=psych

Romeo R. D. (2013). The teenage brain: The stress response and the adolescent brain. *Current Directions in Psychological Science*, *22*(2), 140–145. https://doi.org/10.1177/0963721413475445

Rose, A. J. (2002). Co–rumination in the friendships of girls and boys. *Child Development*, *73*(6), 1830-1843. https://doi.org/10.1111/1467-8624.00509

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

Silverman, W. K., Fleisig, W., Rabian, B., & Peterson, R. A. (1991). Childhood Anxiety Sensitivity Index. *Journal of Clinical Child and Adolescent Psychology*, *20*(2), 162-168. https://doi.org/10.1207/s15374424jccp2002_7

Spielberger, C. (1973). *State-Trait Anxiety Inventory for Children preliminary manual.* Palo Alto, CA: Consulting.

Thomas, C. L., & Cassady, J. C. (2021). Validation of the state version of the State-Trait Anxiety Inventory in a university sample. *SAGE Open*, *11*(3), 21582440211031900. https://doi.org/10.1177/21582440211031900

Tierney, N., Cook, D., McBain, M., & Fay, C. (2020). *naniar: Data structures, summaries, and visualisations for missing data.* R package version 0.6.0. https://CRAN.R-project.org/package=naniar

Tiller, E., Fildes, J., Hall, S., Hicking, V., Greenland, N., Liyanarachchi, D., & Di Nicola, K. (2020). *Youth survey report 2020.* Mission Australia. https://www.missionaustralia.com.au/publications/youth-survey/1717-mission-australia-youth-survey-report-2020/file

University, Evanston, Illinois, USA, https://CRAN.R-project.org/package=psych Version =2.1.3

Venables, W. N. & Ripley, B. D. (2002) *Modern applied statistics with S. Fourth Edition.* Springer, New York. ISBN 0-387-95457-0

version 0.9.9. https://CRAN.R-project.org/package=summarytools

White, B. P. (2014). The perceived stress scale for children: A pilot study in a sample of 153 children. *International Journal of Pediatrics and Child Health*, *2*(2), 45-52. http://dx.doi.org/10.12974/2311-8687.2014.02.02.4

Wickham, H., François, R., Henry, L., & Müller, K. (2021). *dplyr: A grammar of data manipulation.* R package version 1.0.5. https://CRAN.R-project.org/package=dplyr

Wickham., H. (2016). *ggplot2: Elegant graphics for data analysis.* Springer-Verlag New York, 2016. https://ggplot2.tidyverse.org

Wingfield, J., & Sapolsky, R. (2003). Reproduction and resistance to stress: When and how. *Journal of Neuroendocrinology*, *15*(8), 711-724. https://doi.org/10.1046/j.1365-2826.2003.01033.x

Wolcott, M. D., McLaughlin, J. E., Hann, A., Miklavec, A., Beck Dallaghan, G. L., Rhoney, D. H., & Zomorodi, M. (2021). A review to characterise and map the growth mindset theory in health professions education. *Medical Education*, *55*(4), 430-440. https://doi.org/10.1111/medu.14381

Wren, D. G., & Benson, J. (2004). Measuring test anxiety in children: Scale development and internal construct validation. *Anxiety, Stress, & Coping*, *17*(3), 227-240. https://doi.org/10.1080/10615800412331292606

Xie, Y. (2021). *knitr: A general-purpose package for dynamic report generation in R*. R package version 1.37, https://yihui.org/knitr/.

Supplementary Materials

Table S6

COVID-19 Questionnaire Responses

Variable	Cohort (N=236)	Destination: Brain Intervention (N=109)	Stress N' Go Intervention (N=127)	*p*-value
How often have you had discussions about the coronavirus?				.379
A few times a week	120 (50.8%)	58 (53.2%)	62 (48.8%)	
1 time a day	57 (24.2%)	23 (21.1%)	34 (26.8%)	
2 to 5 times a day	46 (19.5%)	23 (21.1%)	23 (18.1%)	
6 to 9 times a day	6 (2.5%)	4 (3.7%)	2 (1.6%)	
10 times of more a day	6 (2.5%)	1 (0.9%)	5 (3.9%0	
N (Missing)	235 (1)	109 (0)	126 (1)	
Since the arrival of the coronavirus to Australia (25 January 2020), have you had symptoms (signs/manifestations) that resemble those of coronavirus (cough, fever, muscle aches, sore throat), even if they were not caused by coronavirus?				
(0 "no symptoms" to 10 "several symptoms")	1.83±2.24	1.96±2.20	1.71±2.28	.119
N (Missing)	228 (8)	107 (2)	121 (6)	
How have these symptoms affected your life in general?				
(0 "it didn't affect me at all" to 10 "it affected me a lot")	1.15±1.87	1.20±1.85	1.10±1.90	.561
N (Missing)	198 (38)	91 (18)	107 (2)	
Are you voluntarily following the news about the coronavirus? (Reading the newspaper, reading news on a phone, watching TV news reports)				.884
No	92 (39.0%)	44 (40.4%)	48 (37.8%)	
Yes	135 (57.2%)	62 (56.9%)	73 (57.5%)	
N (Missing)	227 (9)	106 (3)	121 (6)	
How often (how many hours per day) do you have a look at each of the following news or media sources?				
Traditional media (newspaper, television, radio, etc.)	.57±.92	.67±1.12	.49±.69	.287
N (Missing)	226 (10)	106 (3)	120 (7)	
Social media news feed (Facebook, Twitter, Instagram, etc.)	1.83±2.37	2.02±2.60	1.66±2.15	.199
N (Missing)	225 (11)	105 (4)	120 (7)	
Websites (News.com.au, etc.)	.24±.54	.25±.44	.24±.61	.534
N (Missing)	225 (11)	105 (4)	120(7)	
How worried or stressed are you right now?				
(*1 "not at all" to 7 "a lot")*	3.13±1.51	3.12±1.48	3.13±1.54	.970
N (Missing)	227 (9)	107 (2)	120 (7)	
In your opinion, how much of this stress are you experiencing because of the coronavirus?				
(1 "not at all related" to 7 "extremely related")	1.98±1.28	2.07±1.39	1.91±1.18	.579
N (Missing)	227 (9)	107 (2)	120 (7)	
In the context of this pandemic (of the coronavirus being spread around the world), how worried are you about:				
(1 "not at all worried" to 7 "excessively worried")				

Your health *N* (Missing)	2.12±1.32 227 (9)	2.10±1.34 107 (2)	2.13±1.30 120 (7)	.754
Your parent's health *N* (Missing)	3.42±1.65 226 (10)	3.54±1.67 107 (2)	3.31±1.64 119 (8)	.261
The health of someone who matters to you *N* (Missing)	3.95±1.69 227 (9)	4.05±1.67 107 (2)	3.87±1.71 120 (7)	.323
The continuation of your school year *N* (Missing)	3.04±1.74 226 (10)	3.23±1.78 107 (2)	2.87±1.68 119 (8)	.116
Your parent's job or your job *N* (Missing)	2.82±1.94 227 (9)	3.08±1.92 107 (2)	2.59±1.93 120 (7)	.024*
Missing something (e.g., toilet paper, medicine, fruit, bread, etc.) *N* (Missing)	1.90±1.25 227 (9)	2.07±1.30 107 (2)	1.74±1.17 120 (7)	.010*
Before the coronavirus arrived in Australia, how normally worried or stressed are you? *(1 "not at all" to 7 "a lot")* *N* (Missing)	3.03±1.64 225 (11)	2.98±1.63 107 (2)	3.08±1.65 118 (9)	.674
According to you stress is generally*:* *1 "very negative" to 7 "very positive"?* *N* (Missing)	3.10±1.33 220 (16)	3.05±1.21 104 (5)	3.15±1.43 116 (11)	.715

Note. Continuous data are presented as median (interquartile range) and nominal variables are presented as frequency and per cent. "*N*" is the total sample size for each variable and "(Missing)" is the total number of missing responses from incomplete data.

[a]*p*-value refers to comparisons between intervention groups using the Mann–Whitney *U* test (continuous variables), or Chi-Square χ^2 test (nominal variables with cell count >5) and Fisher's Exact Test (nominal variables with cell count <5).

*Potential confounders ($p < 0.100$ on statistical comparisons between groups)

CAN YOU CHANGE STRESS BELIEFS IN TEENS?

Chapter 1
Exploring stress during adolescence and whether beliefs about stress (stress mindsets) can be changed.

Chapter 2
A review of the literature on whether stress mindsets can be changed through short interventions or manipulations.

Chapter 3
Investigating the efficacy of a short online stress education program at promoting more positive stress mindsets and mental wellbeing in Australian adolescents.

What did the students think about the program?

Chapter 4
A mixed-methods investigation of the student feedback from the program.

YOU ARE HERE

Where to next?

Chapter 5
A psychometric analysis of the Stress Mindset Measure, to determine reliability and validity of the project's primary outcome.

Chapter 6
Situating the research in the context of a global pandemic.

Chapter 7
A review of nail cortisol as an emerging and potentially inclusive measure of retrospective chronic stress levels for future research.

Chapter 8
A discussion on the outcomes of the project, limitations, and future directions.

TARGET JOURNAL: Psychological Methods

Chapter 4

A Mixed-Method Investigation of Student Experiences during Stress N' Go Stress Education Program

Riana Marie[123], Sabine Finlay[124], Audrey-Ann Journault[56], Rebecca Cernik[57], Paul Welch[3], Sonia Lupien[57], Brett McDermott[3], Joseph V Moxon[3], and Zoltan Sarnyai[124*]

[1] Laboratory of Psychiatric Neuroscience, Centre for Molecular Therapeutics, [2] Australian Institute of Tropical Health and Medicine, James Cook University, Townsville, Queensland, Australia

[3] College of Medicine and Dentistry, James Cook University, Townsville, Queensland, Australia

[4] College of Public Health, Medical, and Veterinary Sciences, James Cook University, Townsville, Queensland, Australia

[5] Centre for Studies on Human Stress, [6] Psychology Department, [7] Psychiatry Department, University of Montreal, Canada

[*]Corresponding author:

Professor Zoltán Sarnyai, M.D., Ph.D.

Phone: +61747816992

Email: zoltan.sarnyai@jcu.edu.au

Address: College of Public Health, Medical and Veterinary Sciences

James Cook University, 1 James Cook Drive, Townsville QLD 4811 AUSTRALIA

Abstract

Stress N' Go is a rapid stress education program designed to help adolescents cope with unavoidable but controllable stressors. This mixed-methods investigation aimed to examine how the Stress N' Go program was received by the students who piloted the Australian program. Australian students (*n* = 317, 57% female), aged 13 to 18 years old, were randomly allocated into either the Stress N' Go intervention or the control group (a program with no emphasis on Stress). This investigation focused on responses from students within the Stress N' Go intervention (*n* = 158) to free-text questions asking how the program could be improved and what they learned from the program. The Stress N' Go program was rated positively (about 7 out of 10). The content analysis indicated that technical content, such as graphics and audio, could have been improved. The content of the Stress N' Go videos appeared to be understood by most students, but more applied stress management strategies were desired. Longer stress management programs could be integrated into the school curriculum, as it appears from the free-text responses that adolescents are interested in learning practical ways to cope with stress.

Keywords: Stress Mindsets, Stress, School, Mental Health, Adolescents

A Mixed-Method Investigation of Student Experiences during Stress N' Go Stress Education Program

Adolescence is a vulnerable period of social, emotional, physical, and hormonal changes (Lupien et al., 2009; Romeo, 2013). In Australia, approximately one in three students reported experiencing psychological distress, such as symptoms of depression and anxiety (Headspace, 2020), and coping with stress was of particular concern to Australian adolescents (Tiller et al., 2020). Therefore, there is a need for stress management education in this age group, particularly to help adolescents cope with unavoidable stressors like school or examinations.

Although chronic stress has adverse effects, the acute stress response can be adaptive (McEwen, 2017). The sympathetic nervous system is responsible for the "fight or flight" stress response (McEwen, 2017), which is mediated by interconnected neuroendocrine, metabolic, immune, and cardiovascular mechanisms including the sympathetic-adrenal-medullary (SAM) and the hypothalamic-pituitary-adrenal (HPA) axes (Juster et al., 2010; Sapolsky et al., 2000). The SAM axis allows for the release of epinephrine and norepinephrine to promote alertness and vigilance. Concurrently, the HPA axis involves the release of glucocorticoids, such as cortisol, to maintain homeostasis and direct energy metabolism. These mechanisms are activated in response to physical or psychological stressors, to provide the body with the energy to respond to any potential challenges (McEwen, 2017). This acute response can promote performance and survival; however, the dysregulation of these systems through repeated or unrelenting stress can lead to disease (McEwen, 2017).

Education about the positive effects of the acute physiological stress response may provide students with new beliefs about their performance capabilities, particularly within the school environment. Jamieson et al. (2018) suggest that short interventions integrating stress mindset and stress reappraisal theory could provide beneficial cognitive and behavioural outcomes on performance and mental wellbeing. Crum et al. (2020) further supported this integrated model but discussed it from the perspective of emotion regulation theory. Stress mindsets were conceptualised

by Crum et al. (2013), who suggested that individuals may have implicit beliefs that stress can be "enhancing" or "debilitating". Crum et al. (2013) found that promoting more stress-is-enhancing mindsets resulted in a positive change in these stress beliefs and improvements in work performance perceptions. Stress reappraisal redefines stressors as "challenges" rather than "threats". This theory is based on the Biopsychosocial (BPS) model of challenge and threat, which examines how cognitive appraisal can influence physiological and behavioural performance (Blascovich, 2008; Blascovich & Tomaka, 1996). By encouraging more positive stress mindsets and reappraising stressful situations as potential challenges rather than threats, it may have beneficial effects on performance and psychological wellbeing.

The Stress N' Go Intervention was based on the integrated stress optimisation theory proposed by Jamieson et al. (2018) to teach adolescents about their physiological stress response and associated positive effects. Data in *Chapter 3* suggest that the Stress N' Go intervention promoted more stress-is-enhancing mindsets post-intervention in a small sample of Australian high-school students; however, the students' perceptions and experiences during the program remain unclear. This mixed-method investigation aimed to explore student feedback on the Stress N' Go intervention to gain insight into program satisfaction and performance from the perspective of the student. Although the effectiveness of the intervention is important, student enjoyment is also important to consider, as enjoyment has been associated with improved performance (Van de Weijer-Bergsma & Van der Ven, 2021) and may minimise attrition. Acknowledging the student's voice is critical, as it will provide insight into the efficacy of the Stress N' Go program and areas of improvement from the consumers' perspective.

Method

Participants

Participants were the same adolescents recruited as part of the larger project discussed in *Chapter 3*. To be included in this study, participants needed to respond to the baseline survey and complete at least one post-video survey during the intervention. In this study, there were 489 initial

responses to the baseline survey (excluding responses with no data or previews). Of these responses 439 were consenting and 413 (57% female) were eligible after removing duplicates and erroneous responses. Student consent was obtained, and parental consent was only obtained for Australian students under 16 years of age. This study was approved by the James Cook University Human Research Ethics Committee on the 24th of July, 2019 (ethics number: H7727).

Materials

Free-text Responses

Short online surveys were conducted after each program video, asking students for their feedback about the program (on a scale of 1 to 10, with 10 being the best score) and how the program videos could be improved ("*How could we improve this video capsule? What did you think?*", free text). It should be noted that the student feedback was the cumulative responses to the four videos to provide a preliminary understanding of what students thought about the program as a whole and not for each video. Students were asked at the end of the final video what they had learned/understand from the program (*"What is the most important thing (or things) that you've learnt in the program that could help other people your age?",* free text). These responses were collected online via the Qualtrics platform (Qualtrics, Provo, UT; July 2020 version).

Program

The Stress N' Go education program was the focus of this report and was designed to promote more stress-is-enhancing mindsets and help students cope better with stress. The Destination: Brain program was designed as an active control with no emphasis on stress, instead, containing only basic neuroscience information (e.g., brain structures and functions). Descriptions of each program can be found in *Chapter 3*.

Procedure

This study was conducted as per the protocol discussed previously in *Chapter 3*, which was developed by Journault & Lupien (2020). The school research officer randomly allocated students via their class groups (one condition per homeroom class) into either the control or intervention

(researcher [RM] was blind to this 1:1 class block allocation). Across two weeks, students were asked by their teachers to watch four videos (two per week) for each group during class and answer several short logbook questions after each video. The focus of this chapter is the responses to these logbook questions.

Statistical Analysis

Student enjoyment ratings (Likert scale from 1 to 10) from the Stress N' Go and Destination: Brain program data were compared using a three-way analysis of variance (ANOVA). Using IBM SPSS Statistics v28, the assumption of normality for all variables was satisfied by acceptable skewness and kurtosis ranges (within +2/-2 and +7/-7 respectively) (Byrne, 2010; Hair et al., 2010). Student enjoyment ratings were analysed using a 2 (program) x 2 (gender) x 4 (video number) ANOVA with Bonferroni-corrected simple effects analyses for significant interaction effects. The assumption of sphericity was not met in the model and the Greenhouse-Geisser correction was applied. Data were reported as means and 95% confidence intervals (*CI*), with statistically significant differences indicated by *p*-values < .05. Effect sizes were presented as partial eta squared (η_p^2) with interpretations as follows: .02 (small effect), .06 (moderate effect), and .14 (large effect) (Cohen, 1988; 2013).

Content Analysis

The focus of this investigation was the free-text responses following each Stress N' Go video capsule, as they provide greater insight into the student's perceptions of the program. Students were asked what was the most important thing (or things) they learned from the program, which could help other people their age cope with stress. Responses to this student learning question represent individual participant responses. Feedback from the students was compiled from across all the Stress N' Go videos, and frequency analyses were performed. This student feedback frequency does not represent individual students, but the cumulative responses from students across all four Stress N' Go videos. Free-text content was organised into thematic codes using NVivo v12.6 and summarised

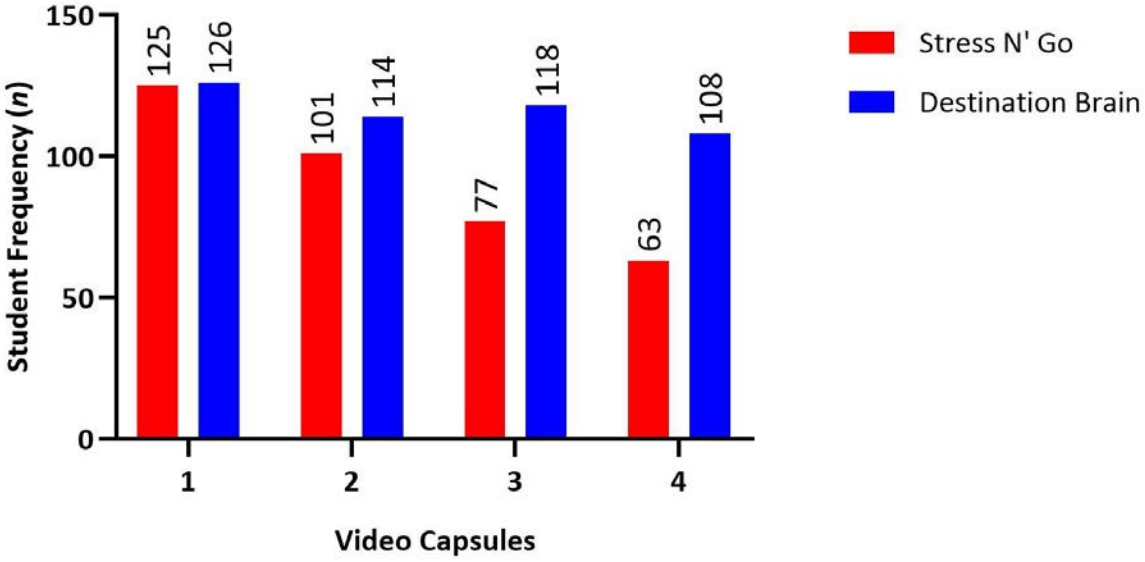
based on the theme reference frequencies (number of times the comment was made) and reported as percentages (the frequency of particular comments divided by the number of participants).

Results

A total of 317 students (57% female, 41% male, and 1% other) responded to at least one of the online surveys delivered post-videos. Of these students, 158 were in the Stress N' Go intervention, and 159 were in the Destination: Brain control group. Figure 11 shows the distribution of students who watched each video stratified by the program. There was a decline in the frequency of students responding to the Stress N' Go videos.

Figure 11

Response Rate after Each Video Stratified by Intervention



Student Enjoyment Ratings

Students were asked to rate how much they enjoyed each video (see Table 10 for descriptive statistics related to these ratings). There was no significant main effect for program ($F_{(1, 127)} < .001$, $p = .994$, $\eta_p^2 < .001$, small effect), gender ($F_{(1, 127)} = 1.265$, $p = .263$, $\eta_p^2 = .010$, small effect), or video ($F_{(2.18, 276.41)} = 2.80$, $p = .058$, $\eta_p^2 = .022$, small effect). There was no significant interaction effect between video and program ($F_{(2.18, 276.41)} = 2.896$, $p = .052$, $\eta_p^2 = .022$, small effect) or video and gender ($F_{(2.18, 276.41)} = 1.007$, $p = .372$, $\eta_p^2 = .008$, small effect). In contrast, there was a significant interaction effect

between program and gender ($F_{(1, 127)} = 5.349$, $p = .022$, $\eta_p^2 = .040$, small effect). Boys rated the Destination: Brain program as significantly more enjoyable than girls who watched Destination: Brain ($F_{(1, 127)} = 7.226$, $p = .008$, $\eta_p^2 = .054$, small effect).

There was also a significant three-way interaction between program, gender, and video ($F_{(2.18, 276.41)} = 6.734$, $p < .001$, $\eta_p^2 = .050$, small effect). Girls enjoyed the fourth Stress N' Go significantly more than the boys who watched the same video ($F_{(1, 127)} = 4.481$, $p = .036$, $\eta_p^2 = .034$, small effect) and the girls who watched the fourth Destination: Brain video ($F_{(1, 127)} = 4.117$, $p = .045$, $\eta_p^2 = .031$, small effect). Girls in the Destination: Brain group enjoyed the second video significantly more than the first video ($F_{(3, 125)} = 4.749$, $p = .004$, $\eta_p^2 = .102$, moderate effect).

Boys in the Destination: Brain group enjoyed the first ($F_{(1, 127)} = 4.048$, $p = .046$, $\eta_p^2 = .031$, small effect), third ($F_{(1, 127)} = 8.373$, $p = .004$, $\eta_p^2 = .062$, moderate effect), and fourth ($F_{(1, 127)} = 8.660$, $p = .004$, $\eta_p^2 = .064$, moderate effect) videos significantly more than the girls. Boys also enjoyed the third and fourth Destination: Brain videos significantly more than boys who watched the third ($F_{(1, 127)} = 4.671$, $p = .033$, $\eta_p^2 = .035$, small effect) and fourth ($F_{(1, 127)} = 8.257$, $p = .005$, $\eta_p^2 = .061$, moderate effect) Stress N' Go videos respectively. Boys enjoyed the fourth Destination: Brain video significantly more than the first Destination: Brain video ($F_{(3, 125)} = 3.312$, $p = .022$, $\eta_p^2 = .074$, moderate effect). Figure 12 visualises these simple effects.

Table 10

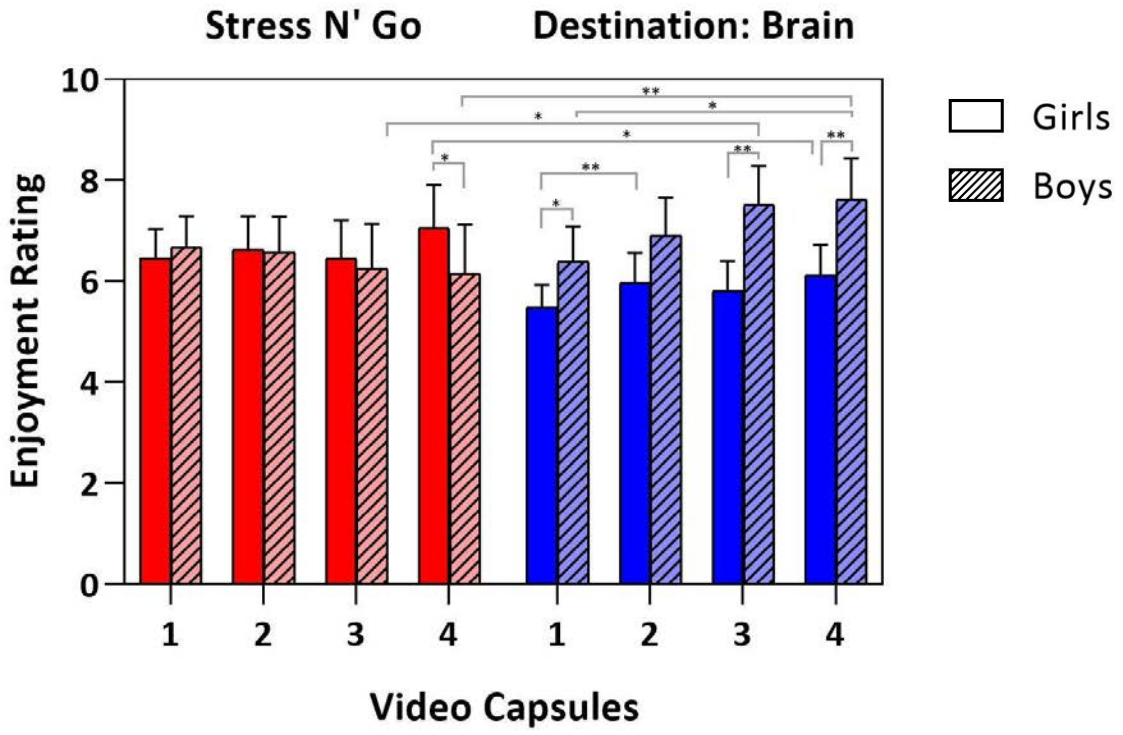
Descriptive and Inferential Statistics for Student Enjoyment Ratings

Video	Mean (95% *CI*)					
	Stress N' Go			Destination: Brain		
	Total Cohort	Girls	Boys	Total Cohort	Girls	Boys
1	6.62 (6.00, 7.23)	6.47 (5.66, 7.27)	6.82 (5.88, 7.76)	6.03 (5.52, 6.53)	5.64 (5.02, 6.27)	6.69 (5.87, 7.51)
2	6.83 (6.20, 7.46)	6.77 (5.94, 7.60)	6.91 (5.94, 7.88)	6.53 (6.02, 7.05)	6.24 (5.60, 6.88)	7.03 (6.19, 7.88)
3	6.62 (5.93, 7.30)	6.97 (5.69, 7.20)	6.14 (5.11, 7.16)	6.58 (6.03, 7.14)	5.98 (5.30, 6.66)	7.62 (6.73, 8.51)
4	6.79 (6.09, 7.48)	7.40 (6.21, 7.90)	5.96 (4.93, 6.98)	6.87 (6.31, 7.44)	6.26 (5.58, 6.94)	7.93 (7.04, 8.83)

Note. For the ANOVA analyses, the sample size was $n = 51$ (29 female) for the Stress N' Go intervention and $n = 80$ (50 female) for the Destination: Brain control.

Figure 12

Mean Student Enjoyment Ratings Stratified by Gender and Program



Note. Stress N' Go (*n* = 51, 57% female) ratings represented in shades of red and Destination: Brain (*n* = 80, 63% female) in shades of blue. Data were stratified by gender, with girls represented by solid colours and boys represented by stripes.

*$p < .05$, **$p < .05$ Bonferroni-corrected simple effects analysis.

Stress N' Go Student Feedback

Student Learnings

There was a total of 98 students who responded to the final video survey and 60 of these students responded to the question about what they had learnt from the program. The majority of the students (53%) reported that they have learned that stress does not always have to be debilitating and that they can use their physiological stress response to their advantage. *"Stress helps us grow stronger when we have the right amount of it, stress helps us expand our limits"* (male, 15 years old), *"Stress is something you can actually use to help you work your best. Also, a stressful situation doesn't have to be overwhelming or frightening"* (female, 13 years old).

Some of these students emphasized the balanced perspective they learned during the program; that stress can be both positive and negative (12%). *"The most important thing I have learnt is that having a small amount of stress can be a good thing, however, too much can overwhelm you"* (female, 16 years old).

Finally, some students stated that the program had taught them stress management or coping strategies (30%). *"Breathing, laughing, singing and praying is good advice whenever you have stress"* (male, 13 years old). Interestingly, deep breathing was referred to the most out of all the strategies (10%). There were also some non-specific or *"I do not know"* responses (13%). Therefore, students indicated that the program helped them view stress from a more positive perspective.

Improvements to the Program

There was a total of 204 responses providing feedback across the four videos, which can be used to present a holistic picture of the main feedback themes across all the videos. Frequency content analysis, combining all video capsule responses, found that the intervention was positively referred to in 29% of the responses. The following are some examples of this positive feedback: *"You couldn't improve it. It was so good as you used real life examples and make [sic] it easy to understand for teenages [sic]"* (male, 14 years old) and *"It gave a very knowledgeable scientific insight on the background of how your body physically responds to stress. I believe this was well presented"* (female, 13 years old). A large proportion of responses (26%) were non-specific or *"I do not know"*. Common areas of improvement observed in the responses were students suggesting that the videos could be more engaging, interesting, or funny (20%).

In relation to improvements in the applied aspects of the program, three sub-themes emerged: technical content (12%), practical scenarios (10%), and additional stress-related content (5%). For technical content, students suggested that the program could include better graphics and video editing as well as more unique and less distracting animations (5%). Some students emphasised that the audio could be louder and more expressive (5%). A few responses suggested that the videos could be shorter and present clearer content (2%).

Students suggested that the videos could include more real-life examples (4%) and provide more specific advice (6%), such as *"adding in more tips as not all will work for everyone"* (female, 16 years old) and *"better explanations or more in depth with psychology*" (female, 16 years old). Interestingly, three students indicated that they did not want to hear content about COVID-19 within the videos.

Finally, students asked for additional stress-related content about how to identify stress (3%) such as *"Expanding on the types of triggers of stress"* (male, 14 years old) and *"Talk about what amount of stress is healthy and can be used to your advantage*" (female, 16 years old). They also stated that they would like to hear about more strategies to help cope with stress (2%)*; "Maybe give ways to deal with negative stress that impacts you badly in stressful situations"* (female, 14 years old) or *"Explain some strategies on how to 'ride the wave'"* (male, 14 years old). Overall, students were receptive to the program but indicated that there could be areas of improvement in the technical and video content.

Discussion

This mixed-method investigation aimed to examine student satisfaction with the Stress N' Go intervention. Exploring program efficacy, from the perspective of the consumer, is critical for future implementations. This study analysed student enjoyment ratings, feedback, and their general understanding of the Stress N' Go program.

Student Enjoyment

Overall, both the Stress N' Go intervention and the control program was rated positively by the students. Towards the end of the program, the control videos (presenting basic neuroscience) were enjoyed more by the male students than the female students. This finding could be attributed to existing gender-science stereotypes; that neuroscience is a more "masculine" discipline (Makarova et al., 2019; Miller et al., 2018). This may also suggest that the enjoyment of programs could be moderated by gender beliefs, which is important to consider in the development of either universal or gender-specific education programs. Overall, the universal design of the Stress N' Go program was

supported, as there were minimal differences between genders within the videos, except for the final video on reappraising stress where girls rated the final Stress N' Go video as significantly more enjoyable than the boys who watched the same video. Finally, there was a decline in the number of students who responded to the surveys after the final two Stress N' Go videos compared to the Destination: Brain control group. This decline may be due to uncontrolled factors within the classrooms or student attendance. It could also be due to student enjoyment; however, ratings from the continuing participants did not decline.

Student Feedback

The prioritisation of the student's voice in education is important for student engagement and wellbeing (Gonski et al., 2018). The majority of the students reported that the most important takeaway from the program, which other students would benefit from, was that stress does not always have to be negative; this suggests students grasped the main concepts presented within the videos. Some students identified the more nuanced perspective about stress, in that, acute stress can be adaptive, while chronic stress can be adverse. Jamieson et al. (2018) suggest that stress mindset skills training should contain this more balanced perspective, as it is more ethical and realistic than presenting a biased program describing only the positive effects of stress. Some students emphasised the importance of practical coping strategies, such as deep diaphragm breathing. Tools, such as deep breathing, laughter, acts of kindness, and social support, are just a few valuable neuroscience-informed stress management tools that should be integrated into student learning outcomes (Fryburg, 2021; Provine, 2001; Uchino, 2006; Yau & Loke, 2021).

Students were asked to suggest areas in the program that could be improved. Overall, the Stress N' Go program was well-received by the students; however, they indicated that it could be more engaging. Students recommended that technical content, such as the animations could be improved, and the audio could have been louder and more expressive. Animated teaching videos can improve student engagement and interest as well as their comprehension of complex concepts (Liu & Elms, 2019; Reed et al., 2021). However, the execution of design, voice-acting, and dialogue is

dependent on the target audience of these videos (Liu & Elms, 2019; Reed et al., 2021). Collaborating with professional animators and voice actors for customised education programs may improve student engagement but may not be cost-effective. In the current study, the program was developed initially for French-speaking students in Quebec, Canada, and then adapted for English-speaking audiences. For a more targeted response in this particular group of adolescents, the videos could be customised further for Australian audiences (e.g., to include the Australian dialect and cultural references). Further, audio comprehension could be improved by ensuring the closed captions are utilised by educators. The Stress N' Go program contained optional closed captions; however, closed captions may not have been turned on while the content was delivered within the classrooms. In future multimedia presentations, content providers should ensure that closed captions are available and utilised to improve the accessibility of content (Morris et al., 2016).

Another area of improvement was to include more content such as education about additional coping strategies and how to identify unhealthy and healthy stress. This theme is supported in current Australian adolescent statistics. For example, in 2020, Australian students reported that one of their biggest concerns was coping with stress (Tiller et al., 2020). This was further reinforced by the 2021 MyStrengths Youth Report, which found that schoolwork was the leading cause of stress and worries in Australian high school students (McCrindle, 2021). Early stress-management interventions, particularly school programs, are effective and may redirect non-productive coping strategies (Kraag et al., 2006; Lupien et al., 2018). As such, in collaboration with researchers, education institutions should consider integrating stress management content, such as stress mindset skills training, early and consistently within the school curriculum.

Three students responded that they were not interested in the content related to the coronavirus (COVID-19) disease pandemic. The education program protocol was developed in 2019, before the pandemic, but the videos (developed in 2020) included COVID-19 as a potential student stressor. The program was also tested in 2020, a few months after the World Health Organisation announced COVID-19 to be a pandemic (World Health Organisation, 2021). Understandably, the

pandemic has had a significant burden on global mental health, such as increased symptoms of anxiety and depression (World Health Organisation, 2020). The Stress N' Go program was designed to be a universal program. However, the location of the current study was in a regional Queensland location that had limited COVID-19 cases (less than 30 cases at the time of testing) and was not currently in lockdown conditions (such as school and business closures) (Queensland Government, 2021), which may suggest why these students may not be interested in this content being included within the program. However, this request was only raised by a small number of students. Although COVID-19 is a global stressor, it should not always take priority in stress education programs, as adolescents face a range of significant stressors, such as school, examination, and relationships (parent, peer, and teacher).

Limitations

Although the content was carefully coded, there may have been some level of subjective interpretation. There were a large number of non-specific or missing responses to the free-text questions, potentially due to these types of questions requiring more effort to complete than Likert scales. The high attrition rate and small sample size, particularly for the intervention arm, in these free-text questions may limit the generalisability of the sample responses and the influence of selection bias cannot be ruled out. The student feedback focused on the program as a whole. It is possible that students could mention the same thing multiple times, and this inflates the theme frequency. However, if a student mentioned the same things after each video, it may suggest that this was an important theme across the program rather than just a single video (e.g., more comments = greater importance = higher score). Future analyses, however, could separate feedback from each video to provide a more comprehensive understanding of how each video can be improved according to the student's perspective. The survey responses are likely specific to the current sample of private school adolescents from mostly white origins within regional Australia and, as such, their feedback may not be generalizable to the wider population. For example, students

from lower socioeconomic status or those facing a greater health burden from the COVID-19 pandemic.

Conclusion

In summary, the universal Stress N' Go program was received well by this group of Australian adolescents. However, student engagement may be improved through targeted, more audience-specific changes to the technical content, such as the graphics and audio. Students grasped the general constructs presented in the program and were interested in learning more practical strategies to manage their stress. Overall, stress mindset skills training, in addition to longer stress management education, should be integrated into the Australian school curriculum to help students learn to cope with stress.

Conflict of Interest

The authors declare no competing financial interests. Destination: Brain and Stress N' Go interventions are freely available for use from the Centre for Studies on Human Stress (https://humanstress.ca/programs/stress-n-go/).

Authors' Contributions

The protocol for the study was developed by AAJ, SL, and RC at the CSHS. Data was collected by RM and aided by PW. Data analysis was performed by RM. The paper was drafted by RM and edited by all authors. All authors read and approved the final manuscript.

Funding

The Australian Government Research Training Program Scholarship, College of Medicine and Dentistry Top-up Scholarship, and College of Medicine and Dentistry Doctoral Completion grant supported this study.

Open Practices Statement

The Australian experiment reported in this article was not formally preregistered. Neither the data nor the materials for the Australian study have been made available on a permanent third-party archive and cannot be shared as informed consent was not attained from the participants of this study.

Acknowledgments

The authors would like to express their thanks to the students, families, and teachers who generously gave their time to this project. The authors would like to acknowledge James Cook University (Australian Institute of Tropical Health and Medicine and the College of Medicine and Dentistry) for their facilities and the guidance of staff members. This includes Emeritus Professor Rhondda Jones, Professor Sarah Larkins, Professor Cate Nagle, and Helen Griffiths for their ethical and methodological guidance as well as Associate Professor Robin Ray and Dr Michele Redman-MacLaren for advice on content analysis. Finally, the authors would like to acknowledge the significant assistance

of Sandrine Charbonneau who aided in the development of the French versions of the Destination Brain and Stress N' Go intervention videos.

References

Cohen, J. (1988; 2013). *Statistical power analysis for the behavioral sciences*. Academic Press.

Blascovich, J. (2008). Challenge, threat, and health. In J. Y. Shah & W. L. Gardner (Eds.), *Handbook of motivation science* (pp. 481–493). The Guilford Press.

Blascovich, J., & Tomaka, J. (1996). The biopsychosocial model of arousal regulation. *Advances in Experimental Social Psychology*, *28*, 1-51. https://doi.org/10.1016/S0065-2601(08)60235-X

Byrne, B. M. (2010). *Structural equation modeling with AMOS: Basic concepts, applications, and programming* (2nd Edition). In: New York: Routledge. https://doi.org/10.4324/9781315757421

Crum, A. J., Jamieson, J. P., & Akinola, M. (2020). Optimizing stress: An integrated intervention for regulating stress responses. *Emotion*, *20*(1), 120-125. https://doi.org/10.1037/emo0000670

Crum, A. J., Salovey, P., & Achor, S. (2013). Rethinking stress: The role of mindsets in determining the stress response. *Journal of Personality and Social Psychology*, *104*(4), 716. https://doi.org/10.1037/a0031201

Fryburg, D. A. (2021). Kindness as a stress reduction–health promotion Intervention: A Review of the Psychobiology of Caring. *American Journal of Lifestyle Medicine*, 1559827620988268. https://doi.org/10.1177/1559827620988268

Gonski, D., Arcus, T., Boston, K., Gould, V., Johnson, W., O'Brien, L., Perry, L., & Roberts, M. (2018). *Through growth to achievement: Report of the review to achieve educational excellence in Australian schools.* Canberra: Commonwealth of Australia. https://www.dese.gov.au/download/4175/through-growth-achievement-report-review-achieve-educational-excellence-australian-schools/18692/document/pdf

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis: International version.* New Jersey, Pearson.

Headspace. (2020). *Insights: youth mental health and wellbeing over time*. Headspace. Retrieved from https://headspace.org.au/assets/Uploads/Insights-youth-mental-health-and-wellbeing-over-time-headspace-National-Youth-Mental-Health-Survey-2020.pdf

Jamieson, J. P., Crum, A. J., Goyer, J. P., Marotta, M. E., & Akinola, M. (2018). Optimizing stress responses with reappraisal and mindset interventions: an integrated model. *Anxiety, Stress, & Coping*, *31*(3), 245-261. https://doi.org/10.1080/10615806.2018.1442615

Journault, A., & Lupien, S. (2020). *Addendum to MATA's study: Stress mindset intervention*. https://doi.org/10.17605/OSF.IO/U4CMF

Juster, R.-P., McEwen, B. S., & Lupien, S. J. (2010). Allostatic load biomarkers of chronic stress and impact on health and cognition. *Neuroscience & Biobehavioral Reviews*, *35*(1), 2-16. https://doi.org/10.1016/j.neubiorev.2009.10.002

Kraag, G., Zeegers, M. P., Kok, G., Hosman, C., & Abu-Saad, H. H. (2006). School programs targeting stress management in children and adolescents: A meta-analysis. *Journal of School Psychology*, *44*(6), 449-472. https://doi.org/10.1016/j.jsp.2006.07.001

Liu, C., & Elms, P. (2019). Animating student engagement: The impacts of cartoon instructional videos on learning experience. *Research in Learning Technology*, *27*. https://doi.org/10.25304/rlt.v27.2124

Lupien, S. J., Juster, R.-P., Raymond, C., & Marin, M.-F. (2018). The effects of chronic stress on the human brain: From neurotoxicity, to vulnerability, to opportunity. *Frontiers in Neuroendocrinology*, *49*, 91-105. https://doi.org/10.1016/j.yfrne.2018.02.001

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

Makarova, E., Aeschlimann, B., & Herzog, W. (2019). The gender gap in STEM Fields: The impact of the gender stereotype of math and science on secondary students' career aspirations. *Frontiers in Education*, *4*(60). https://doi.org/10.3389/feduc.2019.00060

McCrindle. (2021). *MyStrengths youth wellbeing report 2021*. https://s3.amazonaws.com/kajabi-storefronts-production/sites/163568/themes/2149125913/downloads/TnT1pVifTn62tOGicnyT_MyStrengths_Youth_Wellbeing_Report_2021.pdf

McEwen, B. S. (2017). Neurobiological and systemic effects of chronic stress. *Chronic Stress*, *1*, 2470547017692328. https://doi.org/10.1177/2470547017692328

Miller, D. I., Nolla, K. M., Eagly, A. H., & Uttal, D. H. (2018). The development of children's gender-science stereotypes: A meta-analysis of 5 decades of U.S. draw-a-scientist studies. *Child Development*, *89*(6), 1943-1955. https://doi.org/10.1111/cdev.13039

Morris, K. K., Frechette, C., Dukes III, L., Stowell, N., Topping, N. E., & Brodosi, D. (2016). Closed captioning matters: Examining the value of closed captions for" All" Students. *Journal of Postsecondary Education and Disability*, *29*(3), 231-238.

Provine, R. R. (2001). *Laughter: A scientific investigation*. Penguin.

Qualtrics. (July 2020). The output for this paper was generated using Qualtrics software, July 2020 Version of the Qualtrics Research Suite. Copyright © 2021 Qualtrics. Qualtrics and all other Qualtrics product or service names are registered trademarks or trademarks of Qualtrics, Provo, UT, USA. http://www.qualtrics.com

Queensland Government. (2021). *Queensland COVID-19 statistics*. https://www.qld.gov.au/health/conditions/health-alerts/coronavirus-covid-19/current-status/statistics#casesummary

Reed, C. L., Hagen, E., Bukach, C. M., & Couperus, J. W. (2021). Effectiveness of undergraduate-generated animations: Increasing comprehension and engagement for neuroscience majors and non-majors. *Teaching of Psychology*, 00986283211023061. https://doi.org/10.1177/00986283211023061

Romeo R. D. (2013). The teenage brain: The stress response and the adolescent brain. *Current Directions in Psychological Science*, *22*(2), 140–145. https://doi.org/10.1177/0963721413475445

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

Tiller, E., Fildes, J., Hall, S., Hicking, V., Greenland, N., Liyanarachchi, D., & Di Nicola, K. (2020). *Youth Survey Report 2020.* Mission Australia. https://www.missionaustralia.com.au/publications/youth-survey/1717-mission-australia-youth-survey-report-2020/file

Uchino, B. N. (2006). Social support and health: A review of physiological processes potentially underlying links to disease outcomes. *Journal of Behavioral Medicine*, *29*(4), 377-387. https://10.1007/s10865-006-9056-5

Van de Weijer-Bergsma, E., & Van der Ven, S. H. (2021). Why and for whom does personalizing math problems enhance performance? Testing the mediation of enjoyment and cognitive load at different ability levels. *Learning and Individual Differences*, *87*, 101982. https://doi.org/10.1016/j.lindif.2021.101982

World Health Organisation. (2020). *COVID-19 and the need for action on mental health*. https://unsdg.un.org/sites/default/files/2020-05/UN-Policy-Brief-COVID-19-and-mental-health.pdf

World Health Organisation. (2021). *Rolling updates on coronavirus disease (COVID-19).* https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen

Yau, K. K.-Y., & Loke, A. Y. (2021). Effects of diaphragmatic deep breathing exercises on prehypertensive or hypertensive adults: A literature review. *Complementary Therapies in Clinical Practice*, *43*, 101315. https://doi.org/10.1016/j.ctcp.2021.101315

CAN YOU CHANGE STRESS BELIEFS IN TEENS?

Chapter 1
Exploring stress during adolescence and whether beliefs about stress (stress mindsets) can be changed.

Chapter 2
A review of the literature on whether stress mindsets can be changed through short interventions or manipulations.

Chapter 3
Investigating the efficacy of a short online stress education program at promoting more positive stress mindsets and mental wellbeing in Australian adolescents.

Chapter 4
A mixed-methods investigation of the student feedback from the program.

Was the primary outcome reliable?

Chapter 5
A psychometric analysis of the Stress Mindset Measure, to determine reliability and validity of the project's primary outcome.

YOU ARE HERE

Chapter 6
Situating the research in the context of a global pandemic.

Chapter 7
A review of nail cortisol as an emerging and potentially inclusive measure of retrospective chronic stress levels for future research.

Chapter 8
A discussion on the outcomes of the project, limitations, and future directions.

TARGET JOURNAL: Assessment

Chapter 5

A psychometric validation study assessing the reliability and validity of the Stress Mindset Measure - General among Canadian and Australian adolescents

Riana Marie[123], Audrey-Ann Journault[45], Rebecca Cernik[46], Oyelola Adegboye[7], Paul Welch[3], Sonia Lupien[56], Brett McDermott[3], Joseph V Moxon[3], and Zoltan Sarnyai[127*]

[1]Laboratory of Psychiatric Neuroscience, Centre for Molecular Therapeutics, [2] Australian Institute of Tropical Health and Medicine, James Cook University, Townsville, Queensland, Australia

[3] College of Medicine and Dentistry, James Cook University, Townsville, Queensland, Australia

[4] Centre for Studies on Human Stress, [5]Psychology Department, [6]Psychiatry Department, University of Montreal, Canada

[7]College of Public Health, Medical, and Veterinary Sciences, James Cook University, Townsville, Queensland, Australia

[*]Corresponding author:

Professor Zoltán Sarnyai, M.D., Ph.D.

Phone: +61747816992

Email: zoltan.sarnyai@jcu.edu.au

Address: College of Public Health, Medical and Veterinary Sciences

James Cook University, 1 James Cook Drive, Townsville QLD 4811 AUSTRALIA

Abstract

The Stress Mindset Measure – General (SMM-G) is a recently developed 8-item measure of implicit beliefs about whether stress can have positive or negative effects. Few studies have assessed whether this measure is suitable for youth. This study aimed to evaluate the reliability and validity of the SMM-G in a cross-cultural adolescent cohort. Adolescents (13 – 18 years old) were recruited from schools within Canada (*n* = 913, 78% female) and Australia (*n* = 413, 57% female). Participants responded to an online survey containing the SMM-G and stress-related measures (translated into French for the Canadian sample). Only the French-translated SMM-G showed acceptable reliability. Evidence of criterion-related validity suggested that the SMM-G is a distinct but stress-related construct. However, confirmatory factor analysis suggested that the SMM-G did not fit either a single or two-factor model, which reduced its construct validity in these samples. A youth adapted SMM measure would have been more appropriate for these adolescent samples. Therefore, the French-translated version of the scale appeared to be psychometrically sound, but linguistic and cultural factors should be considered before applying the original SMM-G to Australian adolescent samples.

Keywords: Stress mindset, Psychometrics, Validation, Mental health, Adolescents

A psychometric validation study assessing the reliability and validity of the Stress Mindset Measure - General among Canadian and Australian adolescents

Stress is the body's biological response to physical and/or psychological challenges (Lazarus & Folkman, 1984). Although chronic stress is associated with damaging physical or mental health effects, the acute stress response can be adaptive (McEwen, 2017; Wingfield & Sapolsky, 2003). A stress mindset is a person's implicit perspective on whether stress can have positive or negative effects on health and performance (Crum et al., 2013). A mindset is the mental frame/lens or meta-cognitive process people use to select and encode the information that informs their beliefs and subsequent behaviours (Crum et al., 2013). People with a *stress-is-enhancing* mindset may be motivated to view stress as beneficial and in turn, employ productive coping strategies (e.g., seeking help or problem-solving). Conversely, people with a *stress-is-debilitating* mindset may view stress as having negative effects, which may lead to counter-productive coping strategies (e.g., avoidance, catastrophising, or rumination) (Crum et al., 2013).

Crum et al. (2013) suggested that more stress-is-enhancing mindsets could be primed through a short intervention. They found that adults who watched short 3-minute videos encouraging a stress-is-enhancing mindset developed a more positive stress mindset while improving mood and work performance (Crum et al., 2013). To measure stress mindsets, Crum et al. (2013) developed the Stress Mindset Measure - General (SMM-G) as a tool to measure if an individual has a stress-is-enhancing or a stress-is-debilitating mindset. This tool has been utilised in repeated investigations to investigate how stress mindsets can influence psychosocial and work performance (as seen in *Chapter 2*, for example, but not limited to Ben-Avi et al., 2018; Casper et al., 2017; Garvey et al., 2016; Huebschmann & Sheets, 2020; Huettermann & Bruch, 2019; Kim et al., 2020; Maarsingh et al., 2019; Silverstein et al., 2021; Smith et al., 2020; Wols et al., 2020).

At face value, the SMM-G appears to measure stress mindsets; however, Crum et al. (2013) also assessed the psychometric properties (reliability and validity) of this measure. The SMM-G showed good reliability, with an internal consistency of .86 (Crum et al., 2013). Other studies have

also supported the internal consistency of this scale within adult samples (α > .70) (Ben-Avi et al., 2018; Casper et al., 2017; Chen & Fang, 2019; Crum et al., 2017; Garvey et al., 2016; Horiuchi et al., 2018; Karampas et al., 2020; Kilby & Sherman, 2016). Criterion-related validity was also examined within the initial validations, by investigating correlations with other measures of stress. The SMM-G showed appropriate directionality, but weak correlations with the other recorded measures associated with stress amount, appraisal, and coping, suggesting again that it is a distinct stress construct (Crum et al., 2013). The convergent and discriminant validity with other mental health outcomes (such as depression, anxiety, and stress measures) was also supported in another study (Karampas et al., 2020). Using a confirmatory factor analysis, Crum et al. (2013) found a single factor structure, which supported the notion that stress mindset is a distinct construct (construct validity). However, several studies with Chinese, Greek, and Japanese participants have indicated that the SMM-G could measure two separate factors stress-is-enhancing and stress-is-debilitating mindsets (Chen & Fang, 2019; Iwamoto et al., 2019; Karampas et al., 2020).

Overall, there have been limited studies investigating adolescent stress mindsets. Adolescence is a period of social, emotional, and physical changes with heightened stress reactivity (Romeo, 2013). One study has adapted three items of the SMM-G for an American adolescent sample to investigate the protective effects of positive stress mindsets on self-control after adverse life events (Park et al., 2018). They found that the adapted SMM-G had good internal consistency (α = .77) (Park et al., 2018). Another study investigating the protective effects of positive stress mindsets on the well-being of Chinese migrant adolescents found further support for the single factor structure of the SMM-G previously suggested by Crum et al. (2013) (Jiang et al., 2019). However, this study on Chinese adolescents found that the SMM-G had just below acceptable internal consistency (α = .67) (Jiang et al., 2019). This reliability coefficient improved (α = .70), in a later longitudinal study of Chinese migrant adolescents by the same researchers, who also replicated the single factor scale structure in confirmatory factor analysis (Jiang et al., 2020). Further

investigations are warranted to determine if this scale can be used cross-culturally and within an adolescent sample.

Due to the limited availability of adolescent norms for the SMM-G and the small effect size observed in *Chapter 3*, this study aimed to assess the psychometric properties of the English SMM-G and a French-translated version of the Scale (SMM-F) in Australian and Canadian adolescents respectively. Crum et al. (2013) found that stress mindsets were associated with other stress-related domains and likely represented a distinct metacognitive construct. Therefore, it was hypothesised that stress mindsets would be significant but not strongly associated with constructs within the domain of stress, to assess the criterion-related validity of the SMM. These included perceived stress, anxiety sensitivity, state anxiety, and test anxiety. Aligned with previous validations, it was hypothesised that both the SMM-G and SMM-F would show acceptable internal consistency. As previous validations have established that the SMM-G can be reduced to two factors (stress-is-enhancing and stress-is-debilitating constructs), it was hypothesised that the SMM-G would have a two-factor structure in the current samples, as evidenced by the confirmatory factor analysis. It is important to note that a comparison between the factor structure of samples will not be formally tested.

Method

Participants

The study participants were from Quebec, Canada, and North Queensland, Australia. The combined sample consisted of 1326 adolescents (71% female) aged between 13 to 18 years of age (M_{age} = 15.36 years, SD_{age} = 1.23 years). Baseline data from the same cohort of adolescents discussed in *Chapters 3* and *4* were used for the Australian arm of this study. All participants within this age range were eligible to participate in this study after providing their informed consent. Parental consent was not required for Canadian participants above 14 years old. However, parental consent was obtained for Australian students under 16 years of age. This study was approved by the James Cook University Human Research Ethics Committee on the 24th of July 2019 (ethics number: H7727).

The final protocol was approved by the research ethics committee of the Centre intégré universitaire de santé et de services sociaux de l'Est de l'Île de Montréal on April 17th 2020 (ethics number: 2019-1849).

Materials

Instruments used in this study were the Stress Mindset Measure and stress-related questionnaires. The latter included the Perceived Stress Scale for Children, Childhood Anxiety Sensitivity Index, State-Trait Anxiety Inventory for Children- State Subscale, and Children's Test Anxiety Scale). Other measures were collected (e.g., measures of co-rumination, depression, and mental wellbeing) as part of a larger study; however, for this investigation, the reported scales are measures of stress constructs and scales used by both the Canadian and Australian projects.

Stress Mindset Measure (SMM)

Stress Mindset Measure – General (SMM-G; Crum et al., 2013), is a recently developed 8-item measure of stress mindsets (see Table 11). Scores can range from 0 "strongly disagree" to 4 "strongly agree", with higher scores indicating more positive stress mindsets (scores 2+ fall on the more stress-is-enhancing spectrum and scores <2 fall on the stress-is-debilitating spectrum). Mean scores were calculated after items (1,3,5, and 7) were reverse scored. A French version of the scale (SMM-F, see Table 11) was created for the Canadian sample, through double translation by the research team of the Centre for Studies on Human Stress [CSHS] (2019). In the initial validation (Crum et al., 2013), this measure had excellent internal consistency (Cronbach's alpha = .86).

Table 11

The General Items of the Stress Mindset Measure (SMM-G; Crum et al. (2013)) and its French Translation

Item Description
1. The effects of stress are negative and should be avoided (Reverse scored). ***Les effets du stress sont négatifs et devraient être évités.***
2. Experiencing stress facilitates my learning and growth. ***Vivre du stress facilite mes apprentissages et mon développement.***

3. Experiencing stress depletes my health and vitality (Reverse scored).
   Vivre du stress détériore ma santé et ma vitalité.
4. Experiencing stress enhances my performance and productivity.
   Vivre du stress améliore ma performance et ma productivité.
5. Experiencing stress inhibits my learning and growth (Reverse scored).
   Vivre du stress empêche mes apprentissages et mon développement.
6. Experiencing stress improves my health and vitality.
   Vivre du stress améliore ma santé et ma vitalité.
7. Experiencing stress debilitates my performance and productivity (Reverse scored).
   Vivre du stress handicape ma performance et ma productivité.
8. The effects of stress are positive and should be utilised.
   Les effets du stress sont positifs et devraient être exploités.

Stress-related Outcomes

The Childhood Anxiety Sensitivity Index (CASI; Silverman et al., 1991) is an 18-item scale measuring an individual's sensitivity to anxiety. Scores range from 1 "not at all" to 3 "a lot", with items consisting of statements such as *"I don't want other people to know when I feel afraid".* The sum of all the items was calculated (range 18 – 54), with higher scores suggesting an increased sensitivity to anxiety. The internal consistency of this scale and its French version was excellent in its initial validation, respectively Cronbach's alpha of 0.87 (Silverman et al., 1991) and 0.82 (Stassart & Etienne, 2014). Within the current study, this scale showed good internal consistency (Cronbach's alpha: 0.87 for combined data, 0.86 for Canada, and 0.91 for Australia).

The Perceived Stress Scale for Children (PSS-C; White, 2014), is a 14-item of subjective stress with scores ranging from 0 "never" to 3 "often". An example of the items includes *"In the last week how often did you feel scared or nervous?".* Seven items are reversed scored (e.g., "*In the last week, how often did you feel happy?"*). The sum of the items (range 0 – 39, item 1 is not included due to being a practice question) was calculated for the current study. Higher scores indicate greater self-reported stress levels. The PSS-C was translated into French through double-blind translation by the research team of the CSHS (2019). To date, there is limited data available validating this measure.

Within the current study, this scale showed acceptable internal consistency (Cronbach's alpha: 0.73 for combined data, 0.71 for Canada, and 0.80 for Australia).

The Children's Test Anxiety Scale (CTAS; Wren & Benson, 2004), is a 25-item scale that measures the level of performance anxiety a participant might experience during an examination. Scores can range from 1 "almost never" to 4 "almost always" with items such as *"When I take a test… my heart beats fast"*. The sum of all items (range 25 – 100) was calculated with higher scores indicating increased levels of test anxiety. The CTAS was translated into French through double-blind translation by the research team of the CSHS (2019). The internal consistency was excellent (α = .89) during validation (Wren & Benson, 2004). Within the current study, this scale showed good internal consistency (Cronbach's alpha: 0.94 for combined data, 0.94 for Canada, and 0.95 for Australia).

The State-Trait Anxiety Inventory for Children– State Subscale (STAIC-S; Spielberger et al., 1973), is a 20-item measure of momentary anxiety with scores ranging from 1 "very [emotion e.g., *"worried"*]" to 3 "not [emotion e.g., *worried*]". Ten items are reversed scored (e.g., "At this very moment I feel… *"happy"*). The sum of all items (range 20 – 60) was calculated with higher scores suggesting increased levels of momentary anxiety. This subscale's internal consistency was excellent (α = .88) in its initial English validation (Spielberger et al., 1971). The French version of this inventory has been validated and revealed a reliability coefficient of .88 for State anxiety (Turgeon & Chartrand, 2003). Within the current study, this scale showed good internal consistency (Cronbach's alpha: 0.90 for combined data, 0.90 for Canada, and 0.92 for Australia).

Procedure

The protocol was developed by Journault and Lupien (2020). The data used in this psychometric investigation was data collected at baseline (Canada: April to June 2020 and Australia: July 2020) before the implementation of a stress mindset intervention designed to promote stress-is-enhancing mindsets. This baseline data was collected using an online survey containing demographic questions and the self-report scales via the Qualtrics platform (Qualtrics, Provo, UT; July 2020 version). Participants spent about 30 minutes completing this survey. The Canadian study was completed in

French, while the Australian study was completed in English. It is important to note that this data was collected during the coronavirus (COVID-19) pandemic. Both Australia and Canada encouraged sanitary measures such as social distancing, mask-wearing, hand sanitization, and limited the number of people attending indoor/outdoor gatherings (Gouvernement du Québec, 2021; Queensland Government, 2021). The only difference was that for the Australian sample, schools and businesses were still open at the time of testing (Queensland Government, 2021).

Statistical analysis

Analyses were conducted using IBM SPSS Statistics v27, with the SPSS AMOS extension for CFA. Normality was assumed based on the sufficient sample size (N = 1326) and acceptable skewness and kurtosis (within +2/-2 and +7/-7 respectively) (Byrne, 2010; Hair et al., 2010). The independent variable in this study was the country (Canada and Australia). The primary outcomes were the stress mindset scores, i.e., SMM-G and SMM-F. Independent samples t-tests (continuous variables) and Chi-Square tests (categorical variables) were used to investigate differences between country sample characteristics. Internal consistency was assessed using Cronbach's alpha (α) where α values between 0.70 and 0.95 are considered acceptable (Tavakol & Dennick, 2011). Correlations (r) were used to investigate the convergent and discriminant validity between the SMM and the other psychological scales. A Confirmatory Factor Analysis (CFA) was then carried out on the SMM to verify the exploratory factor structure. The following fit indices were used as an indicative of good fit: Chi-squared test ($p > .05$), Root Mean Square Error of Approximation ($0.05 \leq RMSEA \leq 0.08$), comparative fit index ($CFI \geq 0.95$) and Tucker-Lewis fit index ($TLI \geq 0.95$) (Sun, 2005). Additionally, multivariate analysis of variance (MANOVA) was performed to investigate the relationship between the countries on items on the mindset scores with and without adjusting for covariates (demographics showing significant [$p < .05$] differences between countries).

Results

Sample Characteristics

Table 12 presents the characteristics of a total 1326 study participants aged 13 to 18 years from study sites in Quebec, Canada and Queensland, Australia. The Canadian sample consisted of 913 French-speaking students (78% female) from 73 private and public high schools in the province of Quebec, Canada (M_{age} = 15.41 years, SD_{age} = 1.08 years). The Australian sample consisted of 413 English-speaking students (57% female) from a private high school in Queensland, Australia (M_{age} = 15.24 years, SD_{age} = 1.50). There were significant differences in age, gender, and socioeconomic status between the two study sites ($p < .05$).

Table 12

Characteristics of Study Participants

Variable	Combined Cohort	Canada (N=913)	Australia (N=413)	*p*-value[a]
Age (years), *M±SD*[b]	15.36±1.23	15.41±1.08	15.24±1.50	**.034**
Gender, n (%)[c]				
Boys	370 (27.9%)	198 (21.7%)	172 (41.6%)	**<.001**
Girls	942 (71.0%)	708 (77.5%)	234 (56.7%)	
Other/non-specific	14 (1.1%)	7 (0.8%)	7 (1.7%)	
Socioeconomic Status, n (%)[d]				
Very comfortable	255 (19.2%)	148 (16.2%)	107 (25.9%)	**.005**
Quite comfortable	659 (49.7%)	461 (50.5%)	198 (47.9%)	
Moderately comfortable	289 (21.8%)	204 (22.3%)	85 (20.6%)	
Not very comfortable	44 (3.3%)	28 (3.1%)	16 (3.9%)	
Not at all comfortable	7 (0.5%)	6 (0.7%)	1 (0.2%)	
N (Missing)		*847 (66)*	*407 (6)*	
Ethnicity, n (%)[e]				
White origin	N/C	594 (65.1%)	289 (70.0%)	N/C
First Nations people		3 (0.3%)	4 (1.0%)	
Middle eastern or north African descent		29 (3.2%)	4 (1.0%)	
Asian origin		25 (2.7%)	61 (14.8%)	
Black origin		13 (1.4%)	N/R	
Central and Southern America		9 (1.0%)	N/R	
Caribbean origin		16 (1.8%)	N/R	
Multiracial/multiorigins		56 (6.1%)	48 (11.6%)	
SMM Global Score, *M±SD*[f]	1.62±0.67	1.56 ± 0.70	1.77 ± 0.56	**<.001**

Note.

N/R = measures were not recorded in this sample.

N/C is data that is not comparable due to using different measurement techniques.

[a]Differences between the samples were compared using independent samples *t*-tests for continuous variables and Chi-square (χ^2) tests for categorical variables ($p < .05$ indicates significance for both statistical tests).

[b]Missing data: 5 (0.4%) Cohort, 5 (0.4%) Canada, and 0 (0%) Australia

[c]Missing data: none

[d]Missing data: 72 (5.4%) Cohort, 66 (7.2%) Canada, and 6 (1.5%) Australia

[e]Missing data: N/C for whole cohort. 168 (18.4%) Canada, and 7 (1.7%) Australia.

[f]Missing data: 85 (6.4%) Cohort, 20 (2.2%) Canada, and 65 (15.7%) Australia.

Internal Consistency

Overall, the SMM had acceptable internal consistency for the combined cohort (see Table 11). However, when compared between countries, the SMM was just below the acceptable range in the Australian sample, compared to a good internal consistency within the Canadian sample. The overall reliability of the SMM-G for the Australian sample would improve to .69 if item five (*"Experiencing stress inhibits my learning and growth"*) was removed from the scale. The Canadian sample's internal consistency would not be improved by any removal of items.

Within the Australian sample, items 2 *("Experiencing stress facilitates my learning and growth"*) and 5 (*"Experiencing stress inhibits my learning and growth"*) on the SMM-G showed weak negative correlations with several other items (see Figure S1 in the supplementary material for inter-item correlations).

Criterion-Related Validity

There were significant weak to moderate negative relationships between the SMM and the other measures of stress-related constructs (see Table 13). When stratified by country, these associations were mostly moderate for the Canadian sample and weak for the Australian sample.

Table 13

Convergent and Discriminant Validity (Pearson's r correlations) between the Stress Mindset Measure – General and Other Stress-Related Measures and Internal Consistency (Cronbach's alpha)

Label	Measures	1	2	3	4	5
	Combined data					
1	SMM					
2	CASI	-0.28***				
3	PSS-C	-0.21***	0.49***			
4	CTAS	-0.26***	0.60***	0.48***		
5	STAIC-S	-0.26***	0.53***	0.64***	0.48***	
	N	1241	1238	1195	1149	1223
	Mean	1.62	31.61	14.91	57.75	35.03
	SD	0.67	7.33	6.24	16.95	7.03
	Cronbach's alpha	0.78	0.87	0.73	0.94	0.90
	Australia	**1**	**2**	**3**	**4**	**5**
1	SMM					
2	CASI	-0.18**				
3	PSS-C	-0.10	0.48***			
4	CTAS	-0.21***	0.64***	0.49***		
5	STAIC-S	-0.13*	0.57***	0.69***	0.54***	
	N	348	347	343	342	346
	Mean	1.77	31.50	15.28	59.26	34.06
	SD	0.56	8.09	6.85	18.33	7.09
	Cronbach's alpha	0.67	0.91	0.80	0.95	0.92
	Canada	**1**	**2**	**3**	**4**	**5**
1	SMM					
2	CASI	-0.32***				
3	PSS-C	-0.26***	0.50***			
4	CTAS	-0.30***	0.58***	0.47***		
5	STAIC-S	-0.30***	0.52***	0.62***	0.47***	
	N	893	891	852	807	877
	Mean	1.56	31.65	14.76	57.11	35.41
	SD	0.70	7.02	5.98	16.31	6.97
	Cronbach's alpha	0.82	0.86	0.71	0.94	0.90

Note. *p < .05, **p < .01, ***p < .001

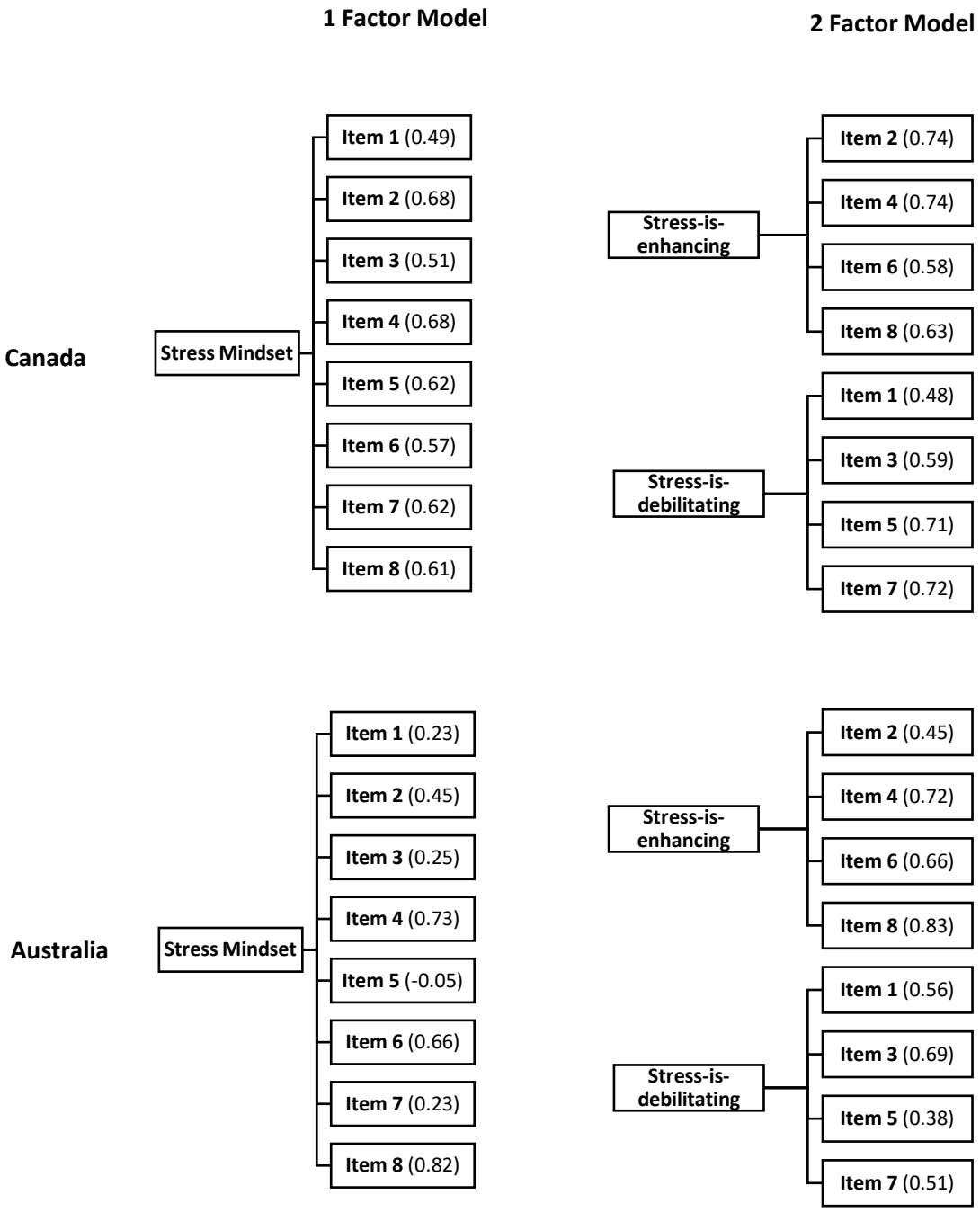
Confirmatory Factor Analysis

CFA was used to assess the fit of the one factor structure originally proposed by Crum et al. (2013). However, this model showed poor fit in both the current Canadian (χ^2 = 390.98, *df* = 20, p < .001, *CFI* = .82, *TLI* =.67, *RMSEA* = .14) and Australian (χ^2 = 222.34, *df* = 20, *p* < .001, *CFI* = .66, *TLI* =.38, *RMSEA* = .16) samples (see Figure 13). Based on more recent validations (Chen & Fang, 2019; Iwamoto et al., 2019; Karampas et al., 2020), a two-factor structure was investigated. CFA found an improved but not quite acceptable fit for this data, using a two-factor structure in both the Canadian (χ^2 = 229.27, *df* = 19, *p* < .001, *CFI* = .90, *TLI* =.80, *RMSEA* = .11) and Australian (χ^2 = 106.43, *df* = 19, *p* < .001, *CFI* = .85, *TLI* =.72, *RMSEA* = .11) samples. Within the Australian sample, item 5 appeared to

be the least internally consistent item based on reliability coefficients. Therefore, a two-factor structure CFA model, without item 5, was investigated. Although improved, this model was still not acceptable (χ^2 = 52.59, *df* = 8, *p* < .001, *CFI* = .90, *TLI* =.74, *RMSEA* = .12).

Figure 13

Standardised Regression Weights from Confirmatory Factor Analyses Stratified by Country

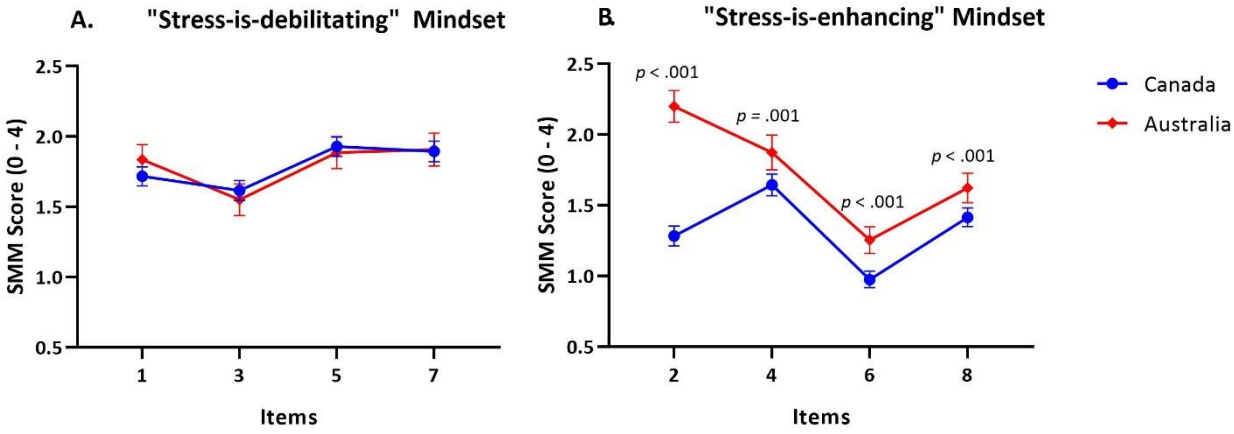


Multivariate Analysis

A Multivariate (SMM-G items) Analysis of Variance (MANOVA) found a significant difference between countries but only for the stress-is-enhancing items (items 2, 4, 6, 8). These differences remained significant after adjusting for age, gender, and socioeconomic status (see Table S7 in supplementary materials for descriptive and inferential MANOVA statistics). Canadian adolescents viewed the effects of stress as less "enhancing" than Australian adolescents (see Figure 14), particularly for item 2 "*Experiencing stress facilitates my learning and growth*", which had a medium effect size (Cohen, 1988; 2013).

Figure 14

Mean (SE) Score for SMM-G Items according to Factor Structure and Country



Note. **A.** There was no difference between countries on the negatively worded items that indicated a more stress-is-debilitating mindset. Data are presented as means ± 95% confidence intervals. **B.** Canadian adolescents responded less positively to the stress-is-enhancing mindset items compared to the Australian adolescents. Data are presented as means ± 95% confidence intervals.

Discussion

This study aimed to assess the reliability and validity of the SMM in a sample of Australian and Canadian adolescents. It was hypothesised that both the SMM-G and SMM-F would show acceptable reliability and validity cross-culturally and have the same single factor structure, as observed in the initial validation (Crum et al., 2013). This hypothesis was partially supported, as the SMM-F, was found to be psychometrically valid. However, the SMM-G did not appear to be as internally consistent in the Australian sample as evidenced by the Cronbach's alpha coefficient. Further, this study found that no model yielded an adequate fit for either a 1 or 2-factor structure and therefore the SMM does not appear psychometrically sound in either sample.

Reliability

The reliability of the SMM-F was supported. The SMM-F showed better internal consistency, consistent with the original adult validation (Crum et al., 2013). In contrast, the SMM-G in the Australian sample had marginally below acceptable internal consistency. The smaller sample size, number of items, language, single-centre location, or factor structure of this scale may have affected the consistency of responses for Australian adolescents (Tavakol & Dennick, 2011). For example, the English version of the SMM-G had a Flesch Reading Ease of 33.8 (college-level) (Flesch, 1979), compared to the French-translated scale, which had a readability score of 66.2 (eighth to ninth-grade level). As such, the college reading level of the SMM-G may not have been suitable for the grade 8 to 12 students in the Australian group. For the Australian sample, the removal of item 5 would have improved the internal consistency of the SMM-G. Item 5 may have had less consistent responses due to factors, such as the readability of the word "inhibits", which may have been above the readability of the Australian students. Alternative words such as "stops" or "prevents" may be easier to understand but warrant further investigations.

Another consideration is that the SMM does not reflect the more nuanced stress mindset theory that stress *can be* enhancing rather than stress *is* enhancing. Jamieson et al. (2018) suggested that stress mindset skills training should provide evidence of both the positive and negative effects of

stress rather than a biased view that stress is entirely positive. This nuanced perspective is not applied within the SMM items (e.g., “the effects of stress *are* positive/negative” rather than “the effects of stress *can be* positive/negative”. Having a more nuanced measure of stress mindset may promote more internally consistent responses. A research group in Australia has developed a measure called the Stress Control Mindset Measure which applies this balanced perspective and is psychometrically sound in adults (Keech et al., 2018; Keech et al., 2021). Therefore, the SMM-F remains reliable for French-speaking Canadian adolescents, but linguistic appropriateness may be an important factor to consider for adolescent samples showing less internally consistent results.

Criterion-Related Validity

In agreement with Crum et al. (2013), stress mindset appears to be a distinct construct from other stress-related scales, such as self-reported stress and anxiety. This finding is based on the convergent and divergent validity of the SMM-G where the correlations with other stress-related scales were mostly weak to moderate negative correlations. Negative correlations with the SMM are directionally appropriate. Higher scores on the SMM suggest a more stress-is-enhancing mindset, compared to the other stress-related scales where higher scores suggest increased levels of subjective stress and anxiety. However, the weak to moderate correlations suggest that the SMM remains a distinct construct, which is possible due to the SMM only measuring implicit metacognitive mindsets about stress rather than self-reported behaviours associated with stress and anxiety.

Factor Structure

Although the CFA indicated that a two-factor structure was marginally better than a one-factor structure, this analysis did not find that either a single or two-factor structure was appropriate for the current adolescent samples. These findings are inconsistent with the single structure found by Crum et al. (2013) and previous validations (Chen & Fang, 2019; Iwamoto et al., 2019; Karampas et al., 2020). This difference between the current samples and the initial American validation by Crum et al. (2013), could have been due to sample variances, such as language, location, and age. However, future analyses (e.g., modification indices) should be used to determine whether the

default assumption of uncorrelated residuals may be a source of misfit for some similarly worded items. Overall, a youth adapted SMM measure, like the three items adapted by Park et al. (2018) may have been more appropriate for these adolescent samples.

Country Differences between SMM-G Items

Canadian adolescents reported stress to have less "enhancing" effects compared to the Australian sample. This difference was even more evident in responses to the item *"Experiencing stress facilitates my learning and growth".* Both studies were conducted a few months after the World Health Organisation (2021) announced coronavirus (COVID-19) disease to be a pandemic. The Canadian sample having a more negative outlook on stress may have been associated with differences, such as living situations or school closure due to the COVID-19 restrictions (Lee, 2020). At the time of testing, the Canadian sample was experiencing strict lockdown restrictions and not attending school. However, the Australian sample was tested a couple of months later while they were at school and not under any strict restrictions within their regional location. School closure may therefore affect the responses to items about learning, growth, or performance, as these are often associated with education. Further, increased media releases and mental health discussions during the pandemic may have increased awareness about stress or potentially increased stress levels in both samples. However, the extent of these factors, especially COVID-19, in influencing the outcomes of this study warrants more empirical investigations.

Limitations

Potential limitations of the Australian study may have contributed to the differences in psychometric properties. For example, the Australian study had a smaller sample size and recruited participants from only one private school, compared to the large Canadian sample from multiple private and public high school institutions. These study limitations may have made the Australian sample less generalisable to the wider Australian adolescent population and therefore more difficult to interpret as Australian norms. Conversely, the Canadian sample had a highly skewed female cohort. Finally, most participants identified as being of White/Caucasian origins and came from

mostly “quite comfortable” socioeconomic statuses, which limits the generalisability of these findings to a wider Australian adolescent cohort.

Conclusion

This cross-cultural study assessed the reliability and validity of the SMM-G in an adolescent sample. The French translation of the scale appears to be reliable for use in Canadian adolescents. The lower reliability of the SMM-G in the Australian cohort may be the result of linguistic factors, such as the adult English version of the scale not being suitable for Australian adolescents. CFA did not yield a satisfactory model fit for either a single or two-factor structure for the SMM in either cohort, suggesting that the adult SMM is not psychometrically sound for these samples. Canadian adolescents appear to find stress to be less “enhancing” than Australian adolescents, possibly due to cultural or pandemic influences. In summary, this investigation highlights the importance of considering the potential effect of age, linguistic, and cultural differences when using validated scales and provides support for the SMM-F for use in adolescent research.

Conflict of Interest

The authors declare that they have no competing interests.

Authors' Contributions

The protocol for the studies was developed by AAJ, SL, and RC at the CSHS. The Canadian and Australian study data were collected by AAJ and RM respectively with assistance from PW. The psychometric analysis was performed by RM and OA. The paper was written by RM and edited by all authors. All authors read and approved the final manuscript.

Funding

The Australian Government Research Training Program Scholarship and College of Medicine and Dentistry Top-up Scholarship supported the Australian study.

Open Practices Statement

The Canadian study was pre-registered: https://osf.io/u4cmf (Journault & Lupien, 2020). The Australian study was not formally preregistered. Neither the data nor the materials from the Australian study have been made available on a permanent third-party archive and cannot be shared as informed consent was not attained from the participants of this study.

Acknowledgments

The authors would like to express their thanks to the students, families, and teachers who generously gave their time to this project. The authors would like to acknowledge James Cook University (Australian Institute of Tropical Health and Medicine and the College of Medicine and Dentistry) for their facilities and the guidance of staff members. This includes Emeritus Professor Rhondda Jones, Professor Sarah Larkins, Professor Cate Nagle, and Helen Griffiths for their ethical and methodological guidance.

References

Ben-Avi, N., Toker, S., & Heller, D. (2018). “If stress is good for me, it's probably good for you too”: Stress mindset and judgment of others' strain. *Journal of Experimental Social Psychology*, *74*, 98-110. https://doi.org/http://dx.doi.org/10.1016/j.jesp.2017.09.002

Byrne, B. M. (2010). *Structural equation modeling with AMOS: Basic concepts, applications, and programming* (2nd Edition). In: New York: Routledge. https://doi.org/10.4324/9781315757421

Casper, A., Sonnentag, S., & Tremmel, S. (2017). Mindset matters: The role of employees’ stress mindset for day-specific reactions to workload anticipation. *European Journal of Work and Organizational Psychology*, *26*(6), 798-810. https://doi.org/10.1080/1359432x.2017.1374947

Chen, H.-L., & Fang, S.-C. (2019b). Job stressors and job performance: Modeling of moderating mediation effects of stress mindset. *Research Journal of Business and Management*, *6*(1), 35-45. https://doi.org/10.17261/Pressacademia.2019.1020

Cohen, J. (1988; 2013). *Statistical power analysis for the behavioral sciences*. Academic Press.

Crum, A. J., Akinola, M., Martin, A., & Fath, S. (2017). The role of stress mindset in shaping cognitive, emotional, and physiological responses to challenging and threatening stress. *Anxiety, Stress, & Coping*, *30*(4), 379-395. https://doi.org/10.1080/10615806.2016.1275585

Crum, A. J., Salovey, P., & Achor, S. (2013). Rethinking stress: The role of mindsets in determining the stress response. *Journal of Personality and Social Psychology*, *104*(4), 716. https://doi.org/10.1037/a0031201

Flesch, R. (1979). *How to write plain English: A book for lawyers and consumers*. Harpercollins.

Garvey, A. M., Germann, F., & Bolton, L. E. (2016). Performance brand placebos: How brands improve performance and consumers take the credit. *Journal of Consumer Research*, *42*(6), 931-951. http://dx.doi.org/10.1093/jcr/ucv094

Gouvernement du Québec. (2021). *List of all infographics related to the prime minister's announcements (COVID-19)*. https://www.quebec.ca/en/premier/premier/access-to-

publications-related-to-the-premiers-announcements-concerning-covid-19/liste-de-toutes-les-infographies-en-lien-avec-les-annonces-du-premier-ministre-covid-19

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis: International version.* New Jersey, Pearson.

Horiuchi, S., Tsuda, A., Aoki, S., Yoneda, K., & Sawaguchi, Y. (2018). Coping as a mediator of the relationship between stress mindset and psychological stress response: a pilot study. *Psychology Research and Behavior Management*, *11*, 47. https://doi.org/10.2147/PRBM.S150400

Huebschmann, N. A., & Sheets, E. S. (2020). The right mindset: Stress mindset moderates the association between perceived stress and depressive symptoms. *Anxiety, Stress & Coping*, *33*(3), 248-255. https://doi.org/10.1080/10615806.2020.1736900

Huettermann, H., & Bruch, H. (2019). Mutual gains? health-related HRM, collective well-being and organizational performance. *Journal of Management Studies*, *56*(6), 1045-1072. https://doi.org/10.1111/joms.12446

Iwamoto, K., Takehashi, H., & Taka, F. (2019). Reliability and validity of a Japanese translation of the Stress Mindset Measure (SMM-J). *Japanese Journal of Psychology*, *90*(6), 592-602. https://doi.org/http://dx.doi.org/10.4992/jjpsy.90.18229

Jamieson, J. P., Crum, A. J., Goyer, J. P., Marotta, M. E., & Akinola, M. (2018). Optimizing stress responses with reappraisal and mindset interventions: an integrated model. *Anxiety, Stress, & Coping*, *31*(3), 245-261. https://doi.org/10.1080/10615806.2018.1442615

Jiang, Y., Ming, H., Tian, Y., Huang, S. L., Sun, L., Li, H. J., & Zhang, H. C. (2020). Cumulative risk and subjective well-being among rural-to-urban migrant adolescents in China: Differential moderating roles of stress mindset and resilience. *Journal of Happiness Studies*, *21*(7), 2429-2449. https://doi.org/10.1007/s10902-019-00187-7

Jiang, Y., Zhang, J., Ming, H., Huang, S. L., & Lin, D. H. (2019). Stressful life events and well-being among rural-to-urban migrant adolescents: The moderating role of the stress mindset and differences

between genders. *Journal of Adolescence*, *74*, 24-32. https://doi.org/10.1016/j.adolescence.2019.05.005

Journault, A., & Lupien, S. (2020). *Addendum to MATA's study: Stress mindset intervention*. https://doi.org/10.17605/OSF.IO/U4CMF

Karampas, K., Pezirkianidis, C., & Stalikas, A. (2020). Psychometric properties of the Stress Mindset Measure (SMM) in a Greek sample. *Psychology*, *11*(08), 1185. https://doi.org/10.4236/psych.2020.118079

Keech, J. J., Hagger, M. S., O'Callaghan, F. V., & Hamilton, K. (2018). The infuence of university students' stress mindsets on health and performance outcomes. *Annals of Behavioral Medicine*, *52*(12), 1046-1059. https://doi.org/10.1093/abm/kay008

Keech, J. J., Orbell, S., Hagger, M. S., O'Callaghan, F. V., & Hamilton, K. (2021). Psychometric properties of the stress control mindset measure in university students from Australia and the UK. *Brain and Behavior*, *11*(2), e01963. https://doi.org/10.1002/brb3.1963

Kilby, C. J., & Sherman, K. A. (2016). Delineating the relationship between stress mindset and primary appraisals: Preliminary findings. *Springerplus*, *5*(1), 1-8. https://doi.org/10.1186/s40064-016-1937-7

Kim, J., Shin, Y., Tsukayama, E., & Park, D. (2020). Stress mindset predicts job turnover among preschool teachers. *Journal of School Psychology*, *78*, 13-22. https://doi.org/10.1016/j.jsp.2019.11.002

Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping*. Springer Publishing Company.

Lee, J. (2020). Mental health effects of school closures during COVID-19. *The Lancet Child & Adolescent Health*, *4*(6), 421. https://doi.org/10.1016/S2352-4642(20)30109-7

Maarsingh, B. M., Bos, J., Van Tuijn, C. F. J., & Renard, S. B. (2019). Changing stress mindset through Stressjam: A virtual reality game using biofeedback. *Games for Health*, *8*(5), 326-331. https://doi.org/http://dx.doi.org/10.1089/g4h.2018.0145

McEwen, B. S. (2017). Neurobiological and systemic effects of chronic stress. *Chronic Stress*, *1*, 2470547017692328. https://doi.org/10.1177/2470547017692328

Park, D., Yu, A., Metz, S. E., Tsukayama, E., Crum, A. J., & Duckworth, A. L. (2018). Beliefs about stress attenuate the relation among adverse life events, perceived distress, and self-control. *Child Development*, *89*(6), 2059-2069. https://doi.org/http://dx.doi.org/10.1111/cdev.12946

Qualtrics. (July 2020). The output for this paper was generated using Qualtrics software, July 2020 Version of the Qualtrics Research Suite. Copyright © 2021 Qualtrics. Qualtrics and all other Qualtrics product or service names are registered trademarks or trademarks of Qualtrics, Provo, UT, USA. http://www.qualtrics.com

Queensland Government. (2021). *Queensland COVID-19 statistics*. https://www.qld.gov.au/health/conditions/health-alerts/coronavirus-covid-19/current-status/statistics#casesummary

Romeo R. D. (2013). The teenage brain: The stress response and the adolescent brain. *Current Directions in Psychological Science*, *22*(2), 140–145. https://doi.org/10.1177/0963721413475445

Silverman, W. K., Fleisig, W., Rabian, B., & Peterson, R. A. (1991). Childhood Anxiety Sensitivity Index. *Journal of Clinical Child and Adolescent Psychology*, *20*(2), 162-168. https://doi.org/10.1207/s15374424jccp2002_7

Silverstein, M. W., Mekawi, Y., Alonzi, S. P., & La Torre, A. (2021). Psychometric properties of the assessment of COVID-19 attitudes and behaviors. *Analyses of Social Issues and Public Policy*, *21*(1), 557-578. https://doi.org/10.1111/asap.12233

Smith, E. N., Young, M. D., & Crum, A. J. (2020). Stress, mindsets, and success in Navy SEALs special warfare training. *Frontiers in Psychology*, *10*, 2962. https://doi.org/10.3389/fpsyg.2019.02962

Spielberger, C. (1973). *State-Trait Anxiety Inventory for Children preliminary manual.* Palo Alto, CA: Consulting.

Spielberger, C. D., Gonzalez-Reigosa, F., Martinez-Urrutia, A., Natalicio, L. F., & Natalicio, D. S. (1971). The State-Trait Anxiety Inventory. *Revista Interamericana de Psicología/Interamerican Journal of Psychology*, *5*(3 & 4). https://doi.org/10.30849/rip/ijp.v5i3 & 4.620

Stassart, C., & Etienne, A. M. (2014). A French translation of the Childhood Anxiety Sensitivity Index (CASI): Factor structure, reliability and validity of this scale in a nonclinical sample of children. *Psychologica Belgica*, *54*(2), 222–241. https://doi.org/10.5334/pb.an

Sun, J. (2005). Assessing goodness of fit in confirmatory factor analysis. *Measurement and Evaluation in Counseling and Development*, *37*(4), 240-256. https://doi.org/http://dx.doi.org/10.1080/07481756.2005.11909764

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53-55. https://doi.org/10.5116/ijme.4dfb.8dfd

Turgeon, L., & Chartrand, É. (2003). Reliability and validity of the revised children's manifest anxiety scale in a French-Canadian sample. *Psychological Assessment*, *15*(3), 378–383. https://doi.org/10.1037/1040-3590.15.3.378

White, B. P. (2014). The perceived stress scale for children: A pilot study in a sample of 153 children. *International Journal of Pediatrics and Child Health*, *2*(2), 45-52. http://dx.doi.org/10.12974/2311-8687.2014.02.02.4

Wingfield, J., & Sapolsky, R. (2003). Reproduction and resistance to stress: when and how. *Journal of Neuroendocrinology*, *15*(8), 711-724. https://doi.org/10.1046/j.1365-2826.2003.01033.x

Wols, A., Poppelaars, M., Lichtwarck-Aschoff, A., & Granic, I. (2020). The role of motivation to change and mindsets in a game promoted for mental health. *Entertainment Computing*, *35*, 100371. https://doi.org/10.1016/j.entcom.2020.100371

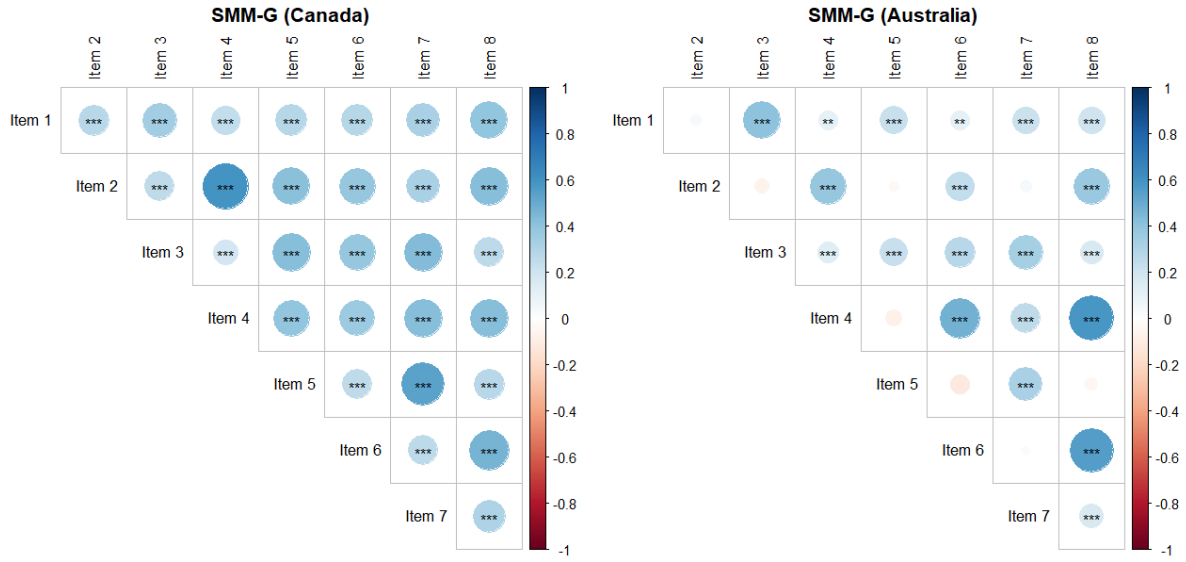
World Health Organisation. (2021). *Rolling updates on coronavirus disease (COVID-19)*. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen

Wren, D. G., & Benson, J. (2004). Measuring test anxiety in children: Scale development and internal construct validation. *Anxiety, Stress, & Coping*, *17*(3), 227-240. https://doi.org/10.1080/10615800412331292606

Supplementary Material

Figure S1

Inter-item correlations for the Canadian SMM-G internal consistency for the Canadian and Australian samples.



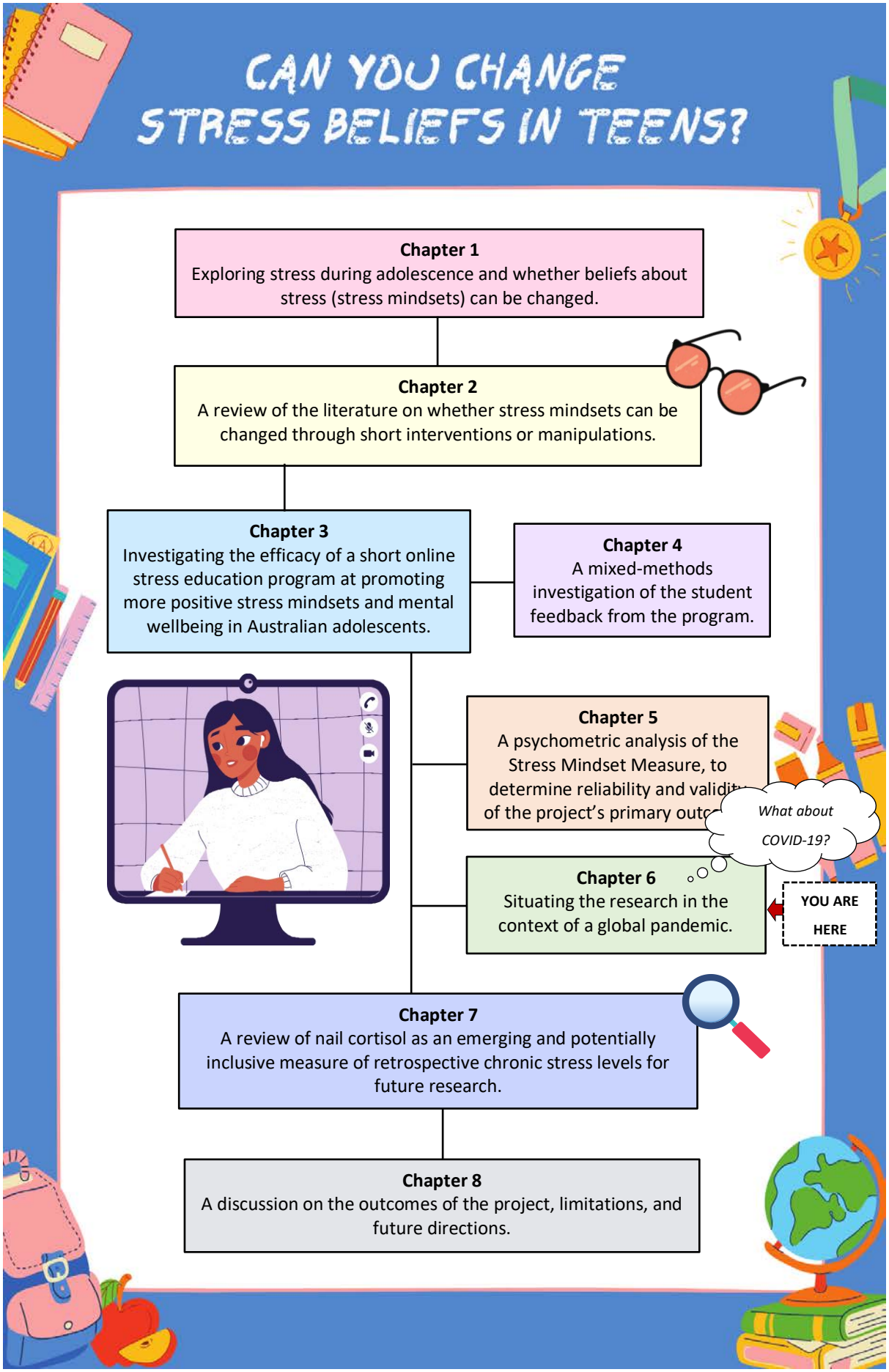
Note. *p < .05, **p <.01, ***p <.001

Table S7

Multivariate Analysis of SMM-G Items according to Country

Factor	SMM Items	*M (SD)*		MANOVA Analysis	
		Canada (n = 886)	Australia (n = 347)	Unadjusted	Adjusted*
Negative Stress	Item 1	1.72 (1.65, 1.78)	1.84 (1.73, 1.94)	$F_{(1, 1231)} = 3.39$, $p = .066$, $\eta_p^2 = .003$	$F_{(1, 1176)} = 2.54$, $p = .066$, $\eta_p^2 = .002$
	Item 3	1.62 (1.55, 1.69)	1.55 (1.44, 1.66)	$F_{(1, 1231)} = .94$, $p = .332$, $\eta_p^2 = .001$	$F_{(1, 1176)} = 3.97$, $p = .332$, $\eta_p^2 = .003$
	Item 5	1.93 (1.86, 2.00)	1.89 (1.77, 2.00)	$F_{(1, 1231)} = .44$, $p = .509$, $\eta_p^2 < .001$	$F_{(1, 1176)} = 1.20$, $p = .509$, $\eta_p^2 = .001$
	Item 7	1.89 (1.82, 1.97)	1.91 (1.79, 2.02)	$F_{(1, 1231)} = .04$, $p = .843$, $\eta_p^2 < .001$	$F_{(1, 1176)} = .09$, $p = .843$, $\eta_p^2 < .001$
Positive Stress	Item 2	1.28 (1.21, 1.35)	2.20 (2.09, 2.31)	$F_{(1, 1231)} = 187.35$, $p < .001$, $\eta_p^2 = .132$	$F_{(1, 1176)} = 182.64$, $p < .001$, $\eta_p^2 = .134$
	Item 4	1.64 (1.57, 1.72)	1.87 (1.75, 2.00)	$F_{(1, 1231)} = 9.62$, $p = .002$, $\eta_p^2 = .008$	$F_{(1, 1176)} = 12.24$, $p < .001$, $\eta_p^2 = .010$
	Item 6	0.97 (0.92, 1.03)	1.25 (1.16, 1.35)	$F_{(1, 1231)} = 24.55$, $p < .001$, $\eta_p^2 = .020$	$F_{(1, 1176)} = 20.54$, $p < .001$, $\eta_p^2 = .017$
	Item 8	1.42 (1.35, 1.48)	1.62 (1.52, 1.73)	$F_{(1, 1231)} = 10.98$, $p < .001$, $\eta_p^2 = .009$	$F_{(1, 1176)} = 11.73$, $p < .001$, $\eta_p^2 = .010$

Note. Data presented as means ± 95% Confidence Intervals. *Adjusted for age, gender, and socioeconomic status


CAN YOU CHANGE STRESS BELIEFS IN TEENS?
Chapter 1
Exploring stress during adolescence and whether beliefs about stress (stress mindsets) can be changed.
Chapter 2
A review of the literature on whether stress mindsets can be changed through short interventions or manipulations.
Chapter 3
Investigating the efficacy of a short online stress education program at promoting more positive stress mindsets and mental wellbeing in Australian adolescents.
Chapter 4
A mixed-methods investigation of the student feedback from the program.
Chapter 5
A psychometric analysis of the Stress Mindset Measure, to determine reliability and validit
of the project's primary outc
What about COVID-19?
Chapter 6
Situating the research in the context of a global pandemic.
YOU ARE HERE
Chapter 7
A review of nail cortisol as an emerging and potentially inclusive measure of retrospective chronic stress levels for future research.
Chapter 8
A discussion on the outcomes of the project, limitations, and future directions.

JOURNAL: International Journal of Environmental Research and Public Health

Chapter 6

A cross-sectional study investigating Canadian and Australian adolescents' perceived experiences of COVID-19, gender differences, and mental health implications

Riana Marie[123†], Audrey-Ann Journault[45†], Rebecca Cernik[46], Paul Welch[3], Sonia Lupien[46], Brett McDermott[3], Joseph V Moxon[3], and Zoltan Sarnyai[127*]

[†] Shared first-authorship

[1] Laboratory of Psychiatric Neuroscience, Centre for Molecular Therapeutics, [2] Australian Institute of Tropical Health and Medicine, James Cook University, Townsville, Queensland, Australia

[3] College of Medicine and Dentistry, James Cook University, Townsville, Queensland, Australia

[4] Centre for Studies on Human Stress, [5] Psychology Department, [6] Psychiatry Department, University of Montreal, Canada

[7]College of Public Health, Medical, and Veterinary Sciences, James Cook University, Townsville, Queensland, Australia

[*]Corresponding author:

Professor Zoltán Sarnyai, M.D., Ph.D.

Phone: +61747816992

Email: zoltan.sarnyai@jcu.edu.au

Address: College of Public Health, Medical and Veterinary Sciences

James Cook University, 1 James Cook Drive, Townsville QLD 4811 AUSTRALIA

Abstract

The coronavirus (COVID-19) disease pandemic has been associated with adverse psychological outcomes. This cross-cultural study (*N* = 1326, 71% female) aimed to investigate Canadian and Australian adolescents' subjective experiences of COVID-19, gender differences, and psychological implications. Mixed-methods analyses were used to examine differences in COVID-19 experiences and mental health outcomes between country and gender in a Canadian (*N* = 913, 78% female) and an Australian sample (*N* = 413, 57% female) of adolescents. Canadian adolescents reported increased COVID-19 discussions and more concerns related to their COVID-19 experiences compared to Australian adolescents. Girls consistently reported more concerns related to COVID-19 and poorer psychological outcomes compared to boys. School lockdown for the Canadian sample may have played a role in these country differences. Further, girls might be at significantly more risk for mental health concerns during COVID-19, which should be considered in adolescent mental health initiatives during the pandemic. Although school disruption and separation of peers due to the pandemic likely have a role in adolescent perceived stressors and mental health, the differences between Canadian and Australian adolescents were less clear and future investigations comparing more objective pre-COVID-19 data to current data are needed.

Keywords: COVID-19, Stress, School, Mental Health, Adolescents

A cross-sectional study investigating Canadian and Australian adolescents' perceived experiences of COVID-19, gender differences, and mental health implications

The coronavirus disease (COVID-19) pandemic is a global stressor with adverse health, psychological, and economic burdens (Callaway et al., 2020; Thombs et al., 2020). To date, the World Health Organization (WHO) reports that there have been approximately 184 million reported cases and almost four million deaths associated with COVID-19 (World Health Organisation, 2021a). This disease has significantly affected individuals and communities who have experienced the loss of loved ones, health fears, future uncertainty, quarantine, social isolation, food/item insecurity, and business/school closures (Thombs et al., 2020). This transitional state of living has been related to poor mental health and well-being outcomes (Bell, 2021; Kumar & Nayar, 2021).

COVID-19 and Mental Health

From a review of past investigations of infectious diseases (e.g., SARS, Ebola, and H1N1 influenza), quarantine was associated with post-traumatic stress symptoms, confusion, and anger (Brooks et al., 2020). The full longitudinal extent of the consequences of the pandemic continues to be determined. One study found higher rates of anxiety, depression, substance use, and lower mental well-being among people in China compared to pre-COVID-19 norms (Ahmed et al., 2020). The psychological impact of COVID-19 and quarantine experiences are still being investigated by living (frequently updated) systematic reviews (Dong et al., 2021; Thombs et al., 2020). Several studies have investigated the mental health and experiences of adolescents during the COVID-19 pandemic and past pandemics.

Adolescent Mental Health

Adolescence is a vulnerable developmental period associated with stressful transitions (Sturman & Moghaddam, 2011) and the onset of psychiatric disorders (Kessler et al., 2007). Therefore, the stress of a pandemic may increase the risk of mental health concerns within this age group (Guessoum et al., 2020). COVID-19 has resulted in many school closures to reduce the transmission of the virus (Viner et al., 2020). The absence of a structured school setting, disruption of

routine, reduced social interactions, and general uncertainty may have psychological implications (Singh et al., 2020). Increased levels of depression in the COVID-19-lockdown group were associated with factors, such as smartphone and internet addiction (Duan et al., 2020). With school closures, education strategies have transitioned to online environments. One study found that although some students were generally satisfied with online education, there was still a large proportion of students not comfortable with this form of learning (Ma et al., 2021). Adolescent studies from multiple countries have found an increased risk of self-reported psychological symptoms, such as depression, anxiety, and stress associated with COVID-19 and lockdown situations (Duan et al., 2020; Giannopoulou et al., 2021; Hafstad et al., 2021; Liang et al., 2020; Ma et al., 2021; Magson et al., 2021; Meda et al., 2021; Ravens-Sieberer et al., 2020; Rogers et al., 2021; Thorisdottir et al., 2021; Zhou et al., 2020). Poorer psychological outcomes were more prevalent in girls (Duan et al., 2020; Hafstad et al., 2021; Magson et al., 2021; Thorisdottir et al., 2021; Zhou et al., 2020). Overall, the current study was conducted to contribute further knowledge about the effects of this pandemic using self-reported experiences of COVID-19 and mental health implications in a cross-cultural cohort of adolescents.

Situating this Study in the Context of a Pandemic

It is important to situate the current research, as this cross-cultural study collected data from April to July of 2020, a few months after the WHO declared COVID-19 to be a pandemic on March 11th, 2020 (World Health Organisation, 2021b). Data were collected in the province of Quebec, Canada and North Queensland, Australia, as these locations were where ethical clearance was attained.

As transmissions increased, governments responded by enforcing restrictions, such as quarantines, social distancing, and mandatory mask-wearing to attempt to reduce transmissions and mortality rates (World Health Organisation, 2021a). These restrictions varied according to country. Therefore, the current research may provide some insight into the differences in COVID-19 experiences and psychological implications between Canadian and Australian adolescents.

As transmissions increased, governments responded by enforcing restrictions, such as quarantines, social distancing, and mandatory mask-wearing, to reduce transmissions and mortality rates (World Health Organisation, 2021a). These restrictions varied according to country. At the time of testing in the province of Quebec (Canada, April to July), there were approximately 5500 (April) to 59,000 (July) confirmed cases, with approximately 100 (April) to 5700 (July) deaths (population ≈ 8.5 million; Ministère de la Santé et des services sociaux, 2021). Conversely, in the state of Queensland (Australia), there had been a total of approximately 1100 confirmed cases and six deaths (population ≈ 5 million) (Queensland Government, 2021). Sanitary measures such as social distancing and hand sanitisation were endorsed, with a 14-day obligatory quarantine if returning from outside of the country (Gouvernement du Québec, 2021; Queensland Government, 2020). The main difference between the two countries was that in Canada, schools were closed, indoor/outdoor gatherings were forbidden, and non-essential businesses were closed (Gouvernement du Québec, 2021). In contrast, Australian schools and businesses were open (Queensland Government, 2020).

Overall, Canada appeared to be experiencing greater economic and education burdens because of COVID-19. School closure may have a significant effect on the mental health of Canadian adolescents. As such, this cross-cultural investigation aimed to explore the differences between Canada and Australia, as well as gender, in adolescent experiences and concerns related to COVID-19. It should be noted that gender identity, rather than biological sex, was explored, as biological sex was not confirmed via the self-report scales; instead, students were asked for their gender identity (boy, girl, other). A secondary objective was to investigate the differences between country and gender on mental health outcomes within the context of the pandemic. It was hypothesised that the Canadian adolescents would report greater concerns related to COVID-19 and poorer mental health outcomes. Consequently, it was also hypothesised that girls would report being more affected by COVID-19 and experiencing worse mental health outcomes than boys. Understanding, cross-cultural differences in adolescent worries and mental health during COVID-19 may inform stress management education and policies during this global stressor.

Method

Participants

Adolescents (*N* = 1326, 71% female) were aged between 13 and 18 years old (*M* = 15.36 years, *SD* = 1.23 years). To be eligible for inclusion in the current study, participants had to be enrolled in high school (approximately 12 to 18 years of age). Canadian students were recruited online from private and public high schools in the province of Quebec from April to July 2020. Australian participants were recruited, using convenience sampling, from a private high school in North Queensland in July 2020. All participants included in this study gave their informed consent. Parental consent was not required for Canadian participants above 14 years old. Parental consent was obtained for Australian students under 16 years of age. This study was conducted in accordance with the Declaration of Helsinki. The Australian study was approved by the James Cook University Human Research Ethics Committee on the 24th of July, 2019 (Ethics number: H7727). The Canadian study protocol was approved by the research ethics committee of the Centre intégré universitaire de santé et de services sociaux de l'Est de l'Île de Montréal on April 17th 2020 (Ethics number: 2019-1849).

Demographics and COVID-19 Questionnaire

Demographics including age, gender, socioeconomic status, ethnicity, and household size were collected. Participants were asked questions related to COVID-19 experiences, worries, and concerns after demographic information was collected. These questions formed a questionnaire but were not derived from validated scales, as, at the time of testing, there were no validated COVID-19 measures due to being in the early stages of the pandemic.

Psychological Scales

Stress

The Perceived Stress Scale for Children (PSS-C; White, 2014) is a 14-item measure of subjective stress, with scores ranging from 0 "never" to 3 "often". The sum of the items (0–39, item 1 is not included due to being a practice question) was calculated for the current

study. Higher scores indicate greater perceived stress levels in the past week (this deviates from the adult scale which examines perceived stress in the past month). The PSS-C was translated into French through double translation (two independent translations from English and French native speakers; see supplementary materials for a more detailed description of this process) by the research team of the Centre for Studies on Human Stress (CSHS). The internal consistency (Cronbach's alpha [α]) of this scale in the current study was α = 0.73 (Canada: α = 0.71 and Australia: α = 0.80). The Stress Mindset Measure—General (SMM-G; Crum et al., 2013) is a recently developed 8-item measure of stress mindsets; the lens through which individuals view the effects of stress (positive versus negative). Scores can range from 0 "strongly disagree" to 4 "strongly agree", with higher scores indicating more positive stress mindsets (scores 2+ fall on the more stress-is-enhancing spectrum and scores <2 fall on the more stress-is-debilitating spectrum). Mean scores for this scale were reported. A French version of the scale was developed for the Canadian sample, through double translation by the CSHS research team. The internal consistency of this scale was α = 0.78 (Canada: α = 0.82 and Australia: α = 0.67).

Anxiety

The Childhood Anxiety Sensitivity Index (CASI; Silverman et al., 1991), is an 18-item scale measuring an individual's sensitivity to anxiety or innate beliefs that anxiety can have harmful consequences. Scores range from 1 "not at all" to 3 "a lot". The sum of all the items was calculated (18 – 54), with higher scores suggesting an increased sensitivity to anxiety. A validated French version was used for the Canadian sample (Stassart & Etienne, 2014). The internal consistency of this scale was α = 0.87 (Canada: α = 0.86 and Australia: α = 0.91). The State-Trait Anxiety Inventory for Children– State Subscale (STAIC-S; Spielberger, 1973), is a 20-item measure of momentary anxiety, with scores ranging from 1 "very [emotion, e.g., *"worried"*]" to 3 "not [emotion, e.g., *worried*]". The sum of all items (20 – 60) was calculated, with higher scores suggesting increased levels of

momentary anxiety. The validated French version of this inventory was used in the Canadian sample (Turgeon & Chartrand, 2003). The internal consistency of this scale was α = 0.90, (Canada: α = 0.90 and Australia: α = 0.92). The Children's Test Anxiety Scale (CTAS; Wren & Benson, 2004), is a 25-item scale that measures the level of performance anxiety a participant might experience during a test. Scores can range from 1 "almost never" to 4 "almost always". The sum of all items (25 – 100) was calculated with higher scores indicating increased levels of test anxiety. The CTAS was translated into French through double translation by the CSHS research team. The internal consistency of this scale was α = 0.94 (Canada: α = 0.94 and Australia: α = 0.95).

Co-Rumination

The Co-Rumination Questionnaire (CRQ) is a short form (9-item) scale extracted by Arroyo (2013) of the original 27-item Co-Rumination Questionnaire (Rose, 2002), which measures how often a participant dwells on negative situations with their friends; for example, "We spend most of our time together talking about problems that my friend or I have". Scores can range from 1 "not true at all" to 5 "very true". The sum of all items (9 – 45) was calculated, with higher scores suggesting that participants engaged in a greater amount of co-rumination with their friends. The CRQ was translated into French through double translation by the CSHS research team. The internal consistency of this scale was α = 0.88 (Canada: α = 0.87 and Australia: α = 0.91).

Depression

The Beck Depression Inventory-II (BDI-II; Beck et al., 1996) is a 21-item scale that was used, after modification based on the French BDI (Bourque & Beaudette, 1982), to assess the intensity and severity of depressive symptomatology in the Canadian sample. This scale has four responses corresponding to a score between 0 and 3 indicating the severity of the symptom. Higher scores indicate greater depression severity. The internal consistency of this scale was α = 0.91 for the Canadian sample. The Patient Health Questionnaire-9 for Adolescents (PHQ-9A; Kroenke et al., 2001, adapted for youth by Johnson et al., 2002), is a 9-item scale that was used to measure depression severity within the Australian sample. Scores can range from 0 "not at all" to 3 "nearly every day", with

higher scores suggesting that the participant may be experiencing a greater number of depression symptoms. The internal consistency of this scale was $\alpha = 0.90$ for the Australian sample.

Procedure

The data used in this between-subjects cross-sectional investigation were collected at baseline (Canada: April to June 2020 and Australia: July 2020) before the implementation of a stress mindset intervention designed to promote stress-is-enhancing mindsets. These baseline data were collected using an online survey via the Qualtrics platform (Qualtrics, Provo, UT, USA; July 2020 version). The online survey consisted of demographic questions, the COVID-19 questionnaire, and randomised validated self-report scales. Participants spent approximately 30 min completing this survey. The Canadian study was completed in French, while the Australian study was completed in English. It is important to disclose that the protocol used in the current study was adapted from Journault and Lupien (2020) and a detailed description of the original protocol can be found at https://osf.io/u4cmf

Statistical Analyses

Analyses were conducted using Statistical Package for the Social Sciences (SPSS v25). Normality was assumed based on the sufficient sample size ($N = 1326$) and acceptable skewness and kurtosis ranges (scores within +2/-2 and +7/-7; Byrne, 2010; Hair et al., 2010), and a visual inspection of quantile-quantile (Q-Q) plots. Missing cases included outliers (only cases outside of scale limits were removed as outliers [$n = 5$]) and incomplete survey responses. The independent variables in this investigation were country (Canada and Australia) and gender (boys and girls). Descriptive statistics are presented as the means and 95% confidence intervals (*CI*). For the COVID-19 questionnaire, continuous data were analysed using a 2 (country) x 2 (gender) analysis of variance (ANOVA) model. Multivariate ANOVAs (MANOVAs) were used to assess questions that had more than one continuous outcome. Effect sizes for the MANOVAs were reported as partial eta squared (η_p^2) and based on interpretations provided by Cohen (1988; 2013): 0.02 (small effect), 0.06 (moderate effect), and 0.14 (large effect). Chi-squared (χ^2) tests were performed for categorical variables. Corresponding effect

sizes were reported as Goodman and Kruskal's tau (τ) and Cramer's V and based on interpretations reported by Kim (2017). Bonferroni-adjusted simple effects for the categorical variables were performed using Z-tests. For the psychological scales, 2 (country) x 2 (gender) ANOVAs were used to investigate the main effects and interaction effects. Bonferroni-adjusted simple effects analyses were performed for significant interaction effects with Cohen's *d* reported for effect size (Cohen, 1988; 2013). The scales used to measure depression severity were transformed into z-scores to compare differences between countries using the two different depression scales (BDI-II and PHQ9-A). Differences were considered significant for all analyses at $p < .05$. An exploratory inter-item analysis was conducted on the PSS-C scale items, using independent samples *t*-tests, with *p*-values of < .01 indicating significance due to multiple comparisons.

Results

Sample Characteristics

The Canadian sample consisted of 913 French-speaking students (78% female) from both private and public high schools in Quebec, Canada (M_{age} = 15.41 years, SD_{age} = 1.08). The Australian sample consisted of 413 English-speaking students (57% female) from a private high school in Queensland, Australia (M_{age} = 15.24 years, SD_{age} = 1.50). The Canadian sample identified mostly as white/Caucasian (65%). The remainder of the sample identified as 6% multiracial/other, 3% Asian origin, 3% Middle Eastern or North African, 1.8% Caribbean origin, 1.4% Black origin, 1% Central and Southern America, and 0.3% First Nations. Similarly, the Australian sample identified mostly as white/Caucasian (70%). The remainder of the sample identified as 15% Asian, 12% multiracial/other, 1% African, and 1% Australian Aboriginal or Torres Strait Islander. Both samples reported being from predominantly "quite comfortable" financial backgrounds (Canada: 51%, Australia: 48%) and living with approximately 5 people in their household at the time of testing.

COVID-19 Questionnaire

See Table S8 for the descriptive statistics related to the COVID-19 questionnaire.

Frequency and Impact of Symptoms Resembling COVID-19

Australian adolescents reported experiencing significantly more physical symptoms resembling COVID-19 compared to Canadian adolescents ($F_{(1, 1285)} = 13.226$, $p < .001$, $\eta_p^2 = .010$, small effect). Girls reported experiencing COVID-19-like symptoms significantly more than boys ($F_{(1, 1285)} = 4.143$, $p = .042$, $\eta_p^2 = .003$, small effect). There was no significant interaction effect between countries and gender ($p > .05$) on frequency of symptoms. Girls reported that the COVID-19-like symptoms they experienced had affected their life significantly more compared to boys ($F_{(1, 784)} = 4.565$, $p = .033$, $\eta_p^2 = .006$, small effect). However, there was no significant interaction effect between countries and gender ($p > .05$) on the impact of symptoms.

COVID-19 Discussions

Canadian adolescents were significantly more likely to discuss COVID-19 compared to Australian adolescents ($\chi^2_{(4, N = 1300)} = 69.839$, $p < .001$, two-tailed, $V = .232$, medium effect, $\tau = .054$). In general, girls were significantly more likely to discuss COVID-19 more than boys ($\chi^2_{(4, N = 1300)} = 36.263$, $p < .001$, two-tailed, $V = .167$, medium effect, $\tau = 0.028$). Bonferroni-adjusted *Z*-tests found that Canadian girls were significantly more likely to discuss COVID-19 approximately 2 to 5 times per day ($p < .05$). In contrast, Canadian boys were significantly more likely to only discuss COVID-19 a few times a week ($p < .05$).

Media Use

Canadian adolescents were significantly more likely to report following the news about COVID-19 than Australian adolescents ($\chi^2_{(1, N = 1291)} = 22.958$, $p < .001$, two-tailed, $V = .133$, small effect, $\tau = 0.018$). Girls in general were significantly more likely to report following the news about COVID-19 compared to boys ($\chi^2_{(1, N = 1291)} = 25.867$, $p < .001$, two-tailed, $V = .142$, small effect, $\tau = 0.020$). Bonferroni-adjusted *Z*-tests found that Canadian girls were significantly more likely to follow the news about COVID-19 ($p < .05$). Canadian adolescents reported consulting traditional media for news (e.g. newspaper, television, or radio) significantly more than Australian adolescents ($F_{(1, 1230)} = 17.355$, $p < .001$, $\eta_p^2 = .014$, small effect). Girls reported consulting traditional ($F_{(1, 1230)} = 6.007$, $p = .014$, $\eta_p^2 = .005$, small effect) and social media ($F_{(1, 1230)} = 8.739$, $p = .003$, $\eta_p^2 = .007$, small effect) for

news significantly more than boys. There was no significant difference between countries and genders in how often participants consulted online websites for news ($p > .05$).

Stress and Concerns Related to COVID-19

Canadian adolescents reported experiencing significantly more stress before COVID-19 ($F_{(1, 1278)} = 17.465$, $p < .001$, $\eta_p^2 = .013$, small effect), at the time of testing ($F_{(1, 1278)} = 10.427$, $p = .001$, $\eta_p^2 = .008$, small effect), and related to COVID-19 ($F_{(1, 1278)} = 201.893$, $p < .001$, $\eta_p^2 = .136$, medium effect) than Australian adolescents. Further, girls in both samples reported experiencing significantly more stress before COVID-19 ($F_{(1, 1278)} = 132.496$, $p < .001$, $\eta_p^2 = .094$, medium effect), at the time of testing ($F_{(1, 1278)} = 110.931$, $p < .001$, $\eta_p^2 = .080$, small effect), and related to COVID-19 ($F_{(1, 1278)} = 14.456$, $p < .001$, $\eta_p^2 = .011$, small effect) compared to boys. There were no significant interaction effects for any of these variables ($p > .05$). A repeated samples ANOVA (country x time) found no significant difference between reported stress levels prior to COVID-19 and at the time of testing for both countries ($F_{(1, 1280)} = 3.710$, $p = .054$, $\eta_p^2 = .003$, small effect).

Canadian adolescents reported experiencing significantly more concern about their personal health ($F_{(1, 1280)} = 9.959$, $p = .002$, $\eta_p^2 = .008$, small effect), the health of their parents ($F_{(1, 1280)} = 40.487$, $p < .001$, $\eta_p^2 = .031$, small effect), and the health of a loved one ($F_{(1, 1280)} = 36.501$, $p < .001$, $\eta_p^2 = .028$, small effect) compared to Australian adolescents. Canadian adolescents were significantly more concerned about the continuation of the school year ($F_{(1, 1280)} = 138.906$, $p < .001$, $\eta_p^2 = .098$, medium effect) compared to Australian adolescents. However, there was no significant country differences in concerns about personal/parental job security ($p > .05$) or access to items ($p > .05$). Girls reported experiencing significantly more concern about their personal health ($F_{(1, 1280)} = 27.188$, $p < .001$, $\eta_p^2 = .021$, small effect), the health of their parents ($F_{(1, 1280)} = 8.158$, $p = .004$, $\eta_p^2 = .006$, small effect), and the health of a loved one ($F_{(1, 1280)} = 18.800$, $p < .001$, $\eta_p^2 = .014$, small effect) compared to boys. Girls were also significantly more concerned about the continuation of the school year ($F_{(1, 1280)} = 58.109$, $p < .001$, $\eta_p^2 = .043$, small effect), personal/parental job security ($F_{(1, 1280)} = 16.225$, $p < .001$, $\eta_p^2 = .013$, small effect), and accessibility of items ($F_{(1, 1280)} = 15.618$, $p < .001$, $\eta_p^2 = .012$, small effect) than boys.

However, there were no significant interaction effects between country and gender for any of these variables ($p > .05$).

Adolescent Mental Health in the Context of COVID-19

See Table 14 for the descriptive statistics related to the mental health outcomes and Table S9 in the Supplementary Materials for the inferential statistics.

Table 14

Mean (95% CI) for Psychological Scales Stratified by Country and Gender

Variable	Canada (*N*=913)		Australia (*N*=413)		Country p-value	Gender p-value
	Boys (*n* = 198)	Girls (*n* = 708)	Boys (*n* = 172)	Girls (*n* = 234)		
PSS-C	12.21 (11.32, 13.11)	15.39 (14.93, 15. 85)	13.94 (12.93, 14.95)	16.13 (15.28, 16.98)	**.004**	**<.001**
N (Missing)	*178 (20)*	*667 (41)*	*140 (32)*	*198 (36)*		
SMM-G	1.61 (1.52, 1.70)	1.54 (1.50, 1.59)	1.81 (1.70, 1.92)	1.75 (1.66, 1.84)	**<.001**	.167
N (Missing)	*197 (1)*	*689 (19)*	*141 (31)*	*202 (32)*		
CASI	27.51 (26.54, 28.49)	32.79 (32.27, 33.30)	28.05 (26.92, 29.18)	33.75 (32.78, 34.71)	.113	**<.001**
N (Missing)	*192 (6)*	*691 (17)*	*144 (28)*	*198 (36)*		
STAIC-S	32.36 (31.38, 33.34)	36.22 (35.71, 36.73)	32.07 (30.94, 33.20)	35.30 (34.36, 36.25)	.200	**<.001**
N (Missing)	*188 (10)*	*682 (26)*	*140 (32)*	*201 (33)*		
CTAS	50.37 (47.90, 52.83)	58.93 (57.66, 60.21)	52.15 (49.45, 54.85)	64.04 (61.75, 66.33)	**.003**	**<.001**
N (Missing)	*169 (29)*	*631 (77)*	*141 (31)*	*196 (38)*		
CRQ	26.68 (25.55, 27.82)	29.69 (29.12, 30.27)	23.73 (22.45, 24.98)	29.94 (28.89, 30.98)	**.010**	**<.001**
N (Missing)	*170 (28)*	*647 (61)*	*139 (33)*	*200 (34)*		
Depression Z Scores (BDI-II, PHQ9-A)	-0.43 (-0.57, -0.28)	0.11 (0.04, 0.19)	-0.35 (0.51, -0.19)	0.24 (0.10, 0.37)	.141	**<.001**
N (Missing)	*173 (25)*	*652 (56)*	*137 (35)*	*203 (31)*		

Note. Continuous data are presented at *M* ± 95% *CI. N/n* = sample size. (*Missing*) = number of missing cases. Bold p-values indicate a statistically significant outcome.

Stress

Australian adolescents reported experiencing significantly more perceived stress compared to Canadian adolescents ($F_{(1, 1179)} = 8.438$, $p = .004$, $\eta_p^2 = .007$, small effect). Further, girls in both samples reported experiencing significantly more perceived stress compared to boys ($F_{(1, 1179)} = 40.105$, $p < .001$, $\eta_p^2 = .033$, small effect). There was no significant interaction between country and gender on the PSS-C ($p > .05$). Canadian adolescents reported significantly more stress-is-debilitating mindsets compared to the Australian adolescents ($F_{(1, 1225)} = 19.789$, $p < .001$, $\eta_p^2 = .016$, small effect).

There were no significant effects for gender ($p > .05$) or the interaction between country and genders ($p > .05$) on the SMM-G.

Anxiety

Australian adolescents reported experiencing significantly more test anxiety compared to Canadian adolescents ($F_{(1, 1133)} = 9.057$, $p = .003$, $\eta_p^2 = .008$, small effect). Girls reported being significantly more sensitive to anxiety ($F_{(1, 1222)} = 135.327$, $p < .001$, $\eta_p^2 = .100$, medium effect), as well as experiencing significantly more state anxiety ($F_{(1, 1207)} = 57.198$, $p < .001$, $\eta_p^2 = .045$, small effect) and test anxiety ($F_{(1, 1133)} = 79.811$, $p < .001$, $\eta_p^2 = .066$, medium effect) compared to boys. There were no other significant effects for country in state anxiety or the interaction between country and genders for both test and state anxiety ($p > .05$).

Co-Rumination

Canadian adolescents reported co-ruminating with others significantly more than Australian adolescents ($F_{(1, 1152)} = 6.616$, $p = .010$, $\eta_p^2 = .006$, small effect). Girls reported co-ruminating significantly more than boys ($F_{(1, 1152)} = 76.420$, $p < .001$, $\eta_p^2 = .062$, medium effect). There was a significant interaction between country and gender ($F_{(1, 1152)} = 9.208$, $p = .002$, $\eta_p^2 = .008$, small effect). Canadian boys reported engaging in co-rumination significantly more compared to Australian boys ($p = .001$, $d = 0.36$, small effect).

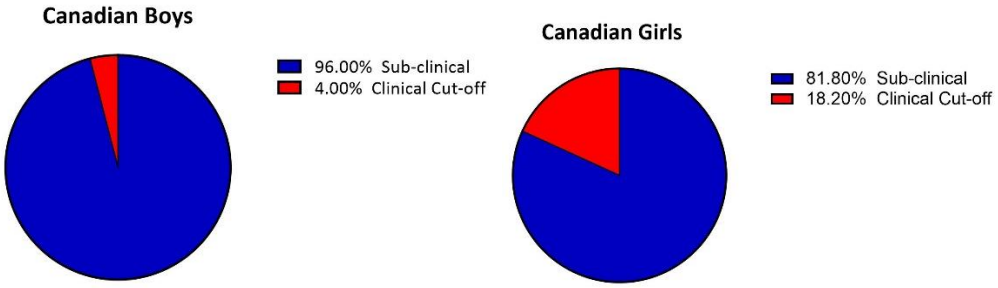
Depression

Girls showed significantly more signs of depression compared to boys ($F_{(1, 1161)} = 68.834$, $p < .001$, $\eta_p^2 = .056$, small effect). There were no other significant effects between country and gender ($p > .05$) on the *z*-scored depression scales. The percentage of students scoring above the clinical cut-off scores is illustrated in pie charts in Figure 15.

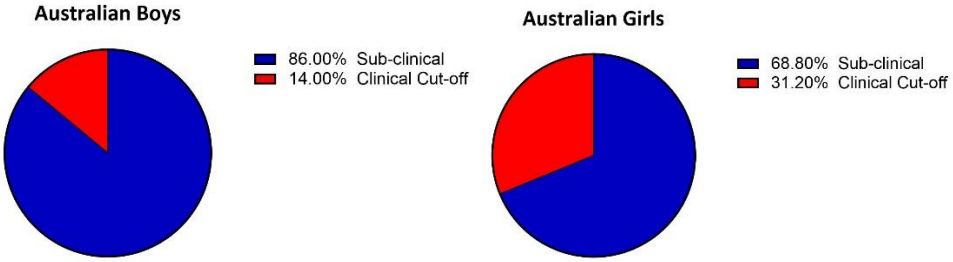
Figure 15

Depression Severity of Adolescents Stratified by Gender

A



B



Note. **A)** Percentage (%) of Canadian boys and girls in the current study scoring equal to or above the clinical cut-off score of 23 (Dolle et al., 2012) on the BDI-II. **B)** Percentage (%) of Australian boys and girls in the current study scoring equal to or above the clinical cut-off score of 11 (Richardson et al., 2010) on the PHQ9-A.

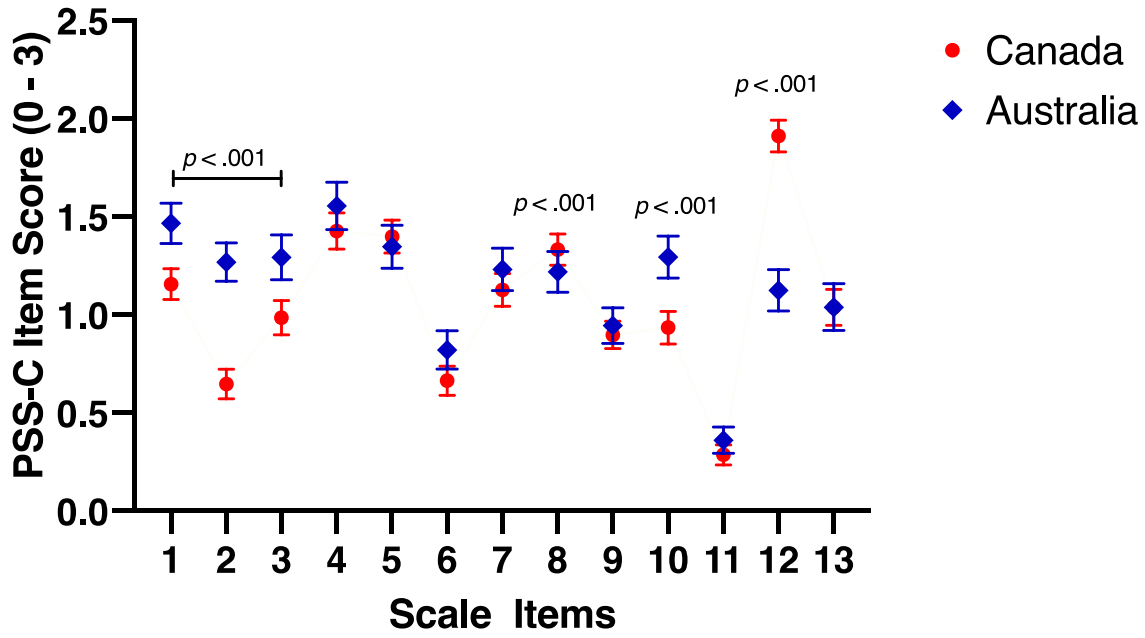
Exploratory Inter-Item Analysis on Perceived Stress

Based on the discrepancy between countries on reported levels of stress within the COVID-19 implementation variables and the PSS-C, additional exploratory analyses were conducted on the PSS-C to further examine the scale items (see Table S10 for scale items and descriptive statistics). Australian adolescents felt significantly more rushed/hurried ($t_{(1185)} = -4.136$, $p < .001$, $d = .27$, small effect), that they did not have enough time to do what they wanted ($t_{(1185)} = -10.354$, $p < .001$, $d = .66$, medium effect), were worried about being too busy ($t_{(1185)} = -4.069$, $p < .001$, $d = .26$, small effect), and did not feel that they were getting enough sleep ($t_{(1183)} = -4.793$, $p < .001$, $d = .31$, small

effect) compared to Canadian adolescents. In contrast, Canadian adolescents reported being significantly more angry ($t_{(1183)}$ = 3.374, p = .001 , d = .22, small effect) and not being able to spend time with their friends ($t_{(1183)}$ = 15.372, p < .001 , d = .99, large effect) compared to Australian adolescents. See Figure 16 for the differences between scale items.

Figure 16

Inter-item Analysis of the PSS-C



Note. Mean (95% *CI*) differences between countries on the PSS-C scale items.

Discussion

This cross-cultural investigation aimed to explore adolescent experiences and concerns related to COVID-19 between countries and gender. A secondary objective was to investigate the differences between country and gender on mental health outcomes within the context of the pandemic.

The hypothesis that adolescents from Canada would report being more affected by the pandemic circumstances and have worse psychological outcomes compared to the Australian adolescents was partially supported. Canadian adolescents did engage in more discussions about COVID-19 and followed the news, particularly traditional media, more than Australian adolescents.

Canadian adolescents also reported experiencing more stress at the time of testing, before COVID-19, and as a consequence of COVID-19 compared to Australian adolescents. Finally, Canadian adolescents reported more concerns about health (personal, parental, and loved ones) and the continuation of the school year, suggesting that the Canadian sample was experiencing more worries and concerns associated with COVID-19. This may have been the result of the stricter lockdown conditions in Canada. Lockdown conditions have been associated with increased concerns and negative mental health trajectories (Elmer et al., 2020; Giannopoulou et al., 2021; Guessoum et al., 2020; Meda et al., 2021; Singh et al., 2020). Unlike Australia, which is an island nation, Canadian adolescents may have also been reporting greater COVID-19 effects, as a result of sharing land boundaries with the United States of America, a country experiencing rising rates of transmission (Dong et al., 2020). Further, increased media consumption of COVID-19-related information was associated with increased worry, but, in turn, more preventative behaviours (Liu, 2020). Therefore, increased concerns and worries in the Canadian sample could be associated with their increased media consumption.

Conversely, the Australian sample reported experiencing significantly more physical symptoms resembling COVID-19, compared to Canada at the time of testing. This finding could be associated with seasonal differences at the time of testing or the increased media consumption prompting more preventative hygiene practices in the Canadian sample (Liu, 2020). Interestingly, adolescents from both countries perceived no difference in their stress levels before COVID-19 and at the time of testing. Although this could be a sign of stress resilience (e.g., acceptance or growth under stress) or difficulty introspecting stress levels from the past, it would be worth comparing more objective and physiological measures of stress from before COVID-19 to now, rather than just relying on these subjective reports.

Although Canadian adolescents reported experiencing more stress at the time of testing on the COVID-19 questionnaire, Australian adolescents reported more perceived stress on the PSS-C. It is unclear why I found contradictory findings and although it may be due to the psychometric

difference between validated psychological measures compared to a simple questionnaire, it could also be associated with the novel pandemic circumstances or the month of testing. Australian adolescents were tested in July, four months after the pandemic was declared, compared to Canadian adolescents who were tested a month after the announcement. The PSS-C contains several questions that may not be particularly relevant to adolescents experiencing strict COVID-19 restrictions (e.g., time spent playing with friends). Australian adolescents felt significantly more rushed/hurried, that they did not have enough time to do what they wanted, were worried about being too busy, and did not feel that they were getting enough sleep compared to Canadian adolescents. Canadian adolescents reported being significantly angrier and there was also a large difference in the lack of time spent with friends than Australian adolescents. These responses could be associated with the fact that Australian adolescents were at school full-time, whereas, Canadian adolescents were in lockdown, not at school, and with very limited face-to-face contact with friends. Similarly, Australian adolescents reported experiencing more test anxiety, which again could be associated with the school environment. From 2020 to 2021, the MyStrengths Youth Mental Health Survey found that schoolwork was the biggest stressor for Australian high school students (McCrindle, 2021), which may align with the increased perceived stress and test anxiety in Australian adolescents. However, the novel COVID-19-related school closures may explain the reports of increased worries, anger, and lack of time spent with friends within the Canadian sample report, as the absence of a structured school setting, disruption of routine, reduced social interactions, and general uncertainty may still have psychological implications (Singh et al., 2020). Further, online learning may not be appropriate for some students, as it has been previously reported that some do not find this type of learning effective (Ma et al., 2021).

Finally, Canadian adolescents reported viewing stress as more debilitating and were co-ruminating more with friends than Australian adolescents. Having a more stress-is-debilitating mindset may be associated with less proactive coping strategies (e.g., ruminating, withdrawal, and avoidance) (Crum et al., 2013). The increased co-rumination in Canadian adolescents aligns with the

more frequent discussions about COVID-19 reported earlier. Although school closure may have limited face-to-face contact with peers, online environments offer novel avenues for social connectedness (Kennedy & Lynch, 2016). Overuse of online media and communication can be linked to poor mental health outcomes, increased co-rumination, online bullying, social isolation, and the spread of misinformation (Duan et al., 2020; Kennedy & Lynch, 2016). Therefore, it may be worth considering the time adolescents spend in online environments, as a potential health-risk behaviour in future investigations.

The hypothesis that the effect of COVID-19 would be greater in girls was supported. Girls reported more discussions about COVID-19 and following the news, particularly traditional and social media. They also reported experiencing more symptoms and felt that these symptoms had a bigger impact compared to boys. Girls reported more subjective stress before, during, and related to COVID-19 than boys. Further, girls were more concerned about health, school continuation, personal/parental job security, and item accessibility. Finally, the hypothesis that girls would be experiencing poorer mental health outcomes compared to boys was supported. Girls reported experiencing more perceived stress, anxiety sensitivity, state anxiety, test anxiety, co-rumination, and depression symptoms. Greater effect sizes were also consistently observed for girls in self-assessed COVID-19 experiences and the psychological outcomes, particularly anxiety sensitivity. This finding is consistent with the increased risk of depression, anxiety, and co-rumination symptoms seen in girls during adolescence (Petersen et al., 1991; Jose et al., 2012).

Although the causes are likely multifaceted, the experience of more stressors and pubertal changes early during adolescence may be associated with this difference between girls and boys (Petersen et al., 1991). It could also be associated with socialisation or gender roles during child-rearing stages, where girls are encouraged to disclose their feelings and consequently answer accordingly on psychological scales assessing mental health (Carter et al., 2011). In contrast, boys may be discouraged from sharing their feelings, as it does not align with traditional masculine gender roles and often experience externalising symptoms such as aggression (Carter et al., 2011). Closeness

with parents appeared to moderate the long-term effects of these challenges (Petersen et al., 1991). There is further evidence to suggest that this gender difference persists during COVID-19 (Duan et al., 2020; Hafstad et al., 2021; Magson et al., 2021; Thorisdottir et al., 2021; Zhou et al., 2020). Adolescent girls also appear to experience more self-assessed health concerns in combination with psychological morbidity (MacLean et al., 2013), which could explain the increased frequency and impact of reported COVID-19-related symptoms in the current study. Therefore, girls report more concerns related to COVID-19 and internalising mental health symptoms, which should be considered in COVID-19-related mental health policies or interventions. However, this should not exclude boys from consideration in policies, as the current study measures may not have captured externalising symptoms of mental health challenges, such as aggression. Future research is warranted to explore the association between gender roles and psychological outcomes during COVID-19.

Limitations

This study was limited by the use of self-report measures, which can sometimes result in biases, such as socially desirable answers or difficulty with introspection (Rosenman et al., 2011), which could explain our contradictory findings on perceived stress. Further, the COVID-19 questionnaire was not a validated scale. Although significant, the majority of the reported differences were only small in size, particularly when investigating country differences. Due to the cross-sectional design, we are unable to establish causation. Therefore, pre-COVID-19 data would be critical to fully determine whether COVID-19 has harmed mental health and wellbeing during adolescence. It is possible that due to the higher proportion of females in the Canadian sample, the differences between countries may also be confounded by female-related mental health risks. A limitation of the Australian sample was that the participants were recruited from a single private school rather than the multiple sites as in the Canadian sample. The diversity of both the Canadian and Australian samples was limited, with most students identifying as Caucasian and financially “quite comfortable”. Finally, differences in language may have also played a role in the differences in responses between countries.

Conclusion

In summary, compared to males, female adolescents from Australia and Canada reported more symptoms of stress, anxiety, and depression during the first months of the COVID-19 pandemic and reported more personal concerns and worries associated with the pandemic. Mental health responses during the pandemic should consider this significant gender difference and the effect of gender roles when developing stress management programs, as girls and boys may experience different responses to certain stressors. Disrupting school and peer interactions could be associated with the increased concerns about the continuation of the school year and being able to spend time with friends in the Canadian sample, compared to the Australian sample who remained at school. Further investigations examining changes before and after COVID-19, as well as scale appropriateness within the pandemic context, are necessary to fully understand the consequences of COVID-19 during adolescence.

Conflict of Interest

The authors declare that they have no competing interests.

Authors' Contributions

The protocol for the studies was developed by A.-A.J., S.L. and R.C. at the CSHS. Conceptualization, A.-A.J., S.L. and R.C.; methodology, A.-A.J., S.L., R.C. and R.M.; formal analysis, R.M. and A.-A.J.; investigation, R.M., A.-A.J., R.C. and P.W.; writing—original draft preparation, R.M.; writing—review and editing, R.M., A.-A.J., R.C., J.V.M., S.L., B.M. and Z.S.; supervision, J.V.M., S.L., B.M. and Z.S.; project administration, R.M., A.-A.J., R.C. and P.W. All authors have read and agreed to the published version of the manuscript.

Funding

The Australian Government Research Training Program Scholarship and College of Medicine and Dentistry Top-up Scholarship supported the Australian arm of this study. The Canadian study was supported by a Foundation Grant from the Canadian Institute for Health Research to S.L. and by a doctoral studentship from the Fonds de recherche en Santé du Québec to A.-A.J. The work of S.L. is supported by a Canada Research Chair on Human Stress. The work of R.C. was supported by a master's scholarship from the Canadian Institutes of Health Research.

Open Practices Statement

The Canadian study was formally pre-registered: https://osf.io/u4cmf, accessed on 7 February 2022. However, the Australian experiment reported in this article was not formally pre-registered. Neither the data nor the materials for the Australian study have been made available on a permanent third-party archive and cannot be shared, as although informed consent was attained for general de-identified summaries, the participants were not asked for consent to share their individual data points in open-access datasets.

Acknowledgments

The authors would like to express their thanks to the students, families, and teachers who generously gave their time to this project. The authors would like to acknowledge James Cook

University (Australian Institute of Tropical Health and Medicine and the College of Medicine and Dentistry) for their facilities and the guidance of staff members. This includes Emeritus Professor Rhondda Jones, Professor Sarah Larkins, Professor Cate Nagle, and Helen Griffiths for their ethical and methodological guidance. Finally, the authors would like to acknowledge the significant assistance of Sandrine Charbonneau who aided in the development of the French versions of the Destination: Brain and Stress N' Go intervention videos.

References

Ahmed, M. Z., Ahmed, O., Aibao, Z., Hanbin, S., Siyu, L., & Ahmad, A. (2020). Epidemic of COVID-19 in China and associated psychological problems. *Asian journal of psychiatry*, *51*, 102092-102092. https://doi.org/10.1016/j.ajp.2020.102092

Arroyo, A. (2013). *Fat talk among female friends: Do friends' responses buffer the relationship between fat talk and health-related outcomes?* [Dissertation, The University of Arizona]. UA Campus Repository. https://repository.arizona.edu/handle/10150/297031

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Beck depression inventory (BDI-II)* (Vol. 10). Pearson.

Bell, G. (2021). Pandemic Passages: An anthropological account of life and liminality during COVID-19. *Anthropology in Action*, *28*(1), 79-84. https://doi.org/10.3167/aia.2021.280115

Bourque, P., & Beaudette, D. (1982). Étude psychometrique du questionnaire de dépression de Beck auprès d'un échantillon d'étudiants universitaires francophones [Psychometric study of the Beck Depression Inventory on a sample of French-speaking university students]. *Canadian Journal of Behavioural Science / Revue canadienne des sciences du comportement*, *14*(3), 211–218. https://doi.org/10.1037/h0081254

Brooks, S. K., Webster, R. K., Smith, L. E., Woodland, L., Wessely, S., Greenberg, N., & Rubin, G. J. (2020). The psychological impact of quarantine and how to reduce it: Rapid review of the evidence. *Lancet*, *395*(10227), 912-920. https://doi.org/10.1016/S0140-6736(20)30460-8

Byrne, B. M. (2010). *Structural equation modeling with AMOS: Basic concepts, applications, and programming* (2nd Edition). In: New York: Routledge. https://doi.org/10.4324/9781315757421

Callaway, E., Cyranoski, D., Mallapaty, S., Stoye, E., & Tollefson, J. (2020). *The coronavirus pandemic in five powerful charts.* In: Nature Publishing Group.

Carter, R., Silverman, W. K., & Jaccard, J. (2011). Sex variations in youth anxiety symptoms: Effects of pubertal development and gender role orientation. *Journal of Clinical Child & Adolescent Psychology*, *40*(5), 730-741. https://doi.org/10.1080/15374416.2011.597082

Cohen, J. (1988; 2013). *Statistical power analysis for the behavioral sciences*. Academic Press.

Crum, A. J., Salovey, P., & Achor, S. (2013). Rethinking stress: the role of mindsets in determining the stress response. *Journal of Personality and Social Psychology*, *104*(4), 716-733. https://doi.org/10.1037/a0031201

Dolle, K., Schulte-Körne, G., O'Leary, A. M., von Hofacker, N., Izat, Y., & Allgaier, A.-K. (2012). The Beck Depression Inventory-II in adolescent mental health patients: Cut-off scores for detecting depression and rating severity. *Psychiatry Research*, *200*(2), 843-848. https://doi.org/10.1016/j.psychres.2012.05.011

Dong, E., Du, H., & Gardner, L. (2020). An interactive web-based dashboard to track COVID-19 in real time. *The Lancet Infectious Diseases*, *20*(5), 533-534. https://doi.org/10.1016/S1473-3099(20)30120-1

Dong, F., Liu, H.-L., Dai, N., Yang, M., & Liu, J.-P. (2021). A living systematic review of the psychological problems in people suffering from COVID-19. *Journal of Affective Disorders*, *292*, 172-188. https://doi.org/10.1016/j.jad.2021.05.060

Duan, L., Shao, X., Wang, Y., Huang, Y., Miao, J., Yang, X., & Zhu, G. (2020). An investigation of mental health status of children and adolescents in china during the outbreak of COVID-19. *Journal of Affective Disorders*, *275*, 112-118. https://doi.org/10.1016/j.jad.2020.06.029

Elmer, T., Mepham, K., & Stadtfeld, C. (2020). Students under lockdown: Comparisons of students' social networks and mental health before and during the COVID-19 crisis in Switzerland. *PLOS One*, *15*(7), e0236337. https://doi.org/10.1371/journal.pone.0236337

Giannopoulou, I., Efstathiou, V., Triantafyllou, G., Korkoliakou, P., & Douzenis, A. (2021). Adding stress to the stressed: Senior high school students' mental health amidst the COVID-19 nationwide lockdown in Greece. *Psychiatry Research*, *295*, 113560-113560. https://doi.org/10.1016/j.psychres.2020.113560

Gouvernement du Québec. (2021). *List of all infographics related to the Prime Minister's announcements (COVID-19)*. https://www.quebec.ca/en/premier/premier/access-to-

publications-related-to-the-premiers-announcements-concerning-covid-19/liste-de-toutes-les-infographies-en-lien-avec-les-annonces-du-premier-ministre-covid-19

Guessoum, S. B., Lachal, J., Radjack, R., Carretier, E., Minassian, S., Benoit, L., & Moro, M. R. (2020). Adolescent psychiatric disorders during the COVID-19 pandemic and lockdown. *Psychiatry Research*, *291*, 113264-113264. https://doi.org/10.1016/j.psychres.2020.113264

Hafstad, G. S., Sætren, S. S., Wentzel-Larsen, T., & Augusti, E.-M. (2021). Adolescents' symptoms of anxiety and depression before and during the Covid-19 outbreak – A prospective population-based study of teenagers in Norway. *The Lancet Regional Health*, *5*, 100093. https://doi.org/10.1016/j.lanepe.2021.100093

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis: International version.* New Jersey, Pearson.

Johnson, J. G., Harris, E. S., Spitzer, R. L., & Williams, J. B. (2002). The patient health questionnaire for adolescents: validation of an instrument for the assessment of mental disorders among adolescent primary care patients. *Journal of Adolescent Health*, *30*(3), 196-204. https://doi.org/10.1016/s1054-139x(01)00333-0

Jose, P. E., Wilkins, H., & Spendelow, J. S. (2012). Does social anxiety predict rumination and co-rumination among adolescents? *Journal of Clinical Child & Adolescent Psychology*, *41*(1), 86-91. https://doi.org/10.1080/15374416.2012.632346

Journault, A., & Lupien, S. (2020). *Addendum to MATA's study: Stress mindset intervention*. https://doi.org/10.17605/OSF.IO/U4CMF

Kennedy, J., & Lynch, H. (2016). A shift from offline to online: Adolescence, the internet and social participation. *Journal of Occupational Science*, *23*(2), 156-167. https://doi.org/10.1080/14427591.2015.1117523

Kessler, R. C., Amminger, G. P., Aguilar-Gaxiola, S., Alonso, J., Lee, S., & Ustün, T. B. (2007). Age of onset of mental disorders: a review of recent literature. *Current Opinion in Psychiatry*, *20*(4), 359–364. https://doi.org/10.1097/YCO.0b013e32816ebc8c

Kim, H.-Y. (2017). Statistical notes for clinical researchers: Chi-squared test and Fisher's exact test. *Restorative Dentistry & Endodontics*, *42*(2), 152-155. https://doi.org/10.5395/rde.2017.42.2.152

Kroenke, K., Spitzer, R. L., & Williams, J. B. W. (2001). The PHQ-9: Validity of a brief depression severity measure. *Journal of General Internal Medicine*, *16*(9), 606-613. https://doi.org/10.1046/j.1525-1497.2001.016009606.x

Kumar, A., & Nayar, K. R. (2021). COVID 19 and its mental health consequences. *Journal of Mental Health*, *30*(1), 1-2. https://doi.org/10.1080/09638237.2020.1757052

Liang, L., Ren, H., Cao, R., Hu, Y., Qin, Z., Li, C., & Mei, S. (2020). The effect of COVID-19 on youth mental health. *Psychiatric Quarterly*, *91*(3), 841-852. https://doi.org/10.1007/s11126-020-09744-3

Liu, P. L. (2020). COVID-19 information seeking on digital media and preventive behaviors: The mediation role of worry. *Cyberpsychology, Behavior, and Social Networking*, *23*(10), 677-682. https://doi.org/10.1089/cyber.2020.0250

Ma, Z., Idris, S., Zhang, Y., Zewen, L., Wali, A., Ji, Y., Pan, Q., & Baloch, Z. (2021). The impact of COVID-19 pandemic outbreak on education and mental health of Chinese children aged 7-15 years: an online survey. *BMC pediatrics*, *21*(1), 95-95. https://doi.org/10.1186/s12887-021-02550-1

MacLean, A., Sweeting, H., Egan, M., Der, G., Adamson, J., & Hunt, K. (2013). How robust is the evidence of an emerging or increasing female excess in physical morbidity between childhood and adolescence? Results of a systematic literature review and meta-analyses. *Social Science & Medicine*, *78*, 96-112. https://doi.org/10.1016/j.socscimed.2012.11.039

Magson, N. R., Freeman, J. Y. A., Rapee, R. M., Richardson, C. E., Oar, E. L., & Fardouly, J. (2021). Risk and protective factors for prospective changes in adolescent mental health during the COVID-19 pandemic. *Journal of Youth and Adolescence*, *50*(1), 44-57. https://doi.org/10.1007/s10964-020-01332-9

McCrindle. (2021). *MyStrengths youth wellbeing report 2021*. https://s3.amazonaws.com/kajabi-storefronts-

production/sites/163568/themes/2149125913/downloads/TnT1pVifTn62tOGicnyT_MyStrengths_Youth_Wellbeing_Report_2021.pdf

Meda, N., Pardini, S., Slongo, I., Bodini, L., Zordan, M. A., Rigobello, P., Visioli, F., & Novara, C. (2021). Students' mental health problems before, during, and after COVID-19 lockdown in Italy. *Journal of Psychiatric Research*, *134*, 69-77. https://doi.org/10.1016/j.jpsychires.2020.12.045

Ministère de la Santé et des services sociaux. (2021). *Historique du portrait quotidien des cas confirmés*. Quebec Retrieved from https://www.donneesquebec.ca/recherche/dataset/covid-19-portrait-quotidien-des-cas-confirmes/resource/d2cf4211-5400-46a3-9186-a81e6cd41de9

Petersen, A. C., Sarigiani, P. A., & Kennedy, R. E. (1991). Adolescent depression: Why more girls? *Journal of Youth and Adolescence*, *20*(2), 247-271. https://doi.org/10.1007/BF01537611

Qualtrics. (July 2020). The output for this paper was generated using Qualtrics software, July 2020 Version of the Qualtrics Research Suite. Copyright © 2021 Qualtrics. Qualtrics and all other Qualtrics product or service names are registered trademarks or trademarks of Qualtrics, Provo, UT, USA. http://www.qualtrics.com

Queensland Government. (2020). *Roadmap to easing Queensland's restrictions.* https://www.torres.qld.gov.au/downloads/file/510/covid-19-restrictions-roadmap-3-july-2020

Queensland Government. (2021). *Queensland COVID-19 statistics*. https://www.qld.gov.au/health/conditions/health-alerts/coronavirus-covid-19/current-status/statistics#casesummary

Ravens-Sieberer, U., Kaman, A., Otto, C., Adedeji, A., Devine, J., Erhart, M., Napp, A.-K., Becker, M., Blanck-Stellmacher, U., Löffler, C., Schlack, R., & Hurrelmann, K. (2020). Mental health and quality of life in children and adolescents during the COVID-19 pandemic-results of the Copsy Study. *Deutsches Arzteblatt international*, *117*(48), 828-829. https://doi.org/10.3238/arztebl.2020.0828

Richardson, L. P., McCauley, E., Grossman, D. C., McCarty, C. A., Richards, J., Russo, J. E., Rockhill, C., & Katon, W. (2010). Evaluation of the patient health questionnaire-9 Item for detecting major depression among adolescents. *Pediatrics*, *126*(6), 1117-1123.

Rogers, A. A., Ha, T., & Ockey, S. (2021). Adolescents' perceived socio-emotional impact of COVID-19 and implications for mental health: Results from a U.S.-based mixed-methods study. *Journal of Adolescent Health*, *68*(1), 43-52. https://doi.org/10.1016/j.jadohealth.2020.09.039

Rose, A. J. (2002). Co–rumination in the friendships of girls and boys. *Child Development*, *73*(6), 1830-1843. https://doi.org/10.1111/1467-8624.00509

Rosenman, R., Tennekoon, V., & Hill, L. G. (2011). Measuring bias in self-reported data. *International Journal of Behavioural & Healthcare Research*, *2*(4), 320-332. https://doi.org/10.1504/IJBHR.2011.043414

Silverman, W. K., Fleisig, W., Rabian, B., & Peterson, R. A. (1991). Childhood Anxiety Sensitivity Index. *Journal of Clinical Child and Adolescent Psychology*, *20*(2), 162-168.

Singh, S., Roy, D., Sinha, K., Parveen, S., Sharma, G., & Joshi, G. (2020). Impact of COVID-19 and lockdown on mental health of children and adolescents: A narrative review with recommendations. *Psychiatry Research*, *293*, 113429-113429. https://doi.org/10.1016/j.psychres.2020.113429

Spielberger, C. (1973). State-Trait Anxiety Inventory for Children preliminary manual. *Palo Alto, CA: Consulting*.

Stassart, C., & Etienne, A. M. (2014). A French translation of the Childhood Anxiety Sensitivity Index (CASI): Factor structure, reliability and validity of this scale in a nonclinical sample of children. *Psychologica Belgica*, *54*(2), 222–241. https://doi.org/10.5334/pb.an

Sturman, D. A., & Moghaddam, B. (2011). The neurobiology of adolescence: Changes in brain architecture, functional dynamics, and behavioral tendencies. *Neuroscience and biobehavioral reviews*, *35*(8), 1704-1712. https://doi.org/10.1016/j.neubiorev.2011.04.003

Thombs, B. D., Bonardi, O., Rice, D. B., Boruff, J. T., Azar, M., He, C., Markham, S., Sun, Y., Wu, Y., Krishnan, A., Thombs-Vite, I., & Benedetti, A. (2020). Curating evidence on mental health during COVID-19: A living systematic review. *Journal of Psychosomatic Research*, *133*, 110113-110113. https://doi.org/10.1016/j.jpsychores.2020.110113

Thorisdottir, I. E., Asgeirsdottir, B. B., Kristjansson, A. L., Valdimarsdottir, H. B., Jonsdottir Tolgyes, E. M., Sigfusson, J., Allegrante, J. P., Sigfusdottir, I. D., & Halldorsdottir, T. (2021). Depressive symptoms, mental wellbeing, and substance use among adolescents before and during the COVID-19 pandemic in Iceland: a longitudinal, population-based study. *The Lancet Psychiatry*, *8*(8), 663-672. https://doi.org/10.1016/S2215-0366(21)00156-5

Turgeon, L., & Chartrand, É. (2003). Reliability and calidity of the revised children's manifest anxiety scale in a French-Canadian sample. *Psychological Assessment*, *15*(3), 378–383. https://doi.org/10.1037/1040-3590.15.3.378

Viner, R. M., Russell, S. J., Croker, H., Packer, J., Ward, J., Stansfield, C., Mytton, O., Bonell, C., & Booy, R. (2020). School closure and management practices during coronavirus outbreaks including COVID-19: a rapid systematic review. *The Lancet Child & Adolescent Health*, *4*(5), 397-404. https://doi.org/10.1016/S2352-4642(20)30095-X

White, B. P. (2014). The perceived stress scale for children: A pilot study in a sample of 153 children. *International Journal of Pediatrics and Child Health*, *2*(2), 45-52. https://doi.org/10.12974/2311-8687.2014.02.02.4

World Health Organisation. (2021a). *Weekly epidemiological update on COVID-19 - 6 July 2021*. World Health Organization. https://www.who.int/publications/m/item/weekly-epidemiological-update-on-covid-19---6-july-2021

World Health Organisation. (2021b). *Rolling updates on coronavirus disease (COVID-19)*. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen

Wren, D. G., & Benson, J. (2004). Measuring test anxiety in children: Scale development and internal construct validation. *Anxiety, Stress, & Coping*, *17*(3), 227-240. https://doi.org/10.1080/10615800412331292606

Zhou, S.-J., Zhang, L.-G., Wang, L.-L., Guo, Z.-C., Wang, J.-Q., Chen, J.-C., Liu, M., Chen, X., & Chen, J.-X. (2020). Prevalence and socio-demographic correlates of psychological health problems in Chinese adolescents during the outbreak of COVID-19. *European Child & Adolescent Psychiatry*, *29*(6), 749-758. https://doi.org/10.1007/s00787-020-01541-4 4

Supplementary Material

Situating the Research

It is important to situate the current research, as this cross-cultural study collected data between April and July of 2020, a few months after the WHO declared COVID-19 to be a pandemic on March 11th, 2020 (World Health Organisation, 2021b). As transmissions increased, governments responded by enforcing restrictions, such as quarantines, social distancing, and mandatory mask-wearing, to reduce transmissions and mortality rates (World Health Organisation, 2021a). These restrictions varied according to country. Therefore, the current research may provide some insight into the differences in COVID-19 experiences and psychological implications between Canadian and Australian adolescents.

At the time of testing in the province of Quebec (Canada, April to July), there were approximately 5500 (April) to 59000 (July) confirmed cases with approximately 100 (April) to 5700 (July) deaths (population ≈ 8.5 million) (Ministère de la Santé et des Services Sociaux, 2021). Conversely, in the state of Queensland (Australia), there had been a total of approximately 1100 confirmed cases and six deaths (population ≈ 5 million; Queensland Government, 2021). In Canada, sanitary measures such as social distancing and hand sanitization were endorsed, with a 14-day obligatory quarantine if returning from outside of the country (Gouvernement du Québec, 2021). Additionally, schools were closed, indoor/outdoor gatherings were forbidden, and non-essential businesses were closed. Queensland encouraged sanitary measures such as social distancing, mask-wearing, hand sanitization, and limited the number of people attending indoor/outdoor gatherings (Queensland Government, 2020). Quarantine was enforced for 14 days if returning from outside of the country or Victoria, Australia. However, schools and businesses were open.

At the time of testing and relative to country populations, Canada reported approximately 250 (April) to 3106 (July) total confirmed cases per million and approximately 5 (April) to 237 (July) total deaths/million population (Dong et al., 2020). Australia reported approximately 400 total

confirmed cases per million and approximately four total deaths per million. Towards the end of participant recruitment in June, Canada was therefore experiencing more confirmed cases and deaths per population million.

Double-Translation Process

The double-translation process requires two individuals: both need to be bilingual in both English and French, but one person's native language (i.e., mother tongue) is French and the other person's native language is English. The original English version of the questionnaire is translated from English to French by the francophone person. In other words, they only see the English items and they must translate them to French. Then, the anglophone receives the document but only sees the French translated items (and thus, does not see the original English items). This person's job is to translate the French items back to English. At the end of this process, both individuals compare the original English items and the items that were produced using the double-translation technique. Doing so ensures that the French items were successfully translated. If the meaning of an item is not exact/could be improved, both individuals come to a consensus on how the item could be worded otherwise in order to obtain a better translation of the original item.

Table S8

Adolescent Experiences of COVID-19 Stratified by Country and Gender

Variable	Canada (*N*=913)		Australia (*N*=413)		Country p-value	Gender p-value
	Boys (*n* = 198)	Girls (*n* = 708)	Boys (*n* = 172)	Girls (*n* = 234)		
Since the arrival of the coronavirus to Australia (25 January 2020), have you had symptoms (signs/manifestations) that resemble those of coronavirus (cough, fever, muscle aches, sore throat), even if they were not caused by coronavirus? (0 "no symptoms" to 10 "several symptoms")	1.11 (0.83, 1.38)	1.37 (1.22, 1.52)	1.58 (1.27, 1.88)	1.85 (1.58, 2.11)	**<.001**	**.042**
N (Missing)	*198 (0)*	*707 (1)*	*163 (9)*	*221 (13)*		

How have these symptoms affected your life in general? (0 "it didn't affect me at all" to 10 "it affected me a lot")	0.91 (0.48, 1.33)	1.29 (1.09)	0.91 (0.58, 1.25)	1.23 (0.95, 1.51)	.867	**.033**
N (Missing)	*85 (113)*	*369 (339)*	*137 (35)*	*197 (37)*		
How often have you had discussions about the coronavirus?					**<.001**	**<.001**
A few times a week	81 (40.9%)	196 (27.7%)	98 (59.0%)	116 (50.9%)		
1 time a day	51 (25.8%)	179 (25.3%)	32 (19.3%)	50 (21.9%)		
2 to 5 times a day	53 (26.8%)	262 (37.0%)	26 (15.7%)	50 (21.9%)		
6 to 9 times a day	6 (3.0%)	45 (6.4%)	3 (1.8%)	10 (4.4%)		
10 times of more a day	7 (3.5%)	26 (3.7%)	7 (4.2%)	2 (0.9%)		
N (Missing)	*198 (0)*	*708 (0)*	*166 (6)*	*228 (6)*		
Are you voluntarily following the news about the coronavirus? (Reading the newspaper, reading news on a phone, watching TV news reports)					**<.001**	**<.001**
No	79 (39.9%)	168 (23.7%)	72 (44.2%)	85 (38.3%)		
Yes	119 (60.1%)	540 (76.3%)	91 (55.8%)	137 (61.7%)		
N (Missing)	*198 (0)*	*708 (0)*	*163 (9)*	*222 (12)*		
How often (how many hours per day) do you have a look at each of the following news or media sources?						
Traditional media (newspaper, television, radio, etc.)	0.79 (0.57, 1.00)	1.18 (1.07, 1.29)	0.53 (0.30, 0.76)	0.62 (0.42, 0.81)	**<.001**	**.014**
N (Missing)	*185 (13)*	*670 (38)*	*160 (12)*	*219 (15)*		
Social media news feed (Facebook, Twitter, Instagram, etc.)	1.47 (1.08, 1.86)	2.11 (1.90, 2.32)	1.72 (1.29, 2.14)	2.15 (1.79, 2.51)	.423	**.003**
N (Missing)	*185 (13)*	*670 (38)*	*160 (12)*	*219 (15)*		
Websites (News.com.au, etc.)	0.25 (0.08, 0.43)	0.44 (0.35, 0.54)	0.31 (0.13, 0.50)	0.22 (0.06, 0.38)	.310	.559
N (Missing)	*185 (13)*	*670 (38)*	*160 (12)*	*219 (15)*		
Before the coronavirus arrived in Australia, how normally worried or stressed are you? (1 "not at all" to 7 "a lot")	2.88 (2.64, 3.12)	4.26 (4.13, 4.38)	2.48 (2.21, 2.74)	3.71 (3.48, 3.94)	**<.001**	**<.001**
N (Missing)	*198 (0)*	*708 (0)*	*158 (14)*	*218 (16)*		
How worried or stressed are you right now? (1 "not at all" to 7 "a lot")	2.98 (2.76, 3.20)	4.01 (3.98, 4.22)	2.65 (2.40, 2.90)	3.75 (3.54, 3.96)	**.001**	**<.001**
N (Missing)	*198 (0)*	*708 (0)*	*158 (14)*	*218 (16)*		
In your opinion, how much of this stress are you experiencing because of the coronavirus? (1 "not at all related" to 7 "extremely related")	3.21 (2.97, 3.45)	3.84 (3.72, 3.97)	1.82 (1.56, 2.09)	2.04 (1.82, 2.27)	**<.001**	**<.001**
N (Missing)	*198 (0)*	*708 (0)*	*158 (14)*	*218 (16)*		

In the context of this pandemic (of the coronavirus being spread around the world), how worried are you about: (1 "not at all worried" to 7 "excessively worried")						
Your health *N (Missing)*	2.12 (1.90, 2.32) *198 (0)*	2.74 (2.63, 2.85) *707 (1)*	1.91 (1.68, 2.15) *159 (13)*	2.31 (2.12, 2.51) *220 (14)*	**.002**	**<.001**
Your parent's health *N (Missing)*	3.94 (3.70, 4.19) *198 (0)*	4.24 (4.11, 4.37) *707 (1)*	3.19 (2.92, 3.46) *159 (13)*	3.55 (3.32, 3.77) *220 (14)*	**<.001**	**.004**
The health of someone who matters to you *N (Missing)*	4.31 (4.08, 4.55) *198 (0)*	4.92 (4.79, 5.05) *707 (1)*	3.76 (3.50, 4.03) *159 (13)*	4.12 (3.90, 4.35) *220 (14)*	**<.001**	**<.001**
The continuation of your school year *N (Missing)*	4.01 (3.74, 4.27) *198 (0)*	4.92 (4.78, 5.06) *707 (1)*	2.50 (2.20, 2.79) *159 (13)*	3.49 (3.25, 3.74) *220 (14)*	**<.001**	**<.001**
Your parent's job or your job *N (Missing)*	2.61 (2.34, 2.88) *198 (0)*	3.38 (3.24, 3.53) *707 (1)*	2.70 (2.40, 3.01) *159 (13)*	2.97 (2.71, 3.23) *220 (14)*	.222	**<.001**
Missing something (e.g., toilet paper, medicine, fruit, bread, etc.) *N (Missing)*	1.70 (1.51, 1.89) *198 (0)*	2.05 (1.95. 2.15) *707 (1)*	1.71 (1.50, 1.92) *159 (13)*	2.07 (1.89, 2.25) *220 (14)*	.850	**<.001**

Note. Continuous data presented at *M* ± 95% *CI*. Categorical data is presented as frequency (percentage). N/n = sample size. (Missing) = number of missing cases. Bold p-values indicate a statistically significant outcome.

Table S9

Inferential Statistics for Psychological Outcomes

Measure	**Interaction Effect (Country*Sex)**	**Main Effects**		**Simple Effects**
		Country	**Sex**	
SMM	F (1, 1225) = .008, p = .930, η_p^2 < .001	F (1, 1225) = 19.789, p < .001, η_p^2 < .016 **Australia ↑**	F (1, 1225) = 1.909, p = .167, η_p^2 = .002	N/A
CASI	F (1, 1222) = .204, p = .652, η_p^2 < .001	F (1, 1222) = 2.519, p = .113, η_p^2 = .002	F (1, 1222) = 135.327, p < .001, η_p^2 =.100 **Girls ↑**	N/A
PSS	F (1, 1179) = .50.105, p = .246, η_p^2 = .001	F (1, 1179) = 8.438, p = .004, η_p^2 =.007 **Australia ↑**	F (1, 1179) = 40.105, p < .001, η_p^2 =.033 **Girls ↑**	N/A
STATE	F (1, 1207) = .454, p = .500, η_p^2 < .001	F (1, 1207) = 1.644, p = .200, η_p^2 =.001	F (1, 1207) = 57.198, p < .001, η_p^2 =.045 **Girls ↑**	N/A

CTAS	F (1, 1133) = 2.111, p = .147, η_p^2 = .002	F (1, 1133) = 9.057, p = .003, η_p^2 =.008 **Australia ↑**	F (1, 1133) = 79.811, p < .001, η_p^2 =.066 **Girls ↑**	N/A
CRQ	F (1, 1152) = 9.208, p = .002, η_p^2 = .008	F (1, 1152) = 6.616, p = .010, η_p^2 =.006 **Canada ↑**	F (1, 1152) = 76.420, p < .001, η_p^2 =.062 **Girls ↑**	**Boys (Canada*Australia):** F (1, 1152) = 11.792, p < .001, η_p^2 =.010 **Canada ↑** **Girls (Canada*Australia):** F (1, 1152) = .160, p = .689, η_p^2 <.001 **Canada (Boys*Girls):** F (1, 1152) = 21.513, p < .001, η_p^2 =.018 **Girls ↑** **Australia (Boys*Girls):** F (1, 1152) = 55.789, p < .001, η_p^2 =.046 **Girls ↑**
Z-scored Depression	F (1, 1161) = .111, p = .740, η_p^2 < .001	F (1, 1161) = 2.174, p = .141, η_p^2 = .002	F (1, 1161) = 68.834, p < .001, η_p^2 = .056 **Girls ↑**	N/A

Note. Arrows indicate the direction of the effect. For example "Australia ↑" suggests that the Australian group reported a significantly greater score on that particular variable. *indicates the interaction between variables.

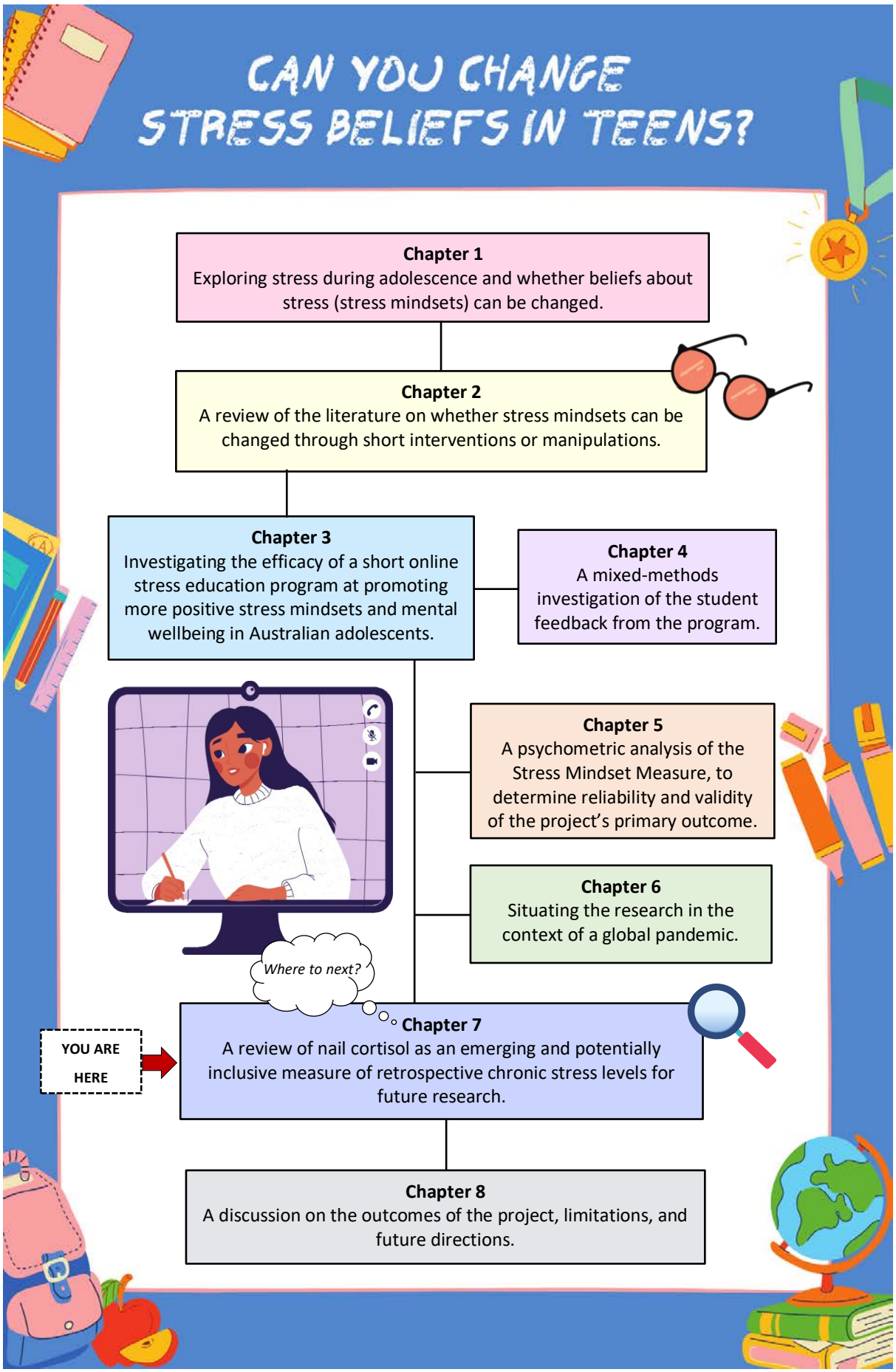
Table S10

Descriptive Statistics for the PSS-C Scale Items

PSS-C Items	Canada (*N* = 913)	Australia (*N* = 413)
1. In the past week, how often did you feel rushed or hurried?	1.16 (1.08, 1.24)	1.47 (1.36, 1.57)
N (Missing)	*847 (66)*	*340 (73)*
2. In the past week, how often did you have enough time to do what you wanted?[R]	0.65 (0.57, 0.72)	1.27 (1.27, 1.37)
N (Missing)	*847 (66)*	*340 (73)*
3. In the past week, how often did you feel worried about being too busy?	0.99 (0.90, 1.07)	1.29 (1.18, 1.41)
N (Missing)	*847 (66)*	*340 (73)*
4. In the past week, how often did you feel worried about grades or school?	1.43 (1.34, 1.52)	1.56 (1.44, 1.68)
N (Missing)	*845 (68)*	*340 (73)*
5. In the past week, how often did your mum and/or dad make you feel better?[R]	1.40 (1.32, 1.48)	1.35 (1.24, 1.46)
N (Missing)	*846 (65)*	*340 (73)*
6. In the past week, how often did your mum and/or dad make you feel loved?[R]	0.67 (0.59, 0.74)	.82 (0.72, 0.92)
N (Missing)	*845 (68)*	*340 (73)*
7. In the past week, how often did you feel scared or nervous?	1.13 (1.04, 1.21)	1.23 (1.12, 1.34)
N (Missing)	*845 (68)*	*340 (73)*
8. In the past week, how often did you feel angry?	1.33 (1.25, 1.41)	1.22 (1.12, 1.32)
N (Missing)	*845 (68)*	*340 (73)*

9. In the past week, how often did you feel happy?[R]	0.90 (0.83, 0.97)	.95 (0.85, 1.04)
N (Missing)	*845 (68)*	*340 (73)*
10. In the past week, how often did you get enough sleep?[R]	0.93 (0.85, 1.02)	1.29 (1.19, 1.40)
N (Missing)	*845 (68)*	*340 (73)*
11. In the past week, how often did you have fights with your friends?	0.29 (0.24, 0.34)	0.36 (0.30, 0.43)
N (Missing)	*845 (68)*	*340 (73)*
12. In the past week, how often did you play with your friends?[R]	1.91 (1.83, 1.99)	1.13 (1.02, 1.23)
N (Missing)	*845 (68)*	*340 (73)*
13. In the past week, how often did you feel that you had enough friends?[R]	1.04 (0.95, 1.13)	1.04 (0.92, 1.16)
N (Missing)	*842 (72)*	*340 (73)*

Note. Continuous data presented at *M* ± 95% *CI*. *N/n* = sample size. *(Missing)* = number of missing cases.


CAN YOU CHANGE STRESS BELIEFS IN TEENS?
Chapter 1
Exploring stress during adolescence and whether beliefs about stress (stress mindsets) can be changed.
Chapter 2
A review of the literature on whether stress mindsets can be changed through short interventions or manipulations.
Chapter 3
Investigating the efficacy of a short online stress education program at promoting more positive stress mindsets and mental wellbeing in Australian adolescents.
Chapter 4
A mixed-methods investigation of the student feedback from the program.
Chapter 5
A psychometric analysis of the Stress Mindset Measure, to determine reliability and validity of the project's primary outcome.
Chapter 6
Situating the research in the context of a global pandemic.
Where to next?
YOU ARE HERE
Chapter 7
A review of nail cortisol as an emerging and potentially inclusive measure of retrospective chronic stress levels for future research.
Chapter 8
A discussion on the outcomes of the project, limitations, and future directions.

JOURNAL: Psychoneuroendocrinology

Chapter 7

Human Nail Cortisol as a Retrospective Biomarker of Chronic Stress: A Systematic Review

Riana Marie[123], Ann-Katrin Kraeuter[4], Brett McDermott[3], Sonia Lupien[5], and Zoltán Sarnyai[126*]

[1] Laboratory of Psychiatric Neuroscience, Centre for Molecular Therapeutics, [2]Australian Institute of Tropical Health and Medicine, James Cook University, Townsville, Queensland, Australia

[3]College of Medicine and Dentistry, James Cook University, Townsville, Queensland, Australia

[4]Faculty of Health and Life Sciences, Northumbria University, Newcastle upon Tyne, United Kingdom

[5]Psychiatry Department, University of Montreal, Canada

[6]College of Public Health, Medical, and Veterinary Sciences, James Cook University, Townsville, Queensland, Australia

[*]Corresponding author:

Professor Zoltán Sarnyai, M.D., Ph.D

Phone: +61747816992

Email: zoltan.sarnyai@jcu.edu.au

Address: College of Public Health, Medical and Veterinary Sciences

James Cook University, 1 James Cook Drive, Townsville QLD 4811 AUSTRALIA

Preamble: One future direction for stress mindset interventions is to determine whether stress mindsets may affect the physiological stress response. It would be interesting to utilise biological markers of both acute and chronic stress to investigate any intervention effects. Chronic stress measures may also provide insight into the stability of any physiological changes associated with stress mindset psychoeducation. Interestingly, nail cortisol is an emerging and potentially more inclusive measure of chronic stress that I believe could be a valuable outcome in future stress mindset investigations.

Abstract

Cortisol is the primary glucocorticoid produced by the activation of the hypothalamic-pituitary-adrenal (HPA) axis after a psychological or physiological stressor. The dysregulation of the HPA axis by chronic stress has been associated with psychiatric disorders. Although hair is currently the main validated source of chronic cortisol concentrations, cortisol is also bound to human nails, another keratinised matrix. Therefore, nail cortisol has the potential to be an alternative retrospective chronic measure of HPA activation. The aim of this systematic review was to assess the temporal resolution, methodological issues, HPA correlates, and target populations in nail cortisol investigations. A qualitative synthesis was performed to assess current literature exploring cortisol concentrations from human nails. A total of 18 eligible human studies extracted from Medline (PubMed and Ovid), ProQuest (PsycINFO), and Scopus found that immunoassays and mass spectrometry were the two primary methods of analysis. However, methodological variability remained evident between studies. Nail cortisol correlated with saliva and hair in some studies and was investigated across multiple developmental periods. Finally, when applied as an outcome measure in health disorders, higher nail cortisol concentrations are associated with acute coronary syndrome and depression. In conclusion, nail cortisol may serve as a retrospective biomarker of chronic stress; however, the ability to track how much cortisol is accumulating within nail clippings is complex and may represent a large timespan. Further, very few studies have reported effect sizes and investigated the effects of covariates, such as age, sex, ethnicity, and nail characteristics, which limits the validation of this measure. Further studies are required to validate the utility of nail cortisol as a biomarker of chronic stress across the human lifespan.

Keywords: Cortisol, Nails, Stress, Mental health, Hypothalamic-Pituitary-Adrenal axis

Human Nail Cortisol as a Retrospective Biomarker of Chronic Stress: A Systematic Review

Stress is an automatic response to physical or psychological demands or threats sensed by the body (Lazarus & Folkman, 1984; Selye, 1965). The acute stress response can promote adaptation and survival, using effective homeostatic mechanisms (Radley et al., 2015). Repeated or prolonged stress responses have been associated with the development of pathology, including mental health disorders (Bekes et al., 2015; Mohr et al., 2014; Rosiek et al., 2016; Sheets & Craighead, 2014), neurodegenerative disorders (Hou et al., 2014; Machado et al., 2014), metabolic disorders (Aschbacher et al., 2014; Lagraauw et al., 2015; Tamashiro et al., 2011), cancers (Kim-Fuchs et al., 2014; Zhao et al., 2015), osteoporosis (Azuma et al., 2015), and periodontal disease (Warren et al., 2014). Consequently, abnormalities in cortisol secretion have been associated with psychiatric conditions (Zorn et al., 2017). The HPA axis is responsible for maintaining homeostasis within the body by releasing glucocorticoids (cortisol) (Juster et al., 2010; Sapolsky et al., 2000). Overall, the dysregulation of the HPA axis can result in damage to the brain and body (McEwen, 2006).

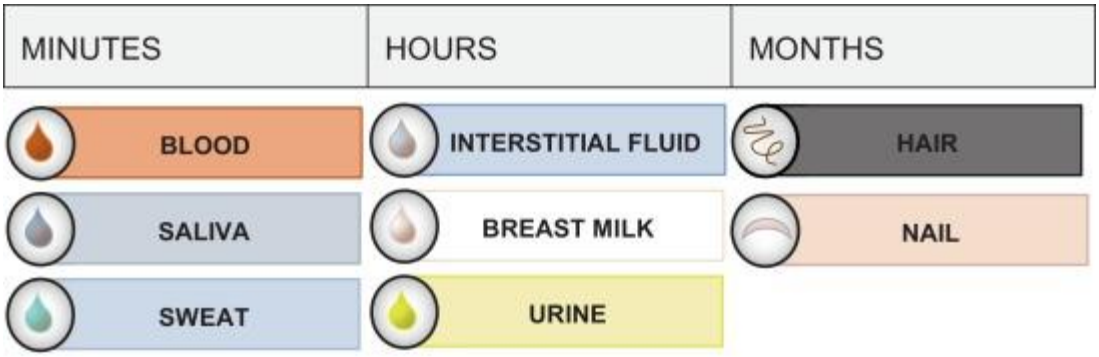
Cortisol is not only a highly effective biomolecule to influence multiple tissues during stress adaptation; it is also a biomarker of the HPA axis activity. Cortisol levels have been used as a diagnostic tool for Addison's disease or Cushing's syndrome, which are disorders characterised by reduced or heightened excretion of cortisol, respectively (Turpeinen & Hamalainen, 2013). Due to its lipophilic nature, this steroid hormone can easily cross the blood-brain barrier and bind to receptors in emotionally and cognitively salient areas, including the hippocampus, amygdala, and frontal lobes (Lupien et al., 2007). Therefore, measuring cortisol concentrations is a valuable tool in the quantification of physiological stress.

Cortisol concentrations can be measured from a variety of sources, each reflecting a specific temporal resolution of HPA axis activation. Figure 17 shows the various sources of cortisol and the approximate concentration accumulation time frame they represent. In humans, acute changes in cortisol have been measured from samples of blood (Dikme & Dikme, 2018; Su et al., 2015), saliva (Lupien et al., 2013), and sweat (Parlak et al., 2018) (see Figure 17). Further, samples from interstitial

fluid (Venugopal et al., 2011), urine (Eswarappa et al., 2018), and breast milk (van der Voorn et al., 2016) capture sub-chronic time intervals (see Figure 17). However, these approaches have inherent challenges. Primarily, these measures are highly mediated by the sleep-wake circadian variations, where high levels of the hormone are present in the morning and low levels at night (Chan & Debono, 2010). This diurnal rhythm can be influenced by various factors including age, sex, ethnicity, body mass index, and sleep deprivation (El-Farhan et al., 2017).

Figure 17

The Temporal Resolution of Cortisol Concentrations in the Body



Given our interest in chronic stress and its implication with various health concerns, it is crucial to measure chronic cortisol levels. Measuring the chronic accumulation of cortisol can eliminate both intra- and inter-day variations (Staufenbiel et al., 2013). Interestingly, cortisol appears to passively diffuse from capillaries into keratinised matrices, such as hair and nails, and accumulates for longer periods of time within these structures, allowing for chronic investigations (de Berker et al., 2007; Lee et al., 2015).

Hair cortisol has become a validated non-invasive measure of chronic cortisol concentrations (for a general review see Staufenbiel et al. (2013). Hair grows approximately 1 centimetre per month (Wennig, 2000). Each centimetre is therefore comparable to a month of integrated cortisol levels (Abell et al., 2016). As such, hair can represent HPA axis activation amassed retrospectively, which is critical when capturing the response to specific long-term stressors, such as natural disasters (Luo et al., 2012). A meta-analysis demonstrated that chronic stress exposure leads to increased hair cortisol

concentrations in healthy individuals (Stalder et al., 2017). However, hair cortisol concentrations can be affected by covariates, such as age, sex, ethnicity, hair length, hair colour/treatment, hair washing frequency, and oral contraceptives (Rippe et al., 2016; Stalder et al., 2017). Nevertheless, hair cortisol has rapidly become an accepted measure of chronic HPA axis activation.

Nails may also offer a potentially retrospective timeline of chronic stress due to being a keratinised matrix similar to hair. The collection of nails is easy and may improve compliance, particularly in longitudinal studies where repeated measurements are necessary. Unlike hair, it is also easy for participants to collect their own samples, which may be valuable in future clinical diagnostic and assessment services. Nail cortisol can be collected when hair samples are unavailable, such as hair loss or baldness. Medical treatments, such as chemotherapy, can result in hair loss. As well, a large proportion of males have short or shaven hair, and excluding these participants from studies using hair cortisol measures can induce a selection bias. One study found that 42% of their community samples were unable to provide hair samples, due to short hair or baldness (Fischer et al., 2017). In this study, 71% of people from Black African and Black Caribbean backgrounds were unable to provide samples (Fischer et al., 2017). Another 29% of participants, from all age groups, were unwilling to provide their hair (Fischer et al., 2017). Culture may thus play a role in a participant's ability or willingness to provide their hair and therefore nail samples may improve the inclusivity of specific populations within stress hormone research.

Current literature has adapted the same non-invasive methodological procedure used with hair to nails (Warnock et al., 2010). Despite emerging interest and a narrative review of nail and hair cortisol (Liu & Doan, 2019), nail cortisol is not an established measure of chronic stress in the literature and there is little information available on the accumulation of cortisol within nails. Therefore, the aim of this systematic review was to assess the temporal resolution, methodological issues, HPA correlates, and target populations of nail cortisol investigations to determine if cortisol extracted from nails is a viable biomarker of chronic HPA axis dysregulation and psychosocial stress.

Method

Protocol

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2015). A qualitative synthesis was performed to critically analyse contrasting laboratory procedures and outcomes.

Eligibility Criteria

This review included journal articles from English peer-reviewed journals. There were no restrictions imposed on publication dates or status. The primary outcome measure required for eligibility was nail cortisol (fingernails and toenails). Only human studies were included. There were no limitations on participant demographics, such as age, sex, or ethnicity, or the use of other outcome measures, in conjunction with nail cortisol concentrations. With the exception of the recent narrative review on nail cortisol (Liu & Doan, 2019), studies of all designs were used to develop a complete review of the nail cortisol concentration collection, extraction, and analysis methods.

Information Sources

Electronic databases were last searched on the 20th of December 2019. All sources from before this date were included in this screening process. The searched databases included Medline (PubMed and Ovid), ProQuest (PsycINFO), and Scopus.

Search Strategy

The following search terms were entered into the selected databases: ‘nail’, ‘fingernail’, ‘toenail’, and ‘cortisol’. These search terms remained consistent for all databases. However, MeSH terms were automatically applied within the Medline databases. Reference lists of eligible full-text articles were also examined.

Study Selection

The reviewer (RM) assessed the eligibility of the studies based initially on the titles and abstracts of each journal article. After this screening process, full-text articles deemed relevant were

subsequently reviewed and, if eligible, included in the synthesis. There were no limits on article publication dates.

Data Collection Process

Data was extracted using a standardised data extraction form piloted on five randomly selected studies and refined accordingly. Data from the final sample of studies were extracted by the reviewer (RM) and thematically coded.

Data Items

The variables of interest in this review included: (1) participant demographics (age, sex, ethnicity/race, and socioeconomic status), (2) laboratory procedures (nail collection, extraction, and analysis), and (3) outcome measures (nail cortisol and correlations with other physiological and psychological measures).

Quality Assessment

Two independent reviewers (RM and AK) conducted a quality assessment using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Checklist (Von Elm et al., 2007). The only modification to this checklist was the separation of some items. This checklist contained a total of 39 items evaluating the reporting of each study's title, abstract, introduction, methodology, results, and discussion. Each item was evaluated as 'reported', 'not reported', or 'not applicable'. The number and percentage of studies, meeting each category, was reported. The completeness of reporting (COR) score was calculated for each study using the formula: *COR (%)* = (reported/(reported+not reported))*100). Studies were given an overall score of 'low' (< 50% COR), 'moderate' (50 – 75% COR), or 'high' (75% COR). Higher scores indicated a greater number of items reported according to the STROBE checklist.

Results

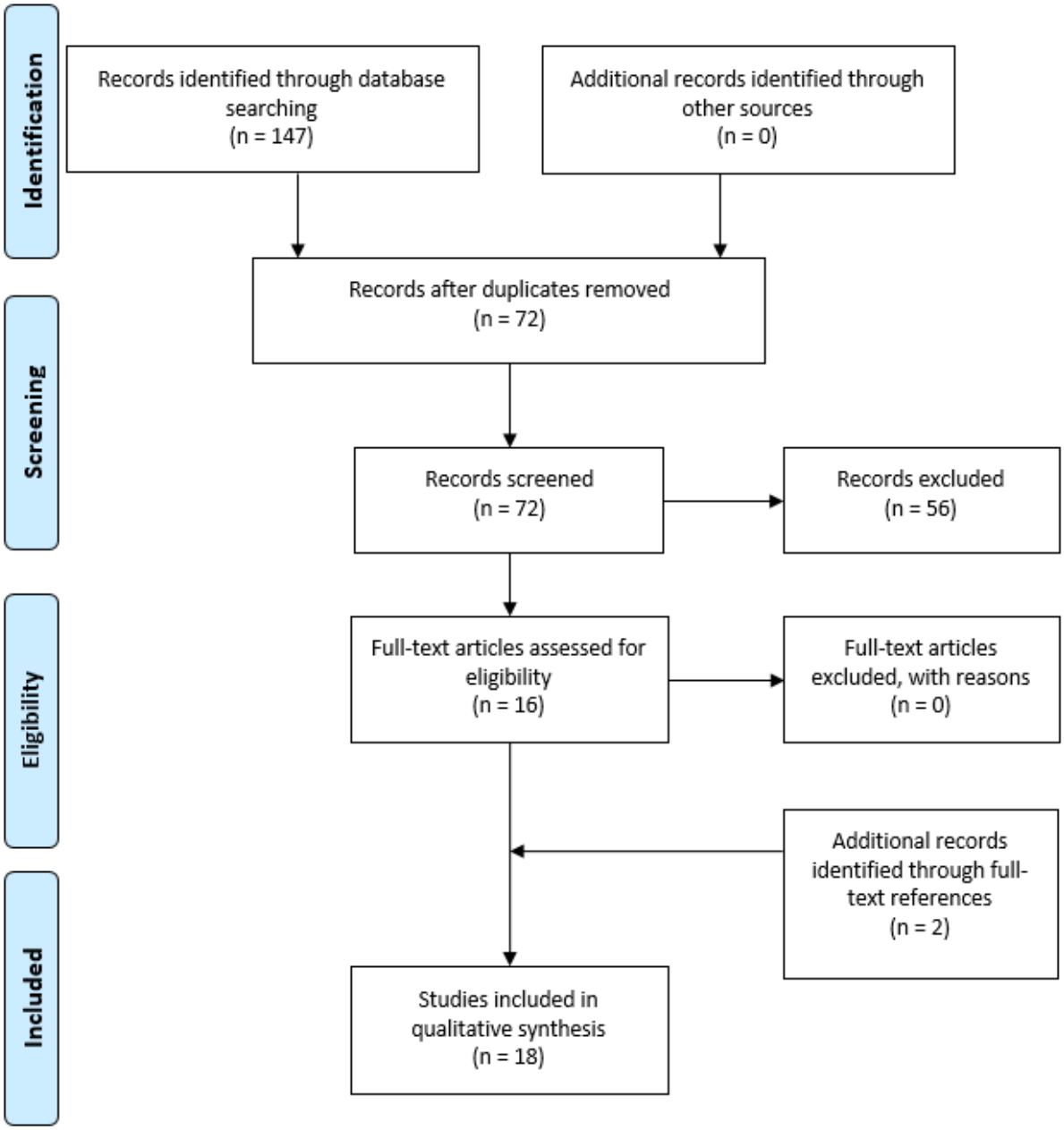
Study Selection

The electronic database search found a total of 147 studies relevant to the search terms (see Figure 18). Duplicates (75) were removed and the titles and abstracts of 72 articles were screened.

This screening process extracted 16 studies. An additional 2 studies were extracted from within the references of these 16 articles. Therefore, a total of 18 studies were reviewed.

Figure 18

PRISMA 2009 Flow Diagram



Note. PRISMA adapted flow diagram outlining the systematic search strategy. From: Moher et al. (2009).

Quality Assessment

A STROBE Checklist quality assessment was performed on 17 studies (see Table S11). The only study not included in the quality assessment was a conference abstract (Hubmann et al., 2016). The most completely reported items were the outcome variables (item 7a, 100%), key results summary (item 18, 100%), and results interpretation (item 20, 100%). When applicable, the least reported items included sample size criteria (Item 10, 6%), description of sensitivity analyses (item 12e, 6%), and the use of a sample size flow diagram (Item 13c, 6%). Partial reporting was often associated with lower COR scores. In addition, only six studies (35%) addressed potential confounders (Item 7b), and only six (35%) described efforts to address bias (item 9). Individually, seven studies had a COR score of less than 50%, and six studies scored between 50 to 75% reporting completeness. Only four studies had a COR score greater than 75%, indicating greater reporting transparency. The mean COR score was 60 ± 17 %. Therefore, the STROBE Checklist items were, on average, only moderately reported by the reviewed studies. The average impact factor of the journals, which published the reviewed studies, was 2.98.

Effect sizes have been reported in Table S12 if a significant effect was found and the relevant data needed for calculations was reported within the article.

Study Characteristics

Out of the 18 eligible studies, 17 were full-text journal articles (see Table S112) and one article was published as a conference abstract (Hubmann et al., 2016). The first article to examine nail cortisol was published in 2010. Approximately 55% of the eligible articles were published between 2018 and 2019. The total cumulative sample size for the included studies was 1650 participants. Developmental periods from infancy to adulthood were investigated and both male and female participants were recruited. All studies assessed nail cortisol concentrations. Secondary outcomes included other stress biomarkers and self-report measures.

Methodological Issues

The validation of nail cortisol concentrations in research requires the homogeneity of laboratory extraction and analysis protocols. A modified outline of the methodological aspects involved in hair cortisol extraction and analysis, produced by Albar et al. (2013), was used to assess the procedures reported by the clinical nail cortisol studies. These methodological procedures included the assay used, cortisol range, type of nail, nail mass, nail polish use, washing method, pulverisation, extraction solvent, duration of extraction and temperature, centrifugation during extraction, solvent evaporation, and storage temperature. Two studies did not provide sufficient information to fully inform this review of methodological aspects, due to either being a conference abstract (Hubmann et al., 2016) or only referencing Warnock et al. (2010) instead of describing a specific procedure (Messerli-Burgy et al., 2018). Nevertheless, the remaining studies informed the review of nail cortisol extraction methodology.

Assay

Nail cortisol concentrations were measured using either immunoassays or mass spectrometry. Immunoassays were the most frequently selected analysis (approximately 67% of the studies) with eight studies using enzyme immunoassay (EIA) (Doan et al., 2018; Fruge et al., 2018; Hubmann et al., 2016; Izawa et al., 2017; Izawa et al., 2015; Messerli-Burgy et al., 2018; Warnock et al., 2010), two studies using an enzyme-linked immunosorbent assay (ELISA) (Nejad et al., 2016), and two studies using an automated immunodiagnostic system (‘immunoassay “Immulite” — DPC’s Immunoassay analyzer’) (Herane-Vives et al., 2017; Herane-Vives et al., 2018). Salimetrics salivary cortisol assays were the most cited brand of ELISA.

The remaining six studies used mass spectrometry including Ultra Performance Liquid Chromatography - Tandem Mass Spectrometry (UPLC-MS/MS) (Ben Khelil et al., 2011) and Liquid Chromatography Electrospray Ionization Tandem Mass Spectrometry (LC/ESI-MS/MS) (Binz et al., 2018; Higashi et al., 2016; Voegel et al., 2018). These studies selected mass spectrometry, due to its analytical specificity and ability to detect cortisol from small nail masses.

Nail Type

All studies collected the unattached anterior portion of the nail. Twelve studies collected fingernail clippings from every digit (Binz et al., 2018; Doan et al., 2018; Herane-Vives et al., 2017; Herane-Vives et al., 2018; Hubmann et al., 2016; Izawa et al., 2017; Izawa et al., 2015; Messerli-Burgy et al., 2018; Voegel et al., 2018; Warnock et al., 2010). One study's eligibility criteria was simply that there was sufficient nail growth in at least one finger (Davison et al., 2019). Another study only used the thumbnail from the right hand of their participants (Ben Khelil et al., 2011). While, one study only collected toenails from the big toe (Voegel et al., 2019).

Two studies collected both fingernail and toenail clippings from every digit (Fruge et al., 2018; Nejad et al., 2016). A significant positive strong correlation was found between the cortisol concentrations of fingernails and toenails stored at room temperature (r = .62, p < 0.001, n = 148) and the fingernails and toenails frozen before analysis (r = .31, p = 0.028, n = 50) (Fruge et al., 2018). A similar correlation was also observed between fingernail and toenail cortisol concentrations in the second study (r = .61, p < 0.001, n = 19) (Nejad et al., 2016).

Finally, one study collected clippings from the thumb and forefinger from both the right and left hands of right-handed participants and toenails from the first toe (Binz et al., 2018). A significant difference was found between the type of nail analysed (p < 0.001, n = 1) (Binz et al., 2018). Cortisol concentrations measured in one individual over seven months were highest for little fingernails (M = 12.2 ± 1.2 pg/mg), intermediate for pooled of index/middle/ring fingernails (M = 9.3 ± 0.9 pg/mg), and lowest for thumbnails (M = 5.9 ± 1.4 pg/mg) (Binz et al., 2018). This difference was hypothesised to be the result of varied fingernail growth rates, where little fingernails are the slowest to grow, allowing them to accumulate higher cortisol concentrations (Binz et al., 2018). Further, a significant difference was found between nails on the right and left hand (p < 0.05, n = 1), where the left hand had higher cortisol levels (Binz et al., 2018). However, two other studies (n = 20 for both) found no significant difference between the cortisol concentrations measured between left and right hands

(Higashi et al., 2016; Voegel et al., 2018). Overall, the free nail pooled from all fingernails was most commonly utilised.

Nail Mass

Warnock et al. (2010) described two methods of extraction involving the mass of the nail sample. These methods included either whole nail extraction (the whole amount of ground nail is used from each participant) or part nail extraction (a specified amount of nail is used consistently for every participant). Warnock et al. (2010) did not report the nail mass range for the whole nail extraction protocol. Further, no significant difference was found between these methods. Although part nail extraction may provide standardisation, Warnock et al. (2010) recommended whole free nail extraction, as it likely reflects a more accurate profile of the participants' cumulative cortisol concentrations.

Out of the 16 human studies reporting methodology, part nail extraction was most commonly used, and nail masses ranged from 10 mg (Binz et al., 2018; Higashi et al., 2016; Voegel et al., 2018), 15 mg (Izawa et al., 2017; Izawa et al., 2015), 20 mg (Fruge et al., 2018), 30 mg (Wu et al., 2018), or 50 mg (Warnock et al., 2010). Two studies specifically weighed out 20 – 30 mg (Herane-Vives et al., 2017) and 10 – 25 mg (Herane-Vives et al., 2018) of nail powder after pulverisation. Studies using the whole nail extraction procedure had nail samples ranging from 2.4 to 75 mg of nail powder/cuttings (Ben Khelil et al., 2011; Doan et al., 2018). Two mass spectrometry studies showed that nail cortisol could reliably be quantified in samples as small as 1 mg (Ben Khelil et al., 2011; Binz et al., 2018). One study's criterion was that the sample had to be >1mg (Davison et al., 2019). Finally, two studies did not report the amount of nail collected or used during the extraction (Nejad et al., 2016). Therefore, there was limited consensus regarding the optimal nail mass required before extraction but 1mg appeared to be the lower limit for analysis.

Nail Polish

Cosmetic products may limit nail steroid quantification. Three studies' eligibility criteria were that participants had not recently worn nail polish and that nail polish use did not occur during the

duration of the study (Doan et al., 2018). Two studies found no significant difference between participants who had used nail polish and nail polish remover and participants who had used no cosmetic products (Ben Khelil et al., 2011; Izawa et al., 2017). Contrary to these findings, one study removed samples with nail polish from the analyses, as they found extremely high cortisol levels, greater than two standard deviations from the mean (Fruge et al., 2018). Although some studies found no effect, studies should remain cautious and adjust for any potentially confounding effects of cosmetic products.

Washing Method

Washing is a critical step in the extraction process as it reduces the likelihood of recently deposited sweat or sebum cortisol (from touching skin or hair) as well as dirt from contaminating the extracted concentration (Meyer et al., 2014). Immunoassay studies used either 2 ml (Fruge et al., 2018), 3 ml (Herane-Vives et al., 2017; Herane-Vives et al., 2018), 5 ml (Fruge et al., 2018; Izawa et al., 2017; Izawa et al., 2015; Nejad et al., 2016; Warnock et al., 2010), or 10 ml (Warnock et al., 2010) of isopropanol to wash their nail samples. These studies reported vortexing their samples for one minute twice with isopropanol. Only one study did not report the amount of isopropanol they used or how many washes occurred (Doan et al., 2018).

Alternative washing methods were used by mass spectrometry studies. One study washed their samples for two minutes in 3 ml of deionised water followed by three minutes in 3 ml of acetone (Binz et al., 2018). Another study washed their samples for three minutes with 2 ml of deionised water followed by two minutes of washing with 2 ml of acetone (Voegel et al., 2018). In a more recent study, the same authors washed their samples for three minutes with 15 ml of deionised water followed by a 2-minute wash in 10 ml of acetone (Voegel et al., 2019). Another study vortexed their samples for 10 seconds once with deionised water (unreported amount) and subsequently twice with 1 ml of methanol (Ben Khelil et al., 2011). While, one study washed their samples with 1ml of methanol and agitated them for 5 minutes (Davison et al., 2019). Finally, one study did not describe any washing procedure before the extraction (Higashi et al., 2016). This study

only reported that the nail samples were dried for three hours at 45 °C. Most studies reported air-drying their samples overnight (Fruge et al., 2018; Herane-Vives et al., 2017; Herane-Vives et al., 2018; Voegel et al., 2018; Warnock et al., 2010). Overall, isopropanol was the most commonly used washing reagent for immunoassays.

Pulverisation

Similar to hair cortisol extraction, it is recommended that the samples are ground or cut to increase the available surface area for solvent penetration and cortisol concentration extraction (Meyer et al., 2014). Twelve studies pulverised their samples using a Retsch ball mill or mixer mill at either 25 Hz (Doan et al., 2018; Warnock et al., 2010) or 30 Hz (Binz et al., 2018; Fruge et al., 2018; Herane-Vives et al., 2017; Herane-Vives et al., 2018; Izawa et al., 2017; Izawa et al., 2015; Voegel et al., 2018; Warnock et al., 2010). These samples were milled for either 2.5 minutes (Warnock et al., 2010), 5 minutes (Binz et al., 2018; Herane-Vives et al., 2017; Herane-Vives et al., 2018; Warnock et al., 2010), 9 minutes (Fruge et al., 2018), 10 minutes (Doan et al., 2018; Voegel et al., 2018), or 40 minutes (Izawa et al., 2017; Izawa et al., 2015). Conversely, three mass spectrometry studies finely cut their samples into <1 and up to 2 mm portions (Ben Khelil et al., 2011; Higashi et al., 2016)One immunoassay study used a mortar and pestle to grind their samples (Nejad et al., 2016). Ball-milling was therefore the preferred pulverisation method.

Extraction Solvent

To extract cortisol tightly bound within the nail plate, an extraction solvent is required. Consistent with hair cortisol research, nail cortisol studies used either 1 ml (Fruge et al., 2018; Nejad et al., 2016; Warnock et al., 2010) or 1.5 ml (Doan et al., 2018; Herane-Vives et al., 2017; Herane-Vives et al., 2018; Izawa et al., 2017; Izawa et al., 2015; Warnock et al., 2010) of methanol during the extraction of cortisol.

Mass spectrometry studies spiked their extraction solvent with an internal standard (IS). For example, two studies used 1 ml methanol and 50 µl IS (40 pg/ µl cortisone-D_7, DHEA-D_5, progesterone-D_9) (Voegel et al., 2018). Another study incubated their samples in 0.7 ml Sorensen

buffer (7.6 pH) and 10 ng cortisol-d3 (Ben Khelil et al., 2011). Another incubated their samples in ethanol and water containing 100 pg $^{2}H_{4}$-cortisol (Higashi et al., 2016). Finally, one mass spectrometry study compared extraction solvents: 1 ml methanol spiked with 2000 pg IS (D7-cortisone) (incubation repeated either once or twice) and 1 ml methanol/acetonitrile/water (25:25:50, *v/v/v)* (Binz et al., 2018). This study found that a single incubation, using methanol, was superior. Both types of assays used methanol as the primary extraction solvent.

Extraction Duration and Temperature

Maximal cortisol concentration recovery requires the incubation of nail samples. Studies typically incubated their samples at room temperature for 18 to 24 hours (Doan et al., 2018; Fruge et al., 2018; Izawa et al., 2017; Izawa et al., 2015; Nejad et al., 2016; Warnock et al., 2010). Two studies only incubated their samples for one hour (Herane-Vives et al., 2017; Herane-Vives et al., 2018), and one study incubated for two hours (Wu et al., 2018). It will be important to determine whether cortisol concentrations differ as a function of extraction duration by using a uniform assay as at present the different assay methods preclude such analysis. Most mass spectrometry studies incubated their samples for two hours at 45 °C (Ben Khelil et al., 2011), 55 °C (Binz et al., 2018; Voegel et al., 2018; Voegel et al., 2019), or 60 °C (Higashi et al., 2016). One mass spectrometry study extracted their samples for 24 hours (Davison et al., 2019). Despite this study, mass spectrometry involved faster extraction periods.

Centrifugation

Centrifugation is required for supernatant formation during cortisol extraction. Some nail cortisol studies centrifuged samples at 1000 g (Higashi et al., 2016), 9000 g (Binz et al., 2018; Voegel et al., 2018), or 10000 g (Fruge et al., 2018). While, other studies reported the centrifugation speed as 1000 rpm (Nejad et al., 2016) or 10,000 rpm (Nejad et al., 2016) or 10,000 rpm (Izawa et al., 2017; Izawa et al., 2015; Warnock et al., 2010). The centrifugation time ranged from 2 minutes (Izawa et al., 2017; Izawa et al., 2015), 5 minutes (Binz et al., 2018; Fruge et al., 2018; Voegel et al., 2018; Warnock et al., 2010), and 10 minutes (Higashi et al., 2016). Although four studies reported centrifuging their

samples, they did not report the centrifugation speed or time (Ben Khelil et al., 2011; Herane-Vives et al., 2017; Herane-Vives et al., 2018). One study did not report any centrifugation process (Doan et al., 2018). Speeds were reported in different units and consequently could not be converted into the same unit without the radius of the centrifuge rotor being reported. Although the differences in centrifuge speed, time, and reported units are unlikely to affect the samples, the standardisation of this protocol stage and its reporting would improve the validity of this novel biomarker

Solvent evaporation

Most studies reported evaporating their samples under a nitrogen gas stream (Binz et al., 2018; Fruge et al., 2018; Herane-Vives et al., 2017; Herane-Vives et al., 2018; Nejad et al., 2016; Voegel et al., 2018; Warnock et al., 2010). For whole nail extraction, Warnock et al. (2010) only described using a fume hood for evaporation overnight (Warnock et al., 2010). Two studies reported evaporating their samples under a vacuum (Doan et al., 2018) and another study just reported evaporating their samples until dry (Wu et al., 2018). Two mass spectrometry studies did not report any evaporation methods (Ben Khelil et al., 2011; Higashi et al., 2016). Some studies reported specific evaporation temperatures during this process, such as 35 °C (Binz et al., 2018; Voegel et al., 2018), 38 °C (Nejad et al., 2016), or 60 °C (Herane-Vives et al., 2017; Herane-Vives et al., 2018; Izawa et al., 2017; Izawa et al., 2015). Overall, solvent evaporation predominantly occurred under a nitrogen gas stream.

Storage

Eleven studies froze their samples prior to assay and stored them at -18 °C (Higashi et al., 2016), -20 °C (Binz et al., 2018; Voegel et al., 2018; Warnock et al., 2010), -30 °C (Herane-Vives et al., 2017; Herane-Vives et al., 2018; Izawa et al., 2017; Izawa et al., 2015; Warnock et al., 2010), or -80 °C (Fruge et al., 2018). Three studies did not report how their samples were stored (Ben Khelil et al., 2011; Doan et al., 2018; Nejad et al., 2016). One study stored their samples in a plastic bag in a cool room until processing approximately 40 months later (Davison et al., 2019). Another study investigated the differences between storing cortisol-extracted nail samples at room temperature or

in a freezer (Fruge et al., 2018). A significant strong positive correlation was found between frozen fingernails and room temperature fingernails ($r = 0.78$, $p < 0.001$, $n = 52$). A similar correlation was found between frozen toenails and room temperature toenails ($r = 0.95$, $p < 0.001$, $n = 72$). Overall, the majority of studies froze their samples before processing.

HPA Correlates

The establishment of nail cortisol as a biomarker of chronic stress relies on evidence of convergent validity with HPA axis measures already established in the literature. Current nail cortisol literature has explored the relationship between nail cortisol and cortisol extracted from other sources including saliva and hair.

Nail Cortisol Ranges

Studies that indicated their cortisol range were reported in *Table 2*. There was little consensus in the measures of central tendency and spread reported between studies (mean, median, minimum/maximum, interquartile range, $10^{th,}$ and 90^{th} percentiles). Further, about 70% of the 18 studies reported their cortisol concentrations as “pg/mg”. While three studies reported their concentrations as “nmol/L”, one study reported “nmol/g”, and another study reported “ng/g”. The extracted nail cortisol concentrations were smaller than the values extracted from hair and saliva. It is difficult to determine reliable normative ranges based on demographic variables due to limited studies, variable assay methods, and limited consensus in reporting of concentration type.

Salivary Cortisol

Three studies measured salivary cortisol in conjunction with nail cortisol (Fruge et al., 2018; Izawa et al., 2015; Messerli-Burgy et al., 2018). One study collected saliva from healthy male (27%) and female (73%) nursing home workers ($N = 37$), four times, (at awakening, 30 minutes after awakening, before lunch, and after work), over the course of one day (Izawa et al., 2015). This collection process was repeated a month later. Fingernail cortisol was collected monthly over a six-month period. Diurnal salivary cortisol concentrations moderately correlated with fingernail cortisol samples collected four months ($r = 0.43$, $p < 0.05$, $n = 32$) and five months ($r = 0.45$, $p < 0.05$, $n = 29$)

later. This delay in association supports the variation in cortisol accumulation within fingernails compared to the acute salivary cortisol response.

Saliva and nail (fingernail and toenail) samples were collected from 109 adult male (13%) and female (87%) cancer survivors participating in vegetable gardening trials at baseline, 12 months, and 24 months (Fruge et al., 2018). A single saliva sample was collected during home visits between 8:00am and 2:00pm at each time point. Participants were asked to clip their nails prior to these home visits. Considering all time points, only room temperature-stored nail samples significantly correlated with salivary cortisol. A positive moderate relationship was found between cortisol quantified from toenails stored in room temperature and salivary cortisol concentrations ($r = 0.58$, $p < 0.001$, $n = 168$). In contrast, a positive weak association was found between cortisol recovered from fingernails stored at room temperature and salivary cortisol concentrations ($r = 0.29$, $p < 0.001$, $n = 147$). Therefore, toenail cortisol concentrations were more strongly associated with salivary cortisol concentrations.

The final study collected five samples of saliva from male (52%) and female (48%) children ($N = 324$) over one day (Messerli-Burgy et al., 2018). Saliva was collected within 5 minutes of awakening (around 7:30 am – 8:00 am), 30 minutes after awakening (before breakfast), before lunchtime (11:30 am – 12:00 pm), before snack (4:00 pm), and at bedtime (8:00 pm). The time period over which fingernail samples were collected was unclear. No significant association was found between nail cortisol concentrations and diurnal salivary cortisol ($r = 0.11$, $p > 0.05$, $n = 191$). Therefore, two out of the three studies showed a relationship between cortisol extracted from nails and saliva.

Hair Cortisol

The detection of cortisol in hair is similar to its detection in nails, particularly its methodology, due to being keratinised tissue. Five studies investigated the relationship between hair and nail cortisol. The first study to examine this relationship sampled healthy middle age to elderly men ($N = 58$) who had not experienced any recent stressful life events (Izawa et al., 2015). Approximately 6 cm of hair was collected to examine cortisol levels across six months and two weeks

of nail growth was collected simultaneously. A significant weak positive correlation was found between hair and nail cortisol levels ($r = 0.29$, $p < 0.05$, $n = 56$). The strength of this relationship was moderate when using rank-order correlations ($r_s = 0.36$, $p < 0.01$, $n = 56$). Using the same methodology, these findings were reproduced by these researchers in a recent study of acute coronary syndrome in middle age to elderly men ($r = 0.22$, $p = 0.006$, $n = 166$; Izawa et al., 2019).

Nails and facial (beard) hair (10 days of growth from each source) from male university students over three time points were collected (Nejad et al., 2016). A significant strong positive correlation was observed between facial hair and toenail cortisol ($r = 0.73$, $p < 0.001$, n =19). Only a significant moderate positive correlation was found between facial hair and fingernail cortisol (r = 0.54, $p = 0.01$, n =19).

Another study collected nails from healthy male (34%) and female (66%) volunteers ($N = 120$) and examined various steroid concentrations within them (Binz et al., 2018). However, when comparing cortisol concentrations in hair compared to toenail (big toe) samples, these researchers found no significant correlation ($r = 0.17$, $p > 0.05$, $n = 120$). Further, a paired t-test found higher cortisol concentrations in hair when compared to toenails ($p < 0.001$, $n = 120$).

Similarly, a recent study using toenail clippings (big toe) from healthy volunteers ($N = 38$) also found no significant correlation between cortisol in hair and toenails ($r = 0.12$, $p > 0.05$, $n = 38$; Voegel et al., 2019). Likewise, they also found higher concentrations of cortisol in hair compared to toenails ($p < .0001$, $n = 38$). This lack of association between hair and nail cortisol in these previous studies may be due to methodological differences, such as only utilising toenails from the big toe instead of pooling all digits and using fingernails.

Early Life Nail Cortisol Concentrations

Nail cortisol may be a practical measure of cortisol across developmental periods, including early childhood and adolescence.

Early Childhood

Only three studies investigated nail cortisol in children. One study examined the nail cortisol concentrations of infants (*n* = 7) and pregnant and non-pregnant mothers (*n* = 31) (Voegel et al., 2018). There was no significant difference between the cortisol levels of female infants and mothers ($p > 0.05$, *n* = 38). The concentrations also remained stable with varying nail masses, which is critical due to the small samples available from infants. Nail clippings were taken at various time points for infants (1 to 15 months post-natal) and mothers (pregnancy week 18 to post-partum month 13). Overall, the focus of this study was on validating the detection and quantification of steroids.

Similarly, a published conference abstract detailed an investigation into longitudinal nail cortisol changes observed in at-risk children (*N* = 125) (Hubmann et al., 2016). Nail clippings were collected at 24 months and 36 months post-natal. There was no significant association between these two time points. A large proportion of these children experienced stable (*n* = 37) or decreased (*n* = 31) nail cortisol concentrations across the time points. The remaining children had increased (*n* = 15) cortisol concentrations. Due to the abstract format, limited information could be extracted to inform the review of this study.

Finally, a recent study has focused on nail cortisol concentrations in preschool children (Messerli-Burgy et al., 2018). Male and female children aged 2 to 6 years old were recruited from 84 childcare centres (*n* = 324). Physiological stress was measured using diurnal salivary alpha-amylase (sAA), salivary cortisol, nail cortisol, heart rate variability, body composition (body mass index), and behavioural problems (Strengths and Difficulties Questionnaire). This study did not find any significant relationships between nail cortisol and the other measures ($p > 0.05$, *n* = 316). In this study, the HPA axis and autonomic nervous system measures were not related. However, the replication of this study using more diverse ages is needed to further examine child stress response pathways and support nail steroid quantification.

Multi-cultural youth

Measuring cortisol from hair can be limited by availability and cultural acceptability. As fingernails are structurally the same across cultures, they may be a more practical and inclusive source of cortisol for some groups. Two studies have measured nail cortisol from African American and Australian Indigenous youth.

The first study recruited high-risk African American male and female adolescents (age not reported) from a low-income background (N = 47, two Caucasian participants) (Doan et al., 2018). The rationale for selecting nail cortisol instead of hair cortisol, as the outcome measure, was due to the increased availability of nails, as a consequence of hair being kept short or shaven in this population. This study found that nail cortisol concentrations were not correlated with perceived subjective stress (r = -0.06, p > .05, n = 44), sleep efficiency (r = 0.19, p > .05, n = 44) or quality (r = 0.08, p > .05, n = 44), daytime disturbances (r = -0.12, p > .05, n = 44), or academic stress (r = 0.16, p > .05, n = 44). However, nail cortisol was significantly associated with self-control (r = 0.42, p = 0.007, n = 44). Therefore, increased nail cortisol concentrations were related to improved self-regulatory abilities.

Similarly, a recent study analysed nail cortisol from Australian Indigenous (n = 179) and non-Indigenous (n = 66) youth as part of the Aboriginal Birth Cohort (ABC) and Top End Cohort (TEC) health assessment programs (Davison et al., 2019). This study had a similar rationale for collecting nails compared to hair as the previous study and further highlighted the need for greater chronic stress biomarker use in Australian and Indigenous contexts. Nail cortisol levels were not significantly different between the Indigenous and non-Indigenous groups within this study (p > 0.05, n = 245). However, there was a significant association with fingernail cortisol and Indigenous status (*Geometric Mean [GM]* = 1.82, p = .027, n = 245) and number of stressful events (*GM* = 0.90, p = .0001, n = 245) after adjusting for age, gender, Indigenous status, and other demographic factors. As the number of stressful events increased, fingernail cortisol levels were significantly reduced in Indigenous youth (*GM* = 0.89, p = .001, n = 179) and women (*GM* = 0.88, p = .003, n = 134). This supports the

hypoactive cortisol response observed over long-term periods of stress, which has been previously observed after periods of cumulative trauma (Elzinga et al., 2008). Further, there was a significant association between increasing fingernail cortisol levels and increasing levels of psychological distress in Indigenous women (*GM* = 1.07, *p* = 0.02, *n* = 95) (Davison et al., 2019).

More studies are needed to improve the generalisability of these findings within young and diverse populations.

Psychosocial Stress in Adulthood

The biological cost of repeated exposure to psychosocial stressors in adulthood may be detected in nail cortisol concentrations. A pilot study examined the effect of exam stress on nail cortisol in young adult university students (*N* = 33, 79% female) with no significant health conditions (Warnock et al., 2010). It was hypothesised that nail cortisol could represent a more targeted period of chronic stress. These original researchers proposed that 1mm of nail clipping was equivalent to 10 days of cortisol accumulation that occurred three months in the past. Fingernail clippings were collected according to the average nail growth rate suggested to represent either a period of no stress or an exam period. This study found a significant increase in the cortisol:DHEA ratio during the exam period ($p < .001$, $n = 31$). This ratio was more reflective of a significant decrease in DHEA, as cortisol only marginally increased during the exam period ($p > 0.05$, $n = 31$). These findings are difficult to interpret as the accumulation of cortisol into nails is more complex than discussed by these authors and not as targeted as they have implied.

Similarly, another study recruited male university students (*N* = 19) to investigate cortisol concentrations in facial hair and nails during minimal stress (university study period), mental stress (exam period), and physical stress (exercise) (Nejad et al., 2016). This study found that facial hair ($p = 0.045$, $n = 19$), fingernail ($p = 0.043$, $n = 19$), and toenail ($p = 0.031$, $n = 19$) cortisol concentrations were significantly higher during the periods of mental and physical stress than baseline. However, no difference was found between either type of stress (exam or physical stress) ($p > 0.05$, $n = 19$). This study, therefore, supported the quantification of cortisol in nails as an indicator of exposure to

environmental stressors. However, unlike the former study, using a mostly female sample, this stronger effect in a male sample may suggest sex has a role in cortisol detection. Further, it is difficult to reliably state that these particular periods of time were reflected in the samples collected, as there is a lack of evidence supporting the temporal resolution of nail cortisol.

Stressful life events in the workplace, perceived stress, and occupational strain were recently investigated in a sample (n = 123, 76% male) of middle-aged workers (hospital personnel and research institute staff) with no significant health conditions (Izawa et al., 2017). Psychosocial correlates were measured using self-report scales. Fingernail clippings were collected at the time of the questionnaires. Adjusting for demographic variables, this study found that stressful life events in the workplace were associated with increased nail cortisol concentrations (β = 0.209, p = 0.019, n = 123). Participants with stressful life events (experienced 1+ events), had significantly higher cortisol levels (t(121) = 2.62, p = 0.010) compared to those without stressful life events. Consistent with nail cortisol research in adolescents (Doan et al., 2018), this study (Izawa et al., 2017) found no association between nail cortisol concentrations and perceived stress (β = -0.082, p = 0.406, n = 123). Job strain was also not associated with nail cortisol levels (β = 0.152, p = 0.125, n = 123).

Despite these studies, a recent investigation found an association between perceived stress and fingernail cortisol in medical university students (r = 0.415, p < 0.001, n = 51, 69% female) (Wu et al., 2018). Participants had their fingernails clipped on Day 0 and on Day 30 were asked to complete the Perceived Stress Scale. On Day 15 and Day 45 fingernail clippings (15 days of growth) were collected. After adjusting for age, gender, body mass index, and physical activity, there was a significant positive association between perceived stress and the cortisol levels of fingernails collected on Day 45 (β = 0.436, p = 0.003, n = 51). There was no significant association between perceived stress and the cortisol levels in Day 15 fingernail samples (r = -0.008, p = 0.956, n = 51). Therefore, the time between the collection of fingernails and reporting perceived stress should be taken into consideration as perceived stress is a measure of a participant's reported current stress

levels while nail cortisol is a far more complex measure of their physiological response to stress over a currently unknown retrospective timeframe.

Health Disorders

Nail cortisol concentrations have been examined in individuals diagnosed with acute coronary syndrome, bipolar I disorder, and major depressive disorder.

Acute Coronary Syndrome

Psychosocial stress has been linked to a greater risk of cardiovascular disease (Lagraauw et al., 2015). Recently, the association between cortisol concentrations and acute coronary syndrome was investigated in middle-aged to elderly males (*N* = 166; Izawa et al., 2019). This study collected hair samples approximately equivalent to six months of cortisol levels prior to the onset of acute coronary syndrome. Fingernail clippings were also collected. Hair and fingernail cortisol concentrations were significantly higher in men with acute coronary syndrome (*n* = 73) compared to healthy controls (*n* = 93) (*OR*: 2.23, *p* = .046, *n* = 162). Higher nail cortisol levels were associated with a greater risk of acute coronary syndrome in traditional risk factor-adjusted models (*OR*: 2.48, *p* = .049, *n* = 162) but not models adjusted for psychosocial risk factors (*OR*: 2.14, *p* = .105, *n* = 162). Therefore, higher fingernail cortisol levels are associated with a greater risk of acute coronary syndrome.

Bipolar I Disorder

Nail cortisol concentrations, as an indicator of bipolar I disorder, have been examined by collecting nail clippings from adult patients (63% male) diagnosed with euthymic (stable mood state) bipolar I disorder (*n* = 40) and age- and gender-matched controls (*n* = 42) (Herane-Vives et al., 2017). These participants were diagnosed, as part of a larger study (Eric et al., 2013), using the Chinese version of the Structured Clinical Interview for “The Diagnostic and Statistical Manual of Mental Disorders” (DSM). Although nail cortisol levels were higher in euthymic participants with bipolar I disorder, this difference was not significant (*z* = -1.65, *p* = 0.09, *n* = 82). Furthermore, no significant associations were found between nail cortisol concentrations and the number of manic episodes, the

number of depressive episodes, the number of psychotic episodes, duration of illness, age of onset, number of hospitalisations or number of medications after adjusting for age and gender ($p > .05$, $n = 82$). However, increased duration of euthymic periods decreased the odds of experiencing higher nail cortisol concentrations (*OR*: 0.19, $p = 0.04$, $n = 82$).

Major Depressive Disorder

Nail cortisol concentrations as a biomarker of major depressive disorder were recently assessed (Herane-Vives et al., 2018). Participants meeting the DSM-IV criteria for major depressive disorder ($n = 26$) were recruited from local psychological therapy and secondary care services. Healthy controls ($n = 45$) were matched by age and gender with the depressed participants. Fingernail clippings representing 15 days of growth were collected. Participants with major depressive disorders showed significantly higher nail cortisol concentrations compared to their matched controls ($p = .003$, $n = 71$). High nail cortisol concentrations were related to increased depression severity scores ($\beta = 0.09$, $p = 0.02$, $n = 71$), a non-reactive depression diagnosis ($\beta = 0.90$, $p = 0.01$, $n = 71$), and greater melancholic symptoms ($\beta = 0.19$, $p = 0.01$, $n = 71$). Lower cortisol concentrations were associated with more severe levels of fatigue after adjusted for age and gender ($\beta = -0.04$, $p = 0.04$, $n = 71$).

Overall, limited investigations into stress-related pathologies make it difficult to investigate a clear link between nail cortisol concentrations and stress-related health concerns.

Discussion

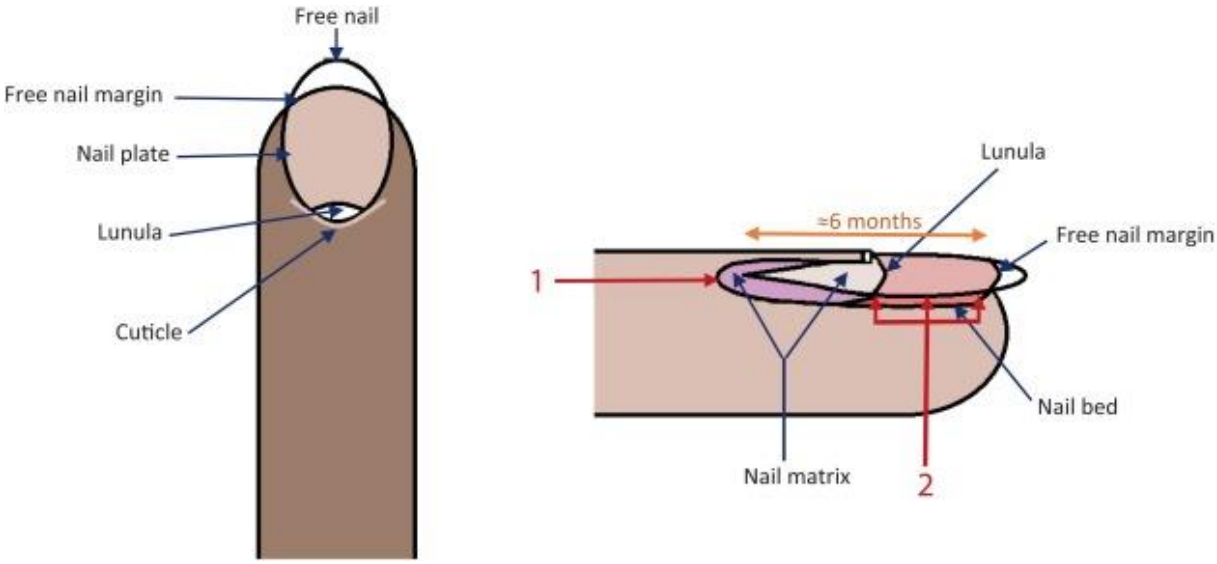
This systematic review qualitatively synthesized the methodological issues and functional correlates of nail cortisol concentrations as a retrospective chronic stress biomarker. Overall, nails are likely a viable source of cortisol for investigating chronic stress. However, continued standardisation and further studies are required for nail cortisol to become established and equivalent to hair cortisol in the literature.

Temporal Resolution

Nail cortisol is fast becoming an alternative to hair and may offer an alternative method of looking at past chronic stress levels. The authors who first reported nail cortisol suggested that it could target specific past events. They proposed that 1 mm of free nail equates to approximately 10 days of circulating cortisol that has occurred three months in the past. Alternatively, the mechanism by which nail cortisol diffuses into nails remains complex. Research indicates that drugs can be diffused into nails via a double mechanism (Palmeri et al., 2000; see Figure 19). Firstly, cortisol can enter the nail via the nail matrix. In adults, fingernails take approximately six months to grow from the nail matrix to become a free nail. Therefore, when the free nail is collected it likely has cortisol concentrations from up to six months in the past. The second major diffusion mechanism is through the nail bed. The nail bed starts at the lunula (end of the nail matrix) and ends at the free nail. Therefore, more recent deposits of cortisol can enter the free nail as it grows out of the nail bed. As such, cortisol concentrations in nails likely range from approximately one week to six months of accumulation. Further, there is a paucity of studies investigating whether there is a washout effect in cortisol extracted from nails.

Figure 19

The diffusion of cortisol into fingernails.



Note. Fingernails take approximately 6 months to grow from the distal nail matrix to the free nail margin. 1) Cortisol is deposited into the distal nail matrix via blood flow. 2) Cortisol is incorporated via the nail bed during growth from the lunula to the free margin of the free nail. Image adapted from Palmeri et al. (2000).

This lack of insight into the temporal resolution of nail cortisol compared to hair cortisol is a significant limitation. Hair cortisol has a more targeted temporal resolution as 1cm from the scalp is approximately 1 month of cortisol accumulation. Although past research suggests that nail growth is faster in younger people, males, and those who bite their nails, which makes the temporal resolution of nail cortisol difficult to track (Yaemsiri et al., 2009). Hair cortisol is also affected by variations in growth rates due to individual differences such as ethnicity (Loussouarn et al., 2016). Alternatively, nail cortisol's retrospective capability may be valuable in neonatal research. Currently, umbilical cord blood cortisol concentrations are a critical measure in neonatal stress hormone research (Su et al., 2015). Hair samples, however, are not always available from infants. As nails develop at eight weeks gestation (Mari et al., 2008), nail samples from newborns could offer insight into prenatal stress, as

well as create the opportunity for source-consistent follow-ups throughout development. The sampling of infant nails may induce a stress response. Consequently, it is recommended that an adult with a close attachment to the infant (a mother for example) collect the nails. Therefore, cortisol extracted from nails may offer researchers a wide but still retrospective alternative temporal resolution of chronic stress responses.

Methodological Issues

The validation of a novel stress measure requires procedural homogeneity and extraction efficacy. Although the methodology of Warnock et al. (2010) was often referenced within studies, most nail cortisol extraction procedures were adapted independently, likely due to reagent and equipment availability. A study investigating nail cortisol methodology which was not included in the final manuscript due to being non-English found that finer grinding and longer extraction times increased cortisol concentrations, which may explain some differences in baseline cortisol concentrations (Izawa et al., 2016). The most frequently used assay in the literature at this point is salivary immunoassay. Consensus over which assay to utilise is poor. Some researchers suggest that mass spectrometry is more specific, sensitive, and reproducible than immunoassay (Turpeinen & Hamalainen, 2013). In addition, other steroids may cross-react within immunoassays (Turpeinen & Hamalainen, 2013). Overall, the type of assay utilised by researchers is likely determined by equipment accessibility and funding. Often mass spectrometry involves expensive instruments while immunoassays may require higher priced reagents. To ensure that low concentrations of cortisol in nails can be measured, the authors recommend using mass spectrometry. Further, Mass spectrometry methods quantified samples as low as 1 mg (Ben Khelil et al., 2011; Binz et al., 2018), while immunoassays were unable to reliably measure cortisol in samples less than 10 mg. However, mass spectrometry methodology can be technically complex and specific to the laboratory it is developed in. For a more automated process, researchers can use immunoassays but these should come from the same manufacturer due to commercially-developed variations. A comparative review of these methods was produced by Stanczyk & Clarke (2010)

HPA Correlates

The establishment of nail cortisol as a measure of HPA axis activation relies on its convergence with already validated measures. For example, nail cortisol, particularly extracted from toenails, was associated with salivary cortisol. However, more studies are needed, using the same salivary collection time points, in order to determine the strength of this relationship. Hair is structurally more comparable to nails than saliva and still potentially reflects a retrospective time period. Nail cortisol was positively correlated with hair in studies that pooled their nail clippings from different digits, but not studies using only big toe toenail clippings. Overall, more research is needed comparing nail cortisol to alternative sources of cortisol in order to strengthen the validity of this novel measure.

Target Populations

Some studies focused their investigations on chronic HPA axis function in early life and adolescence. The dysregulation of the HPA axis in early life is associated with the emergence of psychiatric conditions later in life (Syed & Nemeroff, 2017). Although studies analysed infant and child nail cortisol, the multi-linear relationship between infant and mother cortisol levels and exposure to maternal stress was not examined.

Two studies investigated nail cortisol concentrations in multicultural youth due to its increased cultural acceptability (Davison et al., 2019; Doan et al., 2018). The first study's target population was African American high school students (Doan et al., 2018). However, the age of these students was not reported, which may restrict the generalisability of these findings. Further, no control group was examined to compare whether cortisol levels varied according to ethnicity. The second study compared the cortisol levels of Australian Indigenous and non-Indigenous youth. Indigenous young adults, particularly women, had higher levels of cortisol when adjusted for age, gender, emotional distress, and exposure to stressful events (Davison et al., 2019). However, as the number of stressful events increased, fingernail cortisol levels were significantly reduced. Indigenous youth appeared to experience a blunted cortisol response after exposure to a greater number of

stressful events compared to non-Indigenous youth. This blunted cortisol response is similar to that seen in individuals with post-traumatic stress disorder (Pan et al., 2019) and might be a consequence of the unique stressors Indigenous Australians face such as race-based discrimination and intergenerational disadvantage. Overall, there is a need for further exploration into nail cortisol correlations and early life stress correlates in diverse populations.

Psychosocial stress in adults has also been examined (Izawa et al., 2017; Nejad et al., 2016; Warnock et al., 2010; Wu et al., 2018). Increased nail cortisol levels were found during exam periods in university students. However, this increase was only significant in males. In middle-aged workers, stressful workplace events were associated with increased nail cortisol concentrations. However, nail cortisol was not reliably associated with perceived stress. Confounders such as gender or physical stress may affect this relationship.

Psychosocial stressors and consequently altered HPA axis function can play a role in the development of stress-related pathology. There has been little focus on investigating the link between nail cortisol levels and stress-related disorders in the reviewed literature. Acute coronary syndrome was associated with fingernail cortisol. Only participants diagnosed with depression had increased nail cortisol levels. A lack of association between bipolar I disorder, and nail cortisol may be the result of recruiting euthymic patients. Overall, reproduction is required due to the limited number of studies connecting nail cortisol concentrations to stress-related psychopathology.

Limitations

A limitation of this systematic review was that only very few studies showed above-average reporting completeness. Although various nail types (fingernails and toenails) have been investigated and show different concentrations, a significant limitation of the reviewed studies was the lack of reporting on potential covariates, such as age, sex, ethnicity, medication use, nail growth rate, nail-biting, and nail polish. Very few studies reported effect sizes or reported relevant data required to calculate an effect size. Of the studies with significant findings, nail cortisol appears to have a moderate effect. Additionally, nail cortisol may not always be suitable, particularly for individuals

who engage in nail picking or biting, which leaves no free nail. Only a few studies reported the effects of nail polish use, with limited consensus. In a recent meta-analysis, age and sex mediated hair cortisol levels (Stalder et al., 2017). Males and older participants were more likely to have increased cortisol levels. Although there are not enough studies in the current review to suggest a sex bias, sex may have influenced the studies with sex-skewed samples, particularly those examining exam stress in university students. Additionally, physical activity levels should also be considered, as increased physical activity was associated with higher nail cortisol levels (Nejad et al., 2016). More studies are needed to examine events of stress from diverse sociodemographic samples. Like research investigating hair cortisol, the effect of individual variations should be investigated further or adjusted for in future studies.

Conclusion

Cortisol extracted from human nails is becoming an emerging biomarker of chronic stress. Recent publications utilising this novel source of cortisol have doubled in the past year. The systematic review extracted a total of 18 human studies. A qualitative synthesis was used to examine the methodological issues and functional correlates of nail cortisol. Like hair cortisol, nail cortisol is extracted using analogous procedures. However, variability within and across the type of assay used (immunoassay or mass spectrometry) still exists. Further, nail cortisol concentrations are more complex to track and likely represent a much wider temporal resolution compared to hair. Although limited by the number of available studies, there is some evidence that nail cortisol is correlated to other HPA axis correlates including saliva and hair cortisol. Nail cortisol has been quantified across various developmental periods and populations and may be more practical to measure from some individuals where hair is not accessible or culturally acceptable. In summary, nails are a non-invasive and inclusive source of cortisol, which may offer an alternative but complex temporal resolution of retrospective chronic stress.

Conflict of Interest

The authors declare no conflict of interest.

Funding

The Australian Government Research Training Program Scholarship supported this project.

Acknowledgments

The authors would like to thank Dr Joseph Moxon for his statistical guidance.

References

Abell, J. G., Stalder, T., Ferrie, J. E., Shipley, M. J., Kirschbaum, C., Kivimäki, M., & Kumari, M. (2016). Assessing cortisol from hair samples in a large observational cohort: The Whitehall II study. *Psychoneuroendocrinology*, *73*, 148-156. https://doi.org/10.1016/j.psyneuen.2016.07.214

Albar, W. F., Russell, E. W., Koren, G., Rieder, M. J., & van Umm, S. H. (2013). Human hair cortisol analysis: Comparison of the internationally-reported ELISA methods. *Clinical and Investigative Medicine*, *36*(6), E312-316.

Aschbacher, K., Kornfeld, S., Picard, M., Puterman, E., Havel, P. J., Stanhope, K., Lustig, R. H., & Epel, E. (2014). Chronic stress increases vulnerability to diet-related abdominal fat, oxidative stress, and metabolic risk. *Psychoneuroendocrinology*, *46*, 14-22. https://doi.org/10.1016/j.psyneuen.2014.04.003

Azuma, K., Adachi, Y., Hayashi, H., & Kubo, K. Y. (2015). Chronic psychological stress as a risk factor of osteoporosis. *Journal of UOEH*, *37*(4), 245-253. https://doi.org/10.7888/juoeh.37.245

Bekes, V., Dunkley, D. M., Taylor, G., Zuroff, D. C., Lewkowski, M., Elizabeth Foley, J., Myhr, G., & Westreich, R. (2015). Chronic stress and attenuated improvement in depression over 1 year: The moderating role of perfectionism. *Behavior Therapy*, *46*(4), 478-492. https://doi.org/10.1016/j.beth.2015.02.003

Ben Khelil, M., Tegethoff, M., Meinlschmidt, G., Jamey, C., Ludes, B., & Raul, J. S. (2011). Simultaneous measurement of endogenous cortisol, cortisone, dehydroepiandrosterone, and dehydroepiandrosterone sulfate in nails by use of UPLC-MS-MS. *Analytical and Bioanalytical Chemistry*, *401*(4), 1153-1162. https://doi.org/10.1007/s00216-011-5172-3

Binz, T. M., Gaehler, F., Voegel, C. D., Hofmann, M., Baumgartner, M. R., & Kraemer, T. (2018). Systematic investigations of endogenous cortisol and cortisone in nails by LC-MS/MS and correlation to hair. *Analytical and Bioanalytical Chemistry*, *410*(20), 4895-4903. https://doi.org/10.1007/s00216-018-1131-6

Chan, S., & Debono, M. (2010). Replication of cortisol circadian rhythm: New advances in hydrocortisone replacement therapy. *Therapeutic Advances in Endocrinology and Metabolism*, *1*(3), 129-138. https://doi.org/10.1177/2042018810380214

Davison, B., Singh, G. R., Oguoma, V. M., & McFarlane, J. (2019). Fingernail cortisol as a marker of chronic stress exposure in Indigenous and non-Indigenous young adults. *Stress*, *23*(3), 298–307. https://doi.org/10.1080/10253890.2019.1683159

de Berker, D. A., Andre, J., & Baran, R. (2007). Nail biology and nail science. *International Journal of Cosmetic Science*, *29*(4), 241-275. https://doi.org/10.1111/j.1467-2494.2007.00372.x

Dikme, O., & Dikme, O. (2018). Serum cortisol as a predictor of major adverse pulmonary event in emergency department acutely dyspneic patients. *Emergency Medicine International*, *2018*, 1758643. https://doi.org/10.1155/2018/1758643

Doan, S. N., DeYoung, G., Fuller-Rowell, T. E., Liu, C., & Meyer, J. (2018). Investigating relations among stress, sleep and nail cortisol and DHEA. *Stress*, *21*(2), 188-193. https://doi.org/10.1080/10253890.2018.1429398

El-Farhan, N., Rees, D. A., & Evans, C. (2017). Measuring cortisol in serum, urine and saliva - are our assays good enough? *Annals of Clinical Biochemistry*, *54*(3), 308-322. https://doi.org/10.1177/0004563216687335

Elzinga, B. M., Roelofs, K., Tollenaar, M. S., Bakvis, P., van Pelt, J., & Spinhoven, P. (2008). Diminished cortisol responses to psychosocial stress associated with lifetime adverse events: A study among healthy young subjects. *Psychoneuroendocrinology*, *33*(2), 227-237. https://doi.org/10.1016/j.psyneuen.2007.11.004

Eric, Y. W., Halari, R., Cheng, K. M., Leung, S. K., & Young, A. H. (2013). Cognitive performance is impaired in euthymic Chinese patients with Bipolar 1 Disorder. *Journal of Affective Disorders*, *151*(1), 156-163. https://doi.org/10.1016/j.jad.2013.05.070

Eswarappa, M., Neylan, T. C., Whooley, M. A., Metzler, T. J., & Cohen, B. E. (2018). Inflammation as a predictor of disease course in posttraumatic stress disorder and depression: A prospective

analysis from the Mind Your Heart Study. *Brain, Behavior, and Immunity*, *75*, 220–227. https://doi.org/10.1016/j.bbi.2018.10.012

Fischer, S., Duncko, R., Hatch, S. L., Papadopoulos, A., Goodwin, L., Frissa, S., Hotopf, M., & Cleare, A. J. (2017). Sociodemographic, lifestyle, and psychosocial determinants of hair cortisol in a South London community sample. *Psychoneuroendocrinology*, *76*, 144-153. https://doi.org/10.1016/j.psyneuen.2016.11.011

Fruge, A. D., Cases, M. G., Howell, C. R., Tsuruta, Y., Smith-Johnston, K., Moellering, D. R., & Demark-Wahnefried, W. (2018). Fingernail and toenail clippings as a non-invasive measure of chronic cortisol levels in adult cancer survivors. *Cancer Causes Control*, *29*(1), 185-191. https://doi.org/10.1007/s10552-017-0989-5

Herane-Vives, A., Cleare, A. J., Chang, C. K., de Angel, V., Papadopoulos, A., Fischer, S., Halari, R., Cheung, E. Y. W., & Young, A. H. (2017). Cortisol levels in fingernails, neurocognitive performance and clinical variables in euthymic bipolar I disorder. *The World Journal of Biological Psychiatry*, 1-12. https://doi.org/10.1080/15622975.2017.1298838

Herane-Vives, A., Fischer, S., de Angel, V., Wise, T., Cheung, E., Chua, K. C., Arnone, D., Young, A. H., & Cleare, A. J. (2018). Elevated fingernail cortisol levels in major depressive episodes. *Psychoneuroendocrinology*, *88*, 17-23. https://doi.org/10.1016/j.psyneuen.2017.10.026

Higashi, T., Yamagata, K., Kato, Y., Ogawa, Y., Takano, K., Nakaaze, Y., Iriyama, T., Min, J. Z., & Ogawa, S. (2016). Methods for determination of fingernail steroids by LC/MS/MS and differences in their contents between right and left hands. *Steroids*, *109*, 60-65. https://doi.org/10.1016/j.steroids.2016.02.013

Hou, G., Tian, R., Li, J., & Yuan, T. F. (2014). Chronic stress and Parkinson's disease. *CNS Neuroscience & Therapeutics*, *20*(1), 1-2. https://doi.org/10.1111/cns.12209

Hubmann, P., Neuhauser, A., Schaub, S., Burkhardt, S. C. A., Lanfranchi, A., & Ehlert, U. (2016). A longitudinal view on nail cortisol: Stability and changes over one year in early childhood. *Psychoneuroendocrinology*, *71*, 75. https://doi.org/10.1016/j.psyneuen.2016.07.194

Izawa, S., Matsudaira, K., Miki, K., Arisaka, M., & Tsuchiya, M. (2017). Psychosocial correlates of cortisol levels in fingernails among middle-aged workers. *Stress*, *20*(4), 386-389. https://doi.org/10.1080/10253890.2017.1342808

Izawa, S., Miki, K., Tsuchiya, M., Mitani, T., Midorikawa, T., Fuchu, T., Komatsu, T., & Togo, F. (2015). Cortisol level measurements in fingernails as a retrospective index of hormone production. *Psychoneuroendocrinology*, *54*, 24-30. https://doi.org/10.1016/j.psyneuen.2015.01.015

Izawa, S., Miki, K., Tsuchiya, M., Yamada, H., & Nagayama, M. (2019). Hair and fingernail cortisol and the onset of acute coronary syndrome in the middle-aged and elderly men. *Psychoneuroendocrinology*, 101, 240-245. https://doi.org/10.1016/j.psyneuen.2018.11.021

Izawa, S., Yoshida, R., Ohira, M., Yamaguchi, A., & Nomura, S. (2016). Quantitative measurements of fingernail cortisol: Effects of ground-fingernail grain size and extraction time. Japanese *Journal of Physiological Psychology and Psychophysiology*, *34*(3), 245-249.

Juster, R.-P., McEwen, B. S., & Lupien, S. J. (2010). Allostatic load biomarkers of chronic stress and impact on health and cognition. *Neuroscience & Biobehavioral Reviews*, *35*(1), 2-16. https://doi.org/10.1016/j.neubiorev.2009.10.002

Kim-Fuchs, C., Le, C. P., Pimentel, M. A., Shackleford, D., Ferrari, D., Angst, E., Hollande, F., & Sloan, E. K. (2014). Chronic stress accelerates pancreatic cancer growth and invasion: a critical role for beta-adrenergic signaling in the pancreatic microenvironment. *Brain, Behavior, and Immunity*, *40*, 40-47. https://doi.org/10.1016/j.bbi.2014.02.019

Kirschbaum, C., & Hellhammer, D. H. (1994). Salivary cortisol in psychoneuroendocrine research: recent developments and applications. *Psychoneuroendocrinology*, *19*(4), 313-333. https://doi.org/10.1016/0306-4530(94)90013-2

Lagraauw, H. M., Kuiper, J., & Bot, I. (2015). Acute and chronic psychological stress as risk factors for cardiovascular disease: Insights gained from epidemiological, clinical and experimental studies. *Brain, Behavior, and Immunity*, *50*, 18-30. https://doi.org/10.1016/j.bbi.2015.08.007

Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping*. Springer Publishing Company.

Lee, D. Y., Kim, E., & Choi, M. H. (2015). Technical and clinical aspects of cortisol as a biochemical marker of chronic stress. *BMB Reports*, *48*(4), 209-216. https://doi.org/10.5483/BMBRep.2015.48.4.275

Liu, C. H., & Doan, S. N. (2019). Innovations in biological assessments of chronic stress through hair and nail cortisol: Conceptual, developmental, and methodological issues. *Developmental Psychobiology*, *61*(3), 465-476. https://doi.org/10.1002/dev.21830

Luo, H., Hu, X., Liu, X., Ma, X., Guo, W., Qiu, C., Wang, Y., Wang, Q., Zhang, X., Zhang, W., Hannum, G., Zhang, K., Liu, X., & Li, T. (2012). Hair cortisol level as a biomarker for altered hypothalamic-pituitary-adrenal activity in female adolescents with posttraumatic stress disorder after the 2008 Wenchuan earthquake. *Biological Psychiatry*, *72*(1), 65-69. https://doi.org/10.1016/j.biopsych.2011.12.020

Lupien, S. J., Maheu, F., Tu, M., Fiocco, A., & Schramek, T. E. (2007). The effects of stress and stress hormones on human cognition: Implications for the field of brain and cognition. *Brain and Cognition*, *65*(3), 209-237. https://doi.org/10.1016/j.bandc.2007.02.007

Machado, A., Herrera, A. J., de Pablos, R. M., Espinosa-Oliva, A. M., Sarmiento, M., Ayala, A., Venero, J. L., Santiago, M., Villaran, R. F., Delgado-Cortes, M. J., Arguelles, S., & Cano, J. (2014). Chronic stress as a risk factor for Alzheimer's disease. *Reviews in the Neurosciences*, *25*(6), 785-804. https://doi.org/10.1515/revneuro-2014-0035

Mari, F., Politi, L., & Bertol, E. (2008). Nails of newborns in monitoring drug exposure during pregnancy. *Forensic Science International*, *179*(2), 176-180. https://doi.org/10.1016/j.forsciint.2008.06.001

McEwen, B. S. (2006). Protective and damaging effects of stress mediators: central role of the brain. *Dialogues in Clinical Neuroscience*, *8*(4), 367-381. https://doi.org/10.31887/DCNS.2006.8.4/bmcewen

Messerli-Burgy, N., Arhab, A., Stulb, K., Kakebeeke, T. H., Zysset, A. E., Leeger-Aschmann, C. S., Schmutz, E. A., Ehlert, U., Kriemler, S., Jenni, O. G., Munsch, S., & Puder, J. J. (2018).

Physiological stress measures in preschool children and their relationship with body composition and behavioral problems. *Developmental Psychobiology*. https://doi.org/10.1002/dev.21782

Meyer, J., Novak, M., Hamel, A., & Rosenberg, K. (2014). Extraction and analysis of cortisol from human and monkey hair. *Journal of Visualized Experiments,* (83), e50882-e50882. https://doi.org/10.3791/50882

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L. A., & Group, P.-P. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews*, *4*(1), 1. https://doi.org/10.1186/2046-4053-4-1

Mohr, C., Braun, S., Bridler, R., Chmetz, F., Delfino, J. P., Kluckner, V. J., Lott, P., Schrag, Y., Seifritz, E., & Stassen, H. H. (2014). Insufficient coping behavior under chronic stress and vulnerability to psychiatric disorders. *Psychopathology*, *47*(4), 235-243. https://doi.org/10.1159/000356398

Nejad, J., Ghaseminezhad, M., Sung, K., Hoseinzadeh, F., & Cabibi, J. (2016). A cortisol study; facial hair and nails. *Journal of Steroids & Hormonal Science*, *7*(2). http://dx.doi.org/10.4172/2157-7536.1000177

Palmeri, A., Pichini, S., Pacifici, R., Zuccaro, P., & Lopez, A. (2000). Drugs in nails. Physiology, pharmacokinetics and forensic toxicology. *Clinical Pharmacokinetics*, *38*(2), 95-110. https://doi.org/10.2165/00003088-200038020-00001

Pan, X., Wang, Z., Wu, X., Wen, S. W., & Liu, A. (2018). Salivary cortisol in post-traumatic stress disorder: a systematic review and meta-analysis. *BMC psychiatry*, *18*(1), 1-10. . https://doi.org/10.1186/s12888-018-1910-9

Parlak, O., Keene, S. T., Marais, A., Curto, V. F., & Salleo, A. (2018). Molecularly selective nanoporous membrane-based wearable organic electrochemical device for noninvasive cortisol sensing. *Science Advances*, *4*(7), eaar2904. https://doi.org/10.1126/sciadv.aar2904

Radley, J., Morilak, D., Viau, V., & Campeau, S. (2015). Chronic stress and brain plasticity: Mechanisms underlying adaptive and maladaptive changes and implications for stress-related CNS disorders. *Neuroscience & Biobehavioral Reviews*, *58*, 79-91. https://doi.org/10.1016/j.neubiorev.2015.06.018

Rippe, R. C., Noppe, G., Windhorst, D. A., Tiemeier, H., van Rossum, E. F., Jaddoe, V. W., Verhulst, F. C., Bakermans-Kranenburg, M. J., van, I. M. H., & van den Akker, E. L. (2016). Splitting hair for cortisol? Associations of socio-economic status, ethnicity, hair color, gender and other child characteristics with hair cortisol and cortisone. *Psychoneuroendocrinology*, *66*, 56-64. https://doi.org/10.1016/j.psyneuen.2015.12.016

Rosiek, A., Rosiek-Kryszewska, A., Leksowski, L., & Leksowski, K. (2016). Chronic stress and suicidal thinking among medical students. *International Journal of Environmental Research and Public Health*, *13*(2), 212. https://doi.org/10.3390/ijerph13020212

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

Selye, H. (1965). The stress syndrome. *The American Journal of Nursing*, *65*(3), 97-99. https://doi.org/10.2307/3453119

Sheets, E. S., & Craighead, W. E. (2014). Comparing chronic interpersonal and noninterpersonal stress domains as predictors of depression recurrence in emerging adults. *Behaviour Research and Therapy*, *63*, 36-42. https://doi.org/10.1016/j.brat.2014.09.001

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

Stanczyk, F. Z., & Clarke, N. J. (2010). Advantages and challenges of mass spectrometry assays for steroid hormones. *The Journal of Steroid Biochemistry and Molecular Biology*, *121*(3-5), 491-495. https://doi.org/10.1016/j.jsbmb.2010.05.001

Staufenbiel, S. M., Penninx, B. W., Spijker, A. T., Elzinga, B. M., & van Rossum, E. F. (2013). Hair cortisol, stress exposure, and mental health in humans: a systematic review. *Psychoneuroendocrinology*, *38*(8), 1220-1235. https://doi.org/10.1016/j.psyneuen.2012.11.015

Su, Q., Zhang, H., Zhang, Y., Zhang, H., Ding, D., Zeng, J., Zhu, Z., & Li, H. (2015). Maternal stress in gestation: Birth outcomes and stress-related hormone response of the neonates. *Pediatrics & Neonatology*, *56*(6), 376-381. https://doi.org/10.1016/j.pedneo.2015.02.002

Syed, S. A., & Nemeroff, C. B. (2017). Early life stress, mood, and anxiety disorders. *Chronic Stress*, *1*, 2470547017694461. https://doi.org/10.1177/2470547017694461

Tamashiro, K. L., Sakai, R. R., Shively, C. A., Karatsoreos, I. N., & Reagan, L. P. (2011). Chronic stress, metabolism, and metabolic syndrome. *Stress*, *14*(5), 468-474. https://doi.org/10.3109/10253890.2011.606341

Turpeinen, U., & Hamalainen, E. (2013). Determination of cortisol in serum, saliva and urine. *Best Practice & Research Clinical Endocrinology & Metabolism*, *27*(6), 795-801. https://doi.org/10.1016/j.beem.2013.10.008

van der Voorn, B., de Waard, M., van Goudoever, J. B., Rotteveel, J., Heijboer, A. C., & Finken, M. J. (2016). Breast-milk cortisol and cortisone concentrations follow the diurnal rhythm of maternal hypothalamus-pituitary-adrenal axis activity. *The Journal of Nutrition*, *146*(11), 2174-2179. https://doi.org/10.3945/jn.116.236349

Venugopal, M., Arya, S. K., Chornokur, G., & Bhansali, S. (2011). A realtime and continuous assessment of cortisol in ISF using electrochemical impedance spectroscopy. *Sensors and Actuators A: Physical*, *172*(1), 154-160. https://doi.org/10.1016/j.sna.2011.04.028

Voegel, C. D., Hofmann, M., Kraemer, T., Baumgartner, M. R., & Binz, T. M. (2020). Endogenous steroid hormones in hair: Investigations on different hair types, pigmentation effects and correlation to nails. *Steroids*, *154*, 108547. https://doi.org/10.1016/j.steroids.2019.108547

Voegel, C. D., La Marca-Ghaemmaghami, P., Ehlert, U., Baumgartner, M. R., Kraemer, T., & Binz, T. M. (2018). Steroid profiling in nails using liquid chromatography-tandem mass spectrometry. *Steroids*, *140*, 144-150. https://doi.org/10.1016/j.steroids.2018.09.015

Von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gøtzsche, P. C., Vandenbroucke, J. P., & Initiative, S. (2007). The strengthening the reporting of observational studies in epidemiology (STROBE) statement: Guidelines for reporting observational studies. *PLoS medicine*, *4*(10), e296.

Warnock, F., McElwee, K., Seo, R. J., McIsaac, S., Seim, D., Ramirez-Aponte, T., Macritchie, K. A., & Young, A. H. (2010). Measuring cortisol and DHEA in fingernails: A pilot study. *Neuropsychiatric Disease and Treatment*, *6*, 1-7.

Warren, K. R., Postolache, T. T., Groer, M. E., Pinjari, O., Kelly, D. L., & Reynolds, M. A. (2014). Role of chronic stress and depression in periodontal diseases. *Periodontology 2000*, *64*(1), 127-138. https://doi.org/10.1111/prd.12036

Wennig R. (2000). Potential problems with the interpretation of hair analysis results. *Forensic Science International*, *107*(1-3), 5–12. https://doi.org/10.1016/s0379-0738(99)00146-2

Wu, H., Zhou, K., Xu, P., Xue, J., Xu, X., & Liu, L. (2018). Associations of perceived stress with the present and subsequent cortisol levels in fingernails among medical students: A prospective pilot study. *Psychology Research and Behavior Management*, *11*, 439. https://doi.org/10.2147/PRBM.S181541

Zhao, L., Xu, J., Liang, F., Li, A., Zhang, Y., & Sun, J. (2015). Effect of chronic psychological stress on liver metastasis of colon cancer in mice. *PLOS One*, *10*(10), e0139978. https://doi.org/10.1371/journal.pone.0139978

Zorn, J. V., Schur, R. R., Boks, M. P., Kahn, R. S., Joels, M., & Vinkers, C. H. (2017). Cortisol stress reactivity across psychiatric disorders: A systematic review and meta-analysis. *Psychoneuroendocrinology*, *77*, 25-36. https://doi.org/10.1016/j.psyneuen.2016.11.036

Supplementary Materials

Table S11

Number of items met by each study (N = 17) using the STROBE Checklist and their respective Completeness of Reporting Score (COR)

Section	Item	Recommendation	Criteria Met N (%)		
			Yes	No	N/A
Title and abstract	1a	Indicate the study's design with a commonly used term in the title or the abstract	4 (24)	13 (76)	0 (0)
	1b	Provide in the abstract an informative and balanced summary of what was done and what was found	14 (82)	3 (18)	0 (0)
Introduction					
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	14 (82)	3 (18)	0 (0)
Objectives	3	State specific objectives, including any prespecified hypotheses	16 (94)	1 (6)	0 (0)
Methods					
Study design	4	Present key elements of study design early in the paper	6 (35)	11 (65)	0 (0)
Setting	5a	Describe the setting and locations.	11 (65)	6 (35)	0 (0)
	5b	Describe the relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7 (41)	10 (59)	0 (0)
Participants	6a	Cohort study—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up Case-control study—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls Cross-sectional study—Give the eligibility criteria, and the sources and methods of selection of participants	12 (71)	5 (29)	0 (0)
	6b	Cohort study—For matched studies, give matching criteria and number of exposed and unexposed Case-control study—For matched studies, give matching criteria and the number of controls per case	3 (18)	0 (0)	14 (82)
Variables	7a	Clearly define all outcomes, exposures, and predictors.	17 (100)	0 (0)	0 (0)
	7b	Clearly define all potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6 (35)	11 (65)	0 (0)
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	16 (94)	1 (6)	0 (0)
Bias	9	Describe any efforts to address potential sources of bias	6 (35)	11 (65)	0 (0)
Study size	10	Explain how the study size was arrived at	1 (6)	16 (94)	0 (0)
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	16 (94)	1 (6)	0 (0)
Statistical methods	12a	Describe all statistical methods, including those used to control for confounding	14 (82)	3 (18)	0 (0)
	12b	Describe any methods used to examine subgroups and interactions	8 (47)	9 (53)	0 (0)
	12c	Explain how missing data were addressed	4 (24)	13 (76)	0 (0)
	12d	(a) Cohort study—If applicable, explain how loss to follow-up was addressed Case-control study—If applicable, explain how matching of cases and controls was addressed Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	5 (29)	10 (59)	2 (12)
	12e	Describe any sensitivity analyses	1 (6)	16 (94)	0 (0)
Results					
Participants	13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11 (65)	6 (35)	0 (0)
	13b	Give reasons for non-participation at each stage	7 (41)	10 (59)	0 (0)

	13c	Consider use of a flow diagram	1 (6)	16 (96)	0 (0)
Descriptive data	14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9 (53)	8 (47)	0 (0)
	14b	Indicate number of participants with missing data for each variable of interest	4 (24)	13 (76)	0 (0)
	14c	Cohort study—Summarise follow-up time (eg, average and total amount)	6 (35)	2 (12)	9 (53)
Outcome data	15a	Cohort study—Report numbers of outcome events or summary measures over time	8 (47)	0 (0)	9 (53)
	15b	Case-control study—Report numbers in each exposure category, or summary measures of exposure	3 (18)	0 (0)	14 (82)
	15c	Cross-sectional study—Report numbers of outcome events or summary measures	6 (35)	0 (0)	11 (65)
Main results	16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval).	14 (82)	3 (18)	0 (0)
	16b	Make clear which confounders were adjusted for and why they were included	6 (35)	11 (65)	0 (0)
	16c	Report category boundaries when continuous variables were categorized	14 (82)	3 (18)	0 (0)
	16d	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	0 (0)	0 (0)	17 (100)
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8 (47)	9 (53)	0 (0)
Discussion					
Key results	18	Summarise key results with reference to study objectives	17 (100)	0 (0)	0 (0)
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14 (82)	3 (18)	0 (0)
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17 (100)	0 (0)	0 (0)
Generalisability	21	Discuss the generalisability (external validity) of the study results	14 (82)	3 (18)	0 (0)
Other information					
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15 (88)	2 (12)	0 (0)

Note. Abbreviations: N/A = Not applicable.

Table S12

Human Studies Investigating Cortisol Concentrations in Nails

Authors	Target Group	Sample				Assay	Condition	Cortisol Values (pg/mg unless stated otherwise)							Outcomes
		N	Sex	Mean Age (years)	Cortisol Source			Mean	Median	Standard Deviation	Range -	Range +	*P* value	Effect Size*	
Voegel et al. (2018)	Mothers	12	F	-	Fingernail	MS		4.5	4.3	-	1.2	12.9	$p >$ .05	-	No significant difference between cortisol levels in infants and mothers.
	Infants	8	-	1-15 months	Fingernail	MS		3.9	3.7	-	1.5	7.9			No significant difference between nail cortisol in right or left hands.
Messerli-Bürgy et al. (2018)	Preschool children	324	M F	3.9	Fingernail	EIA	**nmol/L**	0.91	-	1.08	0.1	9.9	$p >$ .05	$r =$ .11	No association between nail and diurnal salivary cortisol concentrations.
					Saliva	LIA	Awakening	12.87	-	1.79	1.74	45.71			
							30 minutes after awakening	15.49	-	1.68	1.51	54.95			
								5.73	-	1.62	0.81	16.59			
							11:30 am	4.81	-	1.89	0.3	35.48			
							4 pm	1.42	-	2.09	0.19	30.2			
							8 pm	-0.08	-	0.04	-0.16	0.06			
							Diurnal slope cortisol (lg)								
Hubmann et al. (2016)	At-risk children	83	-	2 - 3	Fingernail	EIA	Conference abstract	-	-	-	-	-	$p >$ .05	-	No association between nail cortisol concentrations collected 12 months apart.
Doan et al. (2018)	African American adolescents	47	M F	-	Fingernail	EIA		21.1	-	39.5	1.4	239.1	$p <$ .05	$r =$ .42	Higher nail cortisol concentrations were associated with increased self-control.
Davison et al. (2019)	Indigenous young adults	179	M F	25.3	Fingernail	MS		-	4.36	-	2.2*IQR	10.1*IQR	$p >$ .05	-	No significant difference in nail cortisol levels between males and females and between Indigenous and non-Indigenous participants. However, Indigenous participants reported experiencing a greater number of stressful events. Reduced cortisol concentrations were associated with a greater number of stressful events in Indigenous
	Non-Indigenous young adults	66	M F	23.6	Fingernail	MS		-	3.87	-	2.0*IQR	9.7*IQR			

														youth, particularly women. Higher cortisol levels were associated with increased psychological distress in women.
Warnock et al. (2010)	University students	33	M F	20.8	Fingernail	EIA	**nmol/g**						$p >$ .05	-	Nail growth hypothesised to be indicative of an exam period showed non-significantly increased cortisol levels, significantly decreased DHEA levels, and significantly increased Cortisol:DHEA ratios compared to the baseline period.
							Baseline	0.1234	0.1056	0.0886	0.0253	0.4426		
							Exam	0.2119	0.1406	0.3152	0.0249	1.7523		
Nejad et al. (2016)	University students	19	M	> 19	Fingernail	ELISA	Baseline	64.4	-	8.5	-	-	$p <$ .05	FN $r =$ .54[a]	Significantly higher cortisol concentrations were found in periods hypothesized to denote mental or physical stress compared to baseline. Fingernail (FN)[a] and toenail (TN)[b] cortisol concentrations were significantly correlated with facial hair cortisol.
							Mental Stress	94.3	-	15.0	-	-		
							Physical Stress	101.2	-	13.9	-	-		
					Toenail	ELISA	Baseline	57.4	-	12.5	-	-		TN $r =$ .73[b]
							Mental Stress	103.2	-	16.5	-	-		
							Physical Stress	89.7	-	16.0	-	-		
					Facial Hair	ELISA	Baseline	71.2	-	8.1	-	-		
							Mental Stress	115.5	-	10.8	-	-		
							Physical Stress	110.2	-	9.1	-	-		
Wu et al. (2018)	Medical students	51	M F	20.02	Fingernail	ELISA	Day 15	5.65	-	1.88	-	-	$p >$ .05	$r =$ - 0.008	Significant positive association between self-reported perceived stress and fingernail cortisol levels from samples collected 45 days post questionnaire.
							Day 45	5.41	-	1.63	-	-	$p <$ .05	$r =$ .656	
Higashi et al. (2016)	Right-handed volunteers	20	M F	21 – 46	Fingernail	MS	**ng/g** Ratio of Left to Right (L/R) fingernails: If L/R is over 1.2 or below 0.8, there is a difference between the L and R	1.05	-	0.12	0.83	1.27	$p >$ .05	$d =$ .18	No difference in content was found for lipophilic steroids (T and Cortisol) in the left and right-hand nails.

Ben Khelil et al. (2011)	Adult	10	F	32.5	Fingernail	MS		-	69.5	-	36	158	-	-	Validation of an analytical method of simultaneously measuring cortisol, cortisone, DHEA, and DHEAS in small samples of human nails.
Binz et al. (2018)	Adult	122	M F	41	Thumb	MS		5.9	-	1.4	4	-	$p >$ .05	$r =$ .17	Cortisol and cortisone concentrations were dependent on type of nail collected. No significant association between hair and nail cortisol.
					Index, middle, and ring finger			9.3	-	0.9	-	-			
					Little Finger			12.2	-	1.2	-	13.8			
					Toenail	MS		-	3.3	-	0.3	19			
					Hair	MS		-	7	-	1.3	82			
Voegel et al. (2019)	Adult	38	M F	41	Fingernail	MS		-	-	-	-	-	$p >$ .05	$r =$ .12	No significant correlation was found between nail and hair cortisol levels.
					Hair	MS		4.9	3.1	-	1.3	36.1			
Izawa et al. (2015) ***Study 1***	Employed adults	58	M	56.6	Fingernail	EIA		16.5	-	48.7	2.2	292.7	$p <$ .05	$r =$ .29	Nail cortisol was moderately associated with hair cortisol.
					Hair	EIA		-	-	-	-	-			
Izawa et al. (2015) ***Study 2***	Employed adults	37	M F	34.5	Fingernail	EIA	**nmol/L**	-	-	-	-	-	$p <$ .05	$r =$ .43[a]	Salivary cortisol was moderately associated with fingernail cortisol collected 4[a] or 5[b] months after the collection of saliva.
					Saliva	EIA	Awakening	14.2	-	5.4	-	-		$r =$ .45[b]	
							30 minutes after awakening	22.4	-	10.0	-	-			
								8.5	-	3.3	-	-			
							Before lunch	5.5	-	2.3	-	-			
							After work								
Izawa et al. (2017)	Middle-aged workers	123	M F	43.4	Fingernail	EIA	Without stressful life events	4.2	-	2.1	-	-	$p <$ .05	$d =$ .41	Stressful life events, but not job strain and perceived stress, were associated with significantly higher nail cortisol concentrations.
								5.2	-	2.7	-	-			
							With stressful life events								
Fruge et al. (2018)	Adult cancer survivors	109	M F	64.1	Fingernail	EIA	**nmol/L**						$p <$ .05	*RT FN* $r =$ .29 *RT TN*	Room temperature (RT) fingernail and toenail (FN and TN) cortisol levels were significantly associated with
							Frozen	0.0290	0.0084	0.0624	0.0021*10%	0.00622*90%			
							Room Temperature	0.0870	0.0097	0.3319	0.0037*10%	0.1196*90%			

					Toenail	EIA	Frozen	0.0152	0.0049	0.0394	0.0019*10%	0.0250*90%	*r* = .58	salivary cortisol in adult cancer survivors.
							Room Temperature	0.0607	0.0062	0.3004	0.0013*10%	0.0916*90%		
					Saliva	EIA	One sample	0.2894	0.1630	0.5683	0.0589*10%	0.4633*90%		
Izawa et al. (2019)	Acute coronary syndrome (ACS) adults	73	M	60.5	Fingernail	EIA		-	8.2	-	3.9	85.6	*p* < .05	*OR* = 2.23	Acute coronary syndrome was associated with fingernail cortisol in crude and risk-factor adjusted models, but this relationship was attenuated after adjusting for education level and stressful life events.
					Hair			-	11.9	-	1.3	67.2			
	Healthy controls	93	M	59.6	Fingernail	EIA		-	7.0	-	2.2	56.7			
					Hair			-	9.2	-	3.1	45.9			
Herane-Vives et al. (2017)	Euthymic bipolar disorder I (BD-I) patients	40	M F	38.4	Fingernail	AIS		118.6	-	-	25.8*IQR	245.98*IQR	*p* > .05	-	No significant difference in nail cortisol concentrations was found between BD-I patients and healthy controls.
	Healthy controls	42	M F	39.5	Fingernail	AIS		84.8	-	-	33.5*IQR	165.6*IQR			
Herane-Vives et al. (2018)	Adults with major depressive disorder	26	M F	38.1	Fingernail	AIS		201.2	96.4	277.3	60.2*IQR	396.8*IQR	*p* < .05	*d* = .48	Individuals diagnosed with depression had higher fingernail cortisol concentrations.
	Healthy controls	45	M F	39.0	Fingernail	AIS		101.5	76.9	90.5	39.2*IQR	165.6*IQR			

Note. Abbreviations: M = Male; F = Female; - = Not reported/unclear; DHEA = Dehydroepiandrosterone; T = Testosterone; EIA = Enzyme Immunoassay; ELISA = Enzyme-Linked Immunosorbent Assay; AIS = Automated Immunodiagnostic System; LIA = Chemiluminescence immunoassay; MS = Mass Spectrometry; *10% = 10th percentile; *90% = 90th percentile; *IQR = interquartile range; *Effect sizes were only reported for a significant effect and if relevant reported data was available.

CAN YOU CHANGE STRESS BELIEFS IN TEENS?

Chapter 1
Exploring stress during adolescence and whether beliefs about stress (stress mindsets) can be changed.

Chapter 2
A review of the literature on whether stress mindsets can be changed through short interventions or manipulations.

Chapter 3
Investigating the efficacy of a short online stress education program at promoting more positive stress mindsets and mental wellbeing in Australian adolescents.

Chapter 4
A mixed-methods investigation of the student feedback from the program.

Chapter 5
A psychometric analysis of the Stress Mindset Measure, to determine reliability and validity of the project's primary outcome.

Chapter 6
Situating the research in the context of a global pandemic.

Chapter 7
A review of nail cortisol as an emerging and potentially inclusive measure of retrospective chronic stress levels for future research.

What did I find?

YOU ARE HERE

Chapter 8
A discussion on the outcomes of the project, limitations, and future directions.

Chapter 8

Can Stress Turn into Success?

The negative effects of chronic stress on health and well-being are well-known in the literature (McEwen, 2017, 2019; Sapolsky, 1996). However, not all stressors can be avoided or minimised and the acute stress response, itself, is a protective biological mechanism that may promote performance (Jamieson et al., 2018; McEwen, 2017, 2019; Sapolsky, 1996). As such, learning to capitalise on this stress response may have beneficial mental health and performance outcomes (Crum et al., 2020; Jamieson et al., 2018). The integration of stress mindset and stress reappraisal theory into short stress optimisation programs may help individuals learn to manage some unavoidable but controllable stressors and promote mental health and performance (Crum et al., 2020; Jamieson et al., 2018). These programs are especially critical during adolescence, as it is a developmental period of heightened stress reactivity and social, emotional, and physical changes (Lupien et al., 2009; Romeo, 2013). Collectively, this project examined whether beliefs about stress can be changed (*Chapter 2*), implemented a program designed to change beliefs about stress and promote mental health during adolescence (*Chapter 3 & 4*), and examined the limitations (*Chapters 5 & 6*) and future directions (*Chapter 7*) associated with this program.

Changing Stress Mindsets

Stress reappraisal interventions have been systematically validated in the literature (Liu et al., 2019), but with stress mindsets being a relatively new concept, stress mindset interventions have yet to be systematically reviewed. The first aim of this thesis project was to examine whether stress mindsets could be changed through short intervention (key aims and findings can be seen in Table 15). *Chapter 2* systematically reviewed experimental studies investigating primed stress mindsets. On the spectrum of stress-is-debilitating to stress-is-enhancing", most individuals fell into the stress-is-debilitating arm at baseline. This finding supports previous statements by Crum et al. (2013) and Jamieson et al. (2018) suggesting that individuals are biased to believe stress is negative through the

emphasis on the negative effects of chronic stress in the media and literature (Soroka & McAdams, 2015).

Table 15

Key Findings from the Thesis Project

Chapter	Aim	Hypothesis	Outcomes
2	To investigate whether stress mindsets can be changed through short interventions or manipulations.	-	Stress mindsets can be primed
3	To test the effectiveness of the intervention at changing stress mindsets and promoting mental health in Australian adolescents	It was hypothesised that the Stress N' Go program would help Australian adolescents develop more stress-is-enhancing mindsets and promote mental health and wellbeing.	✓ Adolescent stress mindsets can be primed ✗ No direct benefits on mental health
4	To appraise the intervention based on feedback from the adolescents.	It was hypothesised that students would have a greater understanding of their stress response post-intervention and report positive feedback based on the short multimedia format of the program.	✓ Stress N' Go was positively received by students who provided feedback post-videos
5	To assess the reliability and validity of the primary outcome in Canadian and Australian adolescents at baseline.	It was hypothesised that the Stress Mindset Measure would be a reliable and valid measure of the implicit beliefs about stress held by Canadian and Australian adolescents.	✗ The SMM-G used in the Australian sample was not as reliable as the French-translated version used in the Canadian sample ✗ Both samples did not fit a single or two-factor model
6	To situate the research within the context of a global pandemic (COVID-19) and to examine differences between adolescents living in Canada compared to Australia at baseline.	It was hypothesised that the global pandemic would be more stressful for students, particularly females, in stricter lockdown conditions.	✓ The Canadian sample appeared more concerned about COVID-19 ✓ Females reported being more concerned about COVID-19 and poorer mental health outcomes ✗ The Australian sample with no lockdown reported increased perceived stress and test anxiety.
7	To review a prospective future direction for the project	-	Nail cortisol is a more inclusive measure of chronic stress The timeline of stress levels it represents is unclear

Note. ✓ = consistent with hypothesis and ✗ = not consistent with hypothesis

Chapter 2 further found that stress mindsets could be primed in adults to be either stress-is-enhancing or stress-is-debilitating through short interventions promoting the positive and negative

effects of stress respectively. These short interventions included multimedia presentations (Crum et al., 2017; Crum et al., 2018; Crum et al., 2013; Gold, 2019; Hogue, 2019), memory recall tasks (Ben-Avi et al., 2018), novel mental imagery (Keech et al., 2021), online education (Park & Hahm, 2019), and virtual biofeedback reality games (Maarsingh et al., 2019). Therefore, the hypothesis that stress mindsets can be changed through short intervention was supported.

These intervention studies, however, did not provide strong support for the direct effects of these mindset changes on performance and mental health and only two studies investigated the stability of these changes (Crane et al., 2020; Keech et al., 2021). Instead, observational studies on stress mindsets showed promising links between having a stress-is-enhancing mindset and adaptive mental health and performance (Chen & Fang, 2019a; Chen & Fang, 2019b; Hammond et al., 2020; Huettermann & Bruch, 2019; Jiang et al., 2019; Keech et al., 2020; Kim et al., 2020; Nguyen et al., 2020; Park et al., 2018). Despite these findings, more evidence is needed to support the durability of these priming effects and their causal relationship with psychological and performance outcomes, particularly during adolescence.

Stress N' Go Education Program

The second aim of this project was to examine the efficacy of Stress N' Go, a short online neuroscience-informed stress education program designed to promote more stress-is-enhancing mindsets and mental health during adolescence (see Table 15). The cluster randomised controlled trial in *Chapter 3* found that both the Stress N' Go group and control group elicited more stress-is-enhancing mindsets. Informing students that they will be involved in a "stress optimisation" project or students discussing the interventions between each other outside of the classroom, may have contributed to this effect. However, consistent with the hypothesis, the magnitude of the change in stress mindsets was significantly greater in the Stress N' Go program. This finding supports the efficacy of the stress optimisation model proposed by Jamieson et al. (2018) and Crum et al. (2020). The effect observed in this Australian implementation of the program was smaller than the effect observed in the original study by Crum et al. (2013) and the initial Canadian implementation

(Journault & Lupien, 2020). This smaller effect may be due to methodological limitations, such as the discussion between intervention groups within the recruited high school, the appropriateness of the adult SMM, or the influence of the COVID-19 pandemic.

Inconsistent with the hypothesis, *Chapter 3* found no direct changes in mental health associated with the Stress N' Go education program (see Table 15). Changes to mental health often require long-term reinforcement strategies and therapies (Arango et al., 2018; Bishop, 2018). Although there were no immediate mental health benefits directly post-intervention, changing these implicit beliefs about stress to be more positive, may indirectly encourage individuals to select productive coping strategies in the future (Crum et al., 2013; Crum et al., 2020; Jamieson et al., 2018). Follow-up investigations are necessary to examine if there were any indirect effects on future coping strategies selected by the students. Despite no direct mental health benefits, the majority of students reported that they felt the program helped them live better with their stress. To recognise the student voice in the validation of the Stress N' Go program, *Chapter 4* analysed the free-text content of the student feedback from the Stress N' Go program. The program was positively received and there was evidence of students understanding the stress mindset and reappraisal concepts. The students did suggest that the program could be improved through more expressive and animated content as well as additional practical stress management strategies. Overall, it is important to acknowledge the student voice in stress education programs to improve student engagement (Gonski et al., 2018).

The limitations and generalisability of the findings from *Chapter 3* were further examined in *Chapter 5* to examine whether the adult SMM was appropriate for use within an adolescent sample (see Table 15). *Chapter 5* examined the psychometric properties of the English Stress Mindset Measure (SMM-G) and the French-translated version of this scale (SMM-F) used in both the Canadian and Australian Stress N' Go baseline Stress N' Go data. The baseline data was reviewed, as it provided a larger sample size to increase the power of the study. Unlike previous validations (Chen & Fang, 2019b; Crum et al., 2013; Iwamoto et al., 2019; Karampas et al., 2020), the SMM-G and SMM-F

did not adequately fit onto a single or two-factor model and was therefore not psychometrically sound. Overall, the youth-adapted measure by Park et al. (2018) may have been more suitable for this project.

The SMM also appeared to be a distinct measure of the more implicit meta-cognitive process about the nature of stress compared to measures of stress appraisal or stress levels. The French-translated version of the SMM showed good reliability. However, the SMM used in the Australian sample had just below acceptable reliability, potentially due to methodological differences or linguistic factors (Tavakol & Dennick, 2011). Further, the wording of the items could have been too polarising (e.g., Item 1: "The effects of stress *are* positive" rather than "The effects of *stress can be* positive") and may not have been able to capture the more balanced perspective that stress can be both positive and negative (Keech, Orbell, et al., 2021). *Chapter 5,* therefore, provides more support for the SMM-F for use within adolescent samples and future research, but not for the unadapted SMM-G.

Stress Research during a Global Pandemic

Conducting stress-related research, within the context of a global pandemic, raises concerns about the effect of COVID-19 on adolescent stress and the efficacy of stress education during this global stressor. The current Australian sample was from a high school in a regional Queensland location. This location had experienced approximately <30 confirmed cases of COVID-19 and no deaths (Queensland Government, 2021). Despite the low burden of disease in this location, media releases and COVID-19 discussions may influence stress levels (Liu, 2020). In *Chapter 3*, students in both the Stress N' Go group and Destination: Brain group reported experiencing more perceived stress post-intervention. Without pre-COVID-19 data, it is difficult to determine the effect of COVID-19 on student stress levels and responsiveness to intervention. However, these students reported that "school" was currently their biggest stressor, with very little mention of COVID-19 in these free-text responses.

Chapter 6 investigated the difference between the Canadian and Australian samples from *Chapter 5*, on a COVID-19 questionnaire given at baseline. This study aimed to investigate country and gender differences in COVID-19 experiences and mental health outcomes (see Table 15). It was hypothesised that adolescents from Canada would report being affected more by the pandemic circumstances and have worse psychological outcomes compared to the Australian adolescents, due to Canada experiencing lockdown conditions, such as school closure (Gouvernement du Québec, 2021). This was partially supported as the Canadian sample reported engaging in more discussions and concerns related to COVID-19 and engaged in more co-rumination, compared to the Australian samples. Although this was a small effect, these findings align with the larger health and economic burden evident in the Canadian sample at the time of testing (Dong et al., 2020; Gouvernement du Québec, 2021; Ministère de la Santé et des services sociaux, 2021). The Canadian students were in lockdown (schools and businesses closed) in contrast to the Australian group who remained at school during the time of testing (Gouvernement du Québec, 2021; Queensland Government, 2021). Bordering on the United States of America, where COVID-19 transmission was rampant may have also played a role in these increased concerns about COVID-19.

In contrast, the Australian sample reported increased levels of test anxiety and perceived stress, which may have been associated with still being at school rather than COVID-19. Without pre-COVID-19 data, it is difficult to determine the extent of the effect of COVID-19 in this project. As discussed in *Chapter 6*, the perceived stress scale may not be sensitive to the unique pandemic circumstances, as some items are school and friend-specific (White, 2014), which may not be appropriate for adolescents in lockdown. Therefore, based on their free-text responses in *Chapter 3* and findings from the COVID-19 questionnaire in *Chapter 6*, this small sample of Australian students from a private school in regional Queensland did not appear to be experiencing any significant distress related to the current pandemic. This aligns with the MyStrengths Youth Mental Health Survey, which found that schoolwork was the biggest stressor for Australian high school students from 2020 to 2021 (McCrindle, 2021). Concerns about school and coping with stress were also

significant stressors for Australian adolescents before the COVID-19 pandemic (Carlisle et al., 2019). It should be noted, however, that this finding may not be generalisable to wider adolescent populations that have been more adversely affected by this disease, as multiple countries have associated COVID-19 with a greater mental health risk (Duan et al., 2020; Giannopoulou et al., 2021; Hafstad et al., 2021; Liang et al., 2020; Ma et al., 2021; Magson et al., 2021; Meda et al., 2021; Ravens-Sieberer et al., 2020; Rogers et al., 2021; Thorisdottir et al., 2021; Zhou et al., 2020).

In both the Australian and Canadian samples, there was a consistent gender difference in concerns about COVID-19 and psychological outcomes. Adolescent girls reported engaging in more discussions and worries related to COVID-19, as well as more symptoms of stress, anxiety, depression, and co-rumination. These findings are supported consistently in the literature, suggesting that at puberty, females perceive more symptoms of anxiety and depression (Petersen et al., 1991; Jose et al., 2012). In adults, females are diagnosed with more anxiety and mood disorders (Albert, 2015). Therefore, adolescent girls may be at a greater risk of psychological distress, and this potentially could be heightened during a global pandemic (Duan et al., 2020; Hafstad et al., 2021; Magson et al., 2021; Thorisdottir et al., 2021; Zhou et al., 2020). Therefore, universal interventions are important to reach a larger range of adolescents, but gender must be considered during their development.

Stress Physiology

Although the psychological scales used in the current project provide insight into perceived adolescent stress beliefs and mental health, the investigation of changes in physiological stress responses would add to a more comprehensive understanding of the Stress N' Go program's efficacy (see Table 15). The reframing of stress to a balanced perspective has been associated with more adaptive stress physiology (Liu et al., 2017). To the best of my knowledge, stress optimisation programs have not investigated chronic measures of stress such as hair or nail cortisol. Most mindset or reappraisal programs have focused on acute changes using the Trier Social Stress Test, heart rate variability, salivary cortisol (Akinola et al., 2016; Crum et al., 2017; Hogue, 2019; Jamieson et al.,

2010; Jamieson et al., 2012). Hair cortisol is the most established measure of retrospective chronic stress (Staufenbiel et al., 2013); however, nail cortisol, as discussed in *Chapter 7*, may be more inclusive for males and individuals with curly or limited amounts of hair (Phillips et al., 2021). The inclusion of chronic measures, in conjunction with acute measures, of stress may help researchers gain insight into the long-term effects of changing beliefs about stress or specific stressors that were not captured in the current project.

Limitations

There are several limitations to this thesis project. The experimental research (*Chapters 3* to *6*) within this thesis project was limited by the small sample of Australian adolescents from a single private high school. Implementing an intervention in a single location may have allowed students from the control and intervention groups to discuss each of the programs and confound the findings. This may explain why a stronger effect was observed in the Canadian group that implemented the program in 73 private and public schools. The sample of Australian adolescents in this project cannot be generalised to the wider Australian adolescent population, as the students were from a single private high school, identified as being from mostly white ethnic origins, and reported being quite comfortable financially. Further, in *Chapter 4* there was a significant amount of attrition within the Stress N' Go group and a small number of students who provided feedback on all four videos, which may have affected the power of the study. Based on the attrition rates in *Chapter 4*, selection bias cannot be ruled out, as students who potentially did not enjoy the program may have chosen not to respond to the surveys. The efficacy of the program may not have been fully captured by the Stress Mindset Measure, as it was not adapted for adolescents and appeared to lack reliability in the Australian sample when psychometrically investigated in *Chapter 5*. Without pre-COVID-19 data and only sampling from one school, it was difficult to objectively measure the effect of the pandemic on Australian adolescents in *Chapter 6* and the efficacy of the Stress N' Go program. When discussing future directions for this thesis project in *Chapter 7*, the quality of studies investigating nail cortisol was low and suggests a need for emerging biomarkers to be validated before their use in stress

interventions. Overall, larger sample sizes from both private and public high schools across Australia are necessary to provide more robust support for the Stress N' Go program in this country. These limitations identify areas of improvement for future research on this topic.

Suggestions for Future Directions

Participant Demographics

Age. Adolescence is a period when the effects of early life stress become more evident (Kessler et al., 2007; Lupien et al., 2013). Based on the promising findings from the Stress N' Go program, it may be worth adapting the Stress N' Go program to also be applicable for children (<10 years old) and early adolescents (10 to 13 years old) to provide stress regulation strategies earlier in life. Children who experience adverse childhood events (ACE), such as abuse, neglect, or household dysfunction, are at a significantly greater risk of disease and mental health challenges (for a review: Boullier & Blair, 2018). In Australia, it is estimated that approximately 72% of children have experienced at least one ACE (Emerging Minds, 2020). Australian adults exposed to four or more ACEs were 4.6 times more likely to develop depression and 12.2 times more likely to commit suicide (Emerging Minds, 2020). ACEs can disrupt child development and are associated with poor academic performance (Emerging Minds, 2020). Although ACEs are often uncontrollable stressors, the fact that many Australian children might be facing such significant stressors highlights the need for resilience programs or education programs, such as Stress N' Go. This would help them to learn that some stressors do not always have negative outcomes, especially controllable stressors, such as school or exams. Further, the transition from childhood to adolescence may be a significant stressor (Goldstein et al., 2015; Lee et al., 2019; Lupien et al., 2001). This period is particularly stressful as it signals the transition from primary school to high school in Australia as well as the beginning of puberty for many young people (Warren & Yu, 2016). The efficacy of preventative stress education programs, such as Stress N' Go, on a younger cohort of early adolescents (about 10 to 13 years of age) should also be examined. Longitudinal comparisons into adulthood could examine whether stress education programs, like Stress N' Go, during adolescence may have protective effects on mental health in

adulthood. Overall, implementing programs that encourage stress resilience early in life, may help promote mental well-being in the future.

Gender. There is a well-documented mental health gap between genders during adolescence (Oldehinkel & Bouma, 2011). Females report experiencing more internalising symptoms such as greater perceived stress/stressors and are at a greater risk of developing depression and anxiety later in life (Magson et al., 2021; Malooly et al., 2017; Oldehinkel & Bouma, 2011; Östberg et al., 2015). This pattern was further supported in *Chapter 6* where females reported increased perceived stress, anxiety sensitivity, state anxiety, test anxiety, depression, and co-rumination. This gender difference is theorised to be the result of increased stress reactivity and sensitivity to stressors (Oldehinkel & Bouma, 2011), which is supported in *Chapter 6* where adolescent girls reported significantly greater sensitivity to anxiety compared to boys. It is important to note that increased vulnerability to stress observed in females could also be due to their willingness to report stressors, emotions, and seek support (Carter et al., 2011); whereas males may not feel as open about sharing this information due to traditional gender roles encouraging strength and independence in men (Smith et al., 2018). Further, males may experience more externalising symptoms in response to stress, such as aggression or substance abuse (Smith et al., 2018). The type of coping strategies used by males and females may also be significant. Females may sometimes engage in more avoidant or emotion-focused coping like distraction, rumination, and resignation (Hampel & Petermann, 2006; Smith et al., 2018). In contrast, men tend to employ more problem-focused coping strategies such as situation control, but do not utilise as much social support or help-seeking as females and may employ some maladaptive emotion-focused coping such as aggression or divergence (Hampel & Petermann, 2006; Malooly et al., 2017; Smith et al., 2018). Alternatively, males may have a more internal locus of control (the belief that they are in control of the events in their life), which may lead to better psychological adjustment compared to females who tend to have a more external locus of control (beliefs that events in their life are controlled by external forces) (Awaworyi Churchill et al., 2020).

One study suggested that the mental health gap between men and women could be reduced by encouraging women to have a more internal locus of control (Awaworyi Churchill et al., 2020).

Overall, these gender differences are likely a complex interconnection of stress reactivity, genetics, and socialisation, yet it is clear that males and females manage stress differently (Carter et al., 2011; Oldehinkel & Bouma, 2011; Smith et al., 2018). A future direction of the current project would be to include measures of gender roles or externalising mental health symptoms, such as aggression, to develop a more comprehensive profile of both male and female adolescent mental health and their responsiveness to stress regulation programs. Further, future stress regulation programs could selectively focus on helping females develop more internal locus of control and problem-focused coping strategies for males to build stronger social support networks. The integration of locus of control theory with the more specific stress mindset theory may be an interesting avenue for future stress regulation programs. Biofeedback games to regulate stress and anger may also be beneficial, particularly to teach males how to manage externalising symptoms like aggression. For example, biofeedback games like “Stressjam”, discussed in *Chapter 2* (Maarsingh et al., 2019), and “Mightier” developed by Boston Children's Hospital and Harvard Medical School (Ducharme et al., 2021). Although universal stress management or stress optimisation programs may reach the majority, targeted programs may also be beneficial to address this gender difference.

Ethnicity and Socioeconomic Status. Previous research suggests that low socioeconomic status or perceived social status is a risk factor for poor psychological outcomes during adolescence (McLaughlin et al., 2012; Reiss et al., 2019; Wight et al., 2006). Future research should extend the implementation of Stress N’ Go to a diverse range of Australian government-run high schools to test its efficacy but to also benefit adolescents with low perceived social status. Australian Aboriginal and Torres Strait Islander adolescents face a greater risk of mental health challenges (Azzopardi et al., 2020; Dickson et al., 2019). With only about 1 -2% of the sample within the current program identifying as Australian Aboriginal or Torres Strait Islander, it is difficult to objectively determine the efficacy of the Stress N’ Go program in this cohort. Future implementations of a stress optimisation

program may be valuable considering the high risk or mental health challenges faced by this group; however, the program should be more culturally appropriate. For example, the imagery and script would need to represent adolescents from a range of diverse backgrounds. More specifically, cultural learning should be integrated to reflect, recognise, and engage with Australian Aboriginal and Torres Strait Islander peoples, culture, and history (Lowe & Yunkaporta, 2013). Importantly, collaboration with representatives from Indigenous backgrounds is needed to develop a culturally appropriate version of Stress N' Go or similar stress optimisation programs before its implementation within regional or remote communities (Lowe & Yunkaporta, 2013)

Measuring Stress Mindsets

The Stress Mindset Measure - General (Crum et al., 2013) may not capture more nuanced changes in stress mindsets post-Stress N' Go, which could explain the smaller effect observed in *Chapter 3* and less internally consistent responses seen in *Chapter 5*. The SMM-G uses definitive terms such as "Experiencing stress facilitates my learning and growth", which does not reflect the more balanced stress mindset concepts recommended by Jamieson et al. (2018). Jamieson et al. (2018) suggest that individuals should be taught both about how stress "*can be*" enhancing, not stress "*is*" enhancing, to create a more ethical and realistic perspective on stress. Keech et al. (2018; 2020; 2021a;2021b) developed and validated the Stress Control Mindset Measure (SCMM) to address this more nuanced approach. The SCMM uses items, such as "Stress *can be* used to enhance your learning and growth" and emphasises the individual as an active participant in their stress response. The use of this measure may allow for more insight into whether the adolescents within this thesis project had more nuanced changes in their beliefs about the nature of stress. It may also be worth investigating the Stress Mindset Measure – Specific (Crum et al., 2013) to target specific stressors, such as schoolwork, to examine the selective effects of Stress N' Go on specific controllable stressors (e.g., stress reappraisal). Future research will, however, need to make adaptations to the current measures of stress mindsets, as only one study to date has reduced the Stress Mindset

Measure to three items to suit adolescent samples (Park et al., 2018). Studies are needed to adapt and validate the SCMM for children and adolescents.

Measuring Academic Performance

With stress optimisation being an emerging framework, the benefit of this model on academic performance should be explored. The focus of this Stress N' Go project was to examine psychological outcomes rather than academic performance. However, independently, stress reappraisal and stress mindset interventions have been shown to promote academic and occupational performance (Akinola et al., 2016; Ben-Avi et al., 2018; Casper et al., 2017; Chen & Fang, 2019a; Chen & Fang, 2019b; Chen & Hou, 2021; Crum et al., 2013; Hammond et al., 2020; Huettermann & Bruch, 2019; Iwamoto et al., 2020; Jamieson et al., 2010; Jamieson et al., 2012; Keech et al., 2020; Keech et al., 2021; Kim et al., 2020; Smith et al., 2020). In *Chapter 3*, adolescents identified their schooling as their biggest stressor. Future implementations of Stress N' Go could assess changes in grades, performance on tests or teacher reports pre-and post-intervention. Programs promoting stress regulation, and simultaneously academic performance, are especially important within educational settings.

Measuring the Physiological Stress Response

The experimental component of the project was implemented a few months after the WHO declared COVID-19 to be a global pandemic (World Health Organisation, 2021). The collection of biological samples was not advised, as a health precaution, to limit face-to-face contact with participants during the pandemic. As such, the study focused on the use of online self-report scales. The integration of stress physiology, such as cortisol or dehydroepiandrosterone sulfate (DHEA-S), would provide a more objective and comprehensive snapshot of these adolescents' stress levels pre- and post-Stress N' Go. Stress hormones, like cortisol, can easily cross the blood-brain barrier, due to their lipophilic properties (Higashi et al., 2016; Lupien et al., 2007). This accessibility allows stress hormones to bind to receptors in the hippocampus, amygdala, and frontal lobes (Lupien et al, 2007). The dysregulation of stress hormone levels in the brain has consequently been associated with

mental health disorders (Lupien et al., 2007; Zorn et al., 2017). Cortisol levels can be measured from a variety of sources including saliva, hair, nails, sweat, urine, and blood (Lee et al., 2015; Phillips et al., 2021). Further, each source offers a unique timeline of an individual's stress response. Saliva, sweat, urine, and blood measure the acute status of the hypothalamic-pituitary-adrenal (HPA) axis (Lee et al., 2015). As discussed in *Chapter 7*, hair and nails provide a retrospective chronic measure of HPA axis activation (Warnock et al., 2010; Wennig, 2000). Nail cortisol could be a more inclusive chronic stress measure, especially for males and people with curly hair, but the timeframe it measures needs further investigation. Interestingly in *Chapter 2*, increased DHEA-S levels have been associated with more adaptive stress responses and would be an important measure in future investigations (Cho et al., 2019; Crum et al., 2017; Hogue, 2019; Maninger et al., 2009; Morgan et al., 2004). Finally, heart rate variability (intervals between heartbeats) and the integration of biofeedback strategies, like Stressjam (discussed in *Chapter 2*; Maarsingh et al., 2091), to regulate stress levels could be extended to Stress N' Go or stress optimisation programs. Therefore, the inclusion of physiological measures in conjunction with psychological scales may allow researchers to systematically profile stress responses through HPA axis activation and stress-related beliefs or symptoms.

Long-term Stress Management

Although this project adds to the growing evidence that stress mindsets can be primed, the Stress N' Go program did not have any direct or immediate benefits on adolescent mental health in both the Australian and Canadian samples. Although it is possible that the efficacy of Stress N' Go may be limited, the indirect or longitudinal effects of this program cannot be ruled out. Changes in stress mindsets have been associated with positive performance and psychological outcomes (see *Chapter 2*; Crum et al., 2020, Jamieson et al., 2018). It is possible that only collecting data one-week post-intervention may not have captured later cognitive or behavioural changes. For example, promoting more stress-is-enhancing mindsets and educating students about various coping strategies, could lead to these participants selecting more adaptive coping strategies in the future.

Further, changes to mental health often require long-term intervention therapies and reinforcement (Arango et al., 2018; Bishop, 2018). Longitudinal investigations could also examine student wellbeing and performance across different times of the year (i.e., school holidays, start vs. end of the school year, and exams) after programs such as Stress N' Go. Therefore, it is possible that Stress N' Go could have had indirect effects on psychological outcomes, but longitudinal investigations are needed to examine any changes in psychological outcomes post-intervention.

Stress N' Go may reflect an introductory program that could be implemented in early education, which is then followed by repeated short stress management interventions continuing education about coping with stress and mental wellbeing, well into higher education curricula. The students in *Chapter 4* did appear to request more education about how to identify and manage a variety of stressors, which supports the integration of stress management programs in education frameworks. Stress optimisation programs should also look beyond the adolescent, as the only active participant in their stress management system. Adapting programs like Stress N' Go, to inform parents, teachers, and health professionals on how to work together and understand adolescent stress beliefs and coping strategies could help build stronger social support for students, especially males. Social support is an important coping strategy linked to positive psychological outcomes (Fredrick et al., 2018; Heerde & Hemphill, 2018), but if an adolescent does not have a strong support system to turn to, it can make coping with stressors difficult. Bronfenbrenner's ecological systems theory (1992; 2005) suggests that a child's development is influenced by interconnected relationships with their surroundings, from their microsystem (e.g., family, friends, and teachers) to the chronosystem (e.g., environmental changes). Therefore, based on Bronfenbrenner's theory, stress optimisation and management programs could be extended from the adolescents' immediate environment to their wider community systems for more support.

Conclusion

In summary, this thesis project provided support for stress mindsets to be experimentally primed in adults and adolescents using stress mindset psychoeducation. However, the current stress

mindset intervention did not appear to have an immediate effect on promoting adolescent mental health, but this does not eliminate the more indirect cognitive and behavioural changes that may occur with the change in beliefs about stress. The sample of Australian adolescents from a regional Queensland location appeared to benefit from the program by learning to not always view stress as limiting but something that can be positive and help them expand their limits. The online delivery of a stress education program, such as Stress N' Go, could be beneficial during a pandemic and in rural and remote locations around Australia. Stress optimisation programs may also be valuable within educational or clinical settings to help adolescents feel more confident in managing chronic but controllable stressors. However, more longitudinal, and diverse investigations are needed to determine the stability of these changes in beliefs and whether they can promote more adaptive coping strategies. Nevertheless, the effects of adaptive stress should be promoted to help students recognise that not all stressors are detrimental and that they can use stress to their advantage at school, socially, at home, or during examinations.

"The program will help teenagers understand and learn to cope with stress and the stressors of everyday life. It would teach many ways to handle the stress and what stress does to the human body" (male, 14 years old).

References

Akinola, M., Fridman, I., Mor, S., Morris, M. W., & Crum, A. J. (2016). Adaptive appraisals of anxiety moderate the association between cortisol reactivity and performance in salary negotiations. *PLOS One*, *11*(12), e0167977. https://doi.org/10.1371/journal.pone.0167977

Albert P. R. (2015). Why is depression more prevalent in women? *Journal of psychiatry & neuroscience*, *40*(4), 219–221. https://doi.org/10.1503/jpn.150205

Arango, C., Díaz-Caneja, C. M., McGorry, P. D., Rapoport, J., Sommer, I. E., Vorstman, J. A., McDaid, D., Marín, O., Serrano-Drozdowskyj, E., & Freedman, R. (2018). Preventive strategies for mental health. *The Lancet Psychiatry*, *5*(7), 591-604. https://doi.org/10.1016/S2215-0366(18)30057-9

Awaworyi Churchill, S., Munyanyi, M. E., Prakash, K., & Smyth, R. (2020). Locus of control and the gender gap in mental health. *Journal of Economic Behavior & Organization*, *178*, 740-758. https://doi.org/10.1016/j.jebo.2020.08.013

Azzopardi, P., Blow, N., Purcell, T., Brown, N., Ritchie, T., & Brown, A. (2020). Investing in the health of Aboriginal and Torres Strait Islander adolescents: A foundation for achieving health equity. *Medical Journal of Australia*, *212*(5), 202-204. e201. https://doi.org/10.5694/mja2.50500

Ben-Avi, N., Toker, S., & Heller, D. (2018). "If stress is good for me, it's probably good for you too": Stress mindset and judgment of others' strain. *Journal of Experimental Social Psychology*, *74*, 98-110. https://doi.org/http://dx.doi.org/10.1016/j.jesp.2017.09.002

Bishop, F. M. (2018). Self-guided change: The most common form of long-term, maintained health behavior change. *Health Psychology Open*, *5*(1), 2055102917751576. https://doi.org/10.1177/2055102917751576

Boullier, M., & Blair, M. (2018). Adverse childhood experiences. *Paediatrics and Child Health*, *28*(3), 132-137. https://doi.org/10.1016/j.paed.2017.12.008

Bronfenbrenner, U. (2005). Ecological systems theory (1992). In U. Bronfenbrenner (Ed.), *Making human beings human: Bioecological perspectives on human development* (pp. 106–173). Sage Publications Ltd.

Carlisle E., Fildes, J., Hall, S., Perrens, B., Perdriau, A., and Plummer, J. (2019). *Youth survey report 2019*, Sydney, NSW: Mission Australia. https://www.missionaustralia.com.au/publications/youth-survey/1326-mission-australia-youth-survey-report-2019/file

Carter, R., Silverman, W. K., & Jaccard, J. (2011). Sex variations in youth anxiety symptoms: Effects of pubertal development and gender role orientation. *Journal of Clinical Child & Adolescent Psychology*, *40*(5), 730-741. https://doi.org/10.1080/15374416.2011.597082

Casper, A., Sonnentag, S., & Tremmel, S. (2017). Mindset matters: The role of employees' stress mindset for day-specific reactions to workload anticipation. *European Journal of Work and Organizational Psychology*, *26*(6), 798-810. https://doi.org/10.1080/1359432x.2017.1374947

Chen, H.-L., & Fang, S.-C. (2019a). Interaction effect of leader-member exchange and stress mindset on challenge stressor and job performance relationship. *Research Journal of Business and Management*, *6*(4), 281-290. https://doi.org/10.17261/Pressacademia.2019.1158

Chen, H.-L., & Fang, S.-C. (2019b). Job stressors and job performance: Modeling of moderating mediation effects of stress mindset. *Research Journal of Business and Management*, *6*(1), 35-45. https://doi.org/10.17261/Pressacademia.2019.1020

Chen, Z., & Hou, L. (2021). An actor-partner interdependence model of work challenge stressors and work-family outcomes: the moderating roles of dual-career couples' stress mindsets. *Journal of Business and Psychology*, 1-15. https://doi.org/10.1007/s10869-020-09724-1

Cho, S., Park, W. J., Kang, W., Lim, H. M., Ahn, J. S., Lim, D. Y., & Moon, J. D. (2019). The association between serum dehydroepiandrosterone sulfate (DHEAS) levels and job-related stress among female nurses. *Annals of Occupational and Environmental Medicine*, *31*, e18. https://doi.org/10.35371/aoem.2019.31.e18

Crane, M. F., Kho, M., Kangas, M., Griffin, B., Karin, E., Earl, J. K., & Harris, C. B. (2020). Strengthening resilience in over 50's: A nested clustered-randomized controlled trial of adaptive systematic self-reflection. *Anxiety, Stress, & Coping*, *33*(6), 623-641. https://doi.org/10.1080/10615806.2020.1768375

Crum, A. J., Akinola, M., Martin, A., & Fath, S. (2017). The role of stress mindset in shaping cognitive, emotional, and physiological responses to challenging and threatening stress. *Anxiety, Stress, & Coping*, *30*(4), 379-395. https://doi.org/10.1080/10615806.2016.1275585

Crum, A. J., Akinola, M., Turnwald, B. P., Kaptchuk, T. J., & Hall, K. T. (2018). Catechol-O-methyltransferase moderates effect of stress mindset on affect and cognition. *PLOS One*, *13*(4), e0195883. https://doi.org/10.1371/journal.pone.0195883

Crum, A. J., Jamieson, J. P., & Akinola, M. (2020). Optimizing stress: An integrated intervention for regulating stress responses. *Emotion*, *20*(1), 120-125. https://doi.org/10.1037/emo0000670

Crum, A. J., Salovey, P., & Achor, S. (2013). Rethinking stress: The role of mindsets in determining the stress response. *Journal of Personality and Social Psychology*, *104*(4), 716. https://doi.org/10.1037/a0031201

Dickson, J. M., Cruise, K., McCall, C. A., & Taylor, P. J. (2019). A systematic review of the antecedents and prevalence of suicide, self-harm and suicide ideation in Australian Aboriginal and Torres Strait Islander youth. *International Journal of Environmental Research and Public Health*, *16*(17), 3154.

Dong, E., Du, H., & Gardner, L. (2020). An interactive web-based dashboard to track COVID-19 in real time. *The Lancet Infectious Diseases*, *20*(5), 533-534. https://doi.org/10.1016/S1473-3099(20)30120-1

Duan, L., Shao, X., Wang, Y., Huang, Y., Miao, J., Yang, X., & Zhu, G. (2020). An investigation of mental health status of children and adolescents in china during the outbreak of COVID-19. *Journal of Affective Disorders*, *275*, 112-118. https://doi.org/10.1016/j.jad.2020.06.029

Ducharme, P., Kahn, J., Vaudreuil, C., Gusman, M., Waber, D., Ross, A., Rotenberg, A., Rober, A., Kimball, K., Peechatka, A. L., & Gonzalez-Heydrich, J. (2021). A "Proof of Concept" randomized controlled trial of a video game requiring emotional regulation to augment anger control training. *Frontiers in Psychiatry*, *12*, 591906-591906. https://doi.org/10.3389/fpsyt.2021.591906

Emerging Minds. (2020). *Adverse Childhood Experiences (ACEs): Summary of evidence and impacts*. https://d2p3kdr0nr4o3z.cloudfront.net/content/uploads/2020/02/19102540/ACES-Summary-of-Evidence-and-Impacts-V2.pdf

Flesch, R. (1979). *How to write plain English: A book for lawyers and consumers*. Harpercollins.

Fredrick, S. S., Demaray, M. K., Malecki, C. K., & Dorio, N. B. (2018). Can social support buffer the association between depression and suicidal ideation in adolescent boys and girls?. *Psychology in the Schools*, *55*(5), 490-505. https://doi.org/10.1002/pits.22125

Giannopoulou, I., Efstathiou, V., Triantafyllou, G., Korkoliakou, P., & Douzenis, A. (2021). Adding stress to the stressed: Senior high school students' mental health amidst the COVID-19 nationwide lockdown in Greece. *Psychiatry Research*, *295*, 113560-113560. https://doi.org/10.1016/j.psychres.2020.113560

Gold, J. (2019). Overcoming students' limiting viewpoints via learner & stress mindset teaching interventions. *The European Journal of Social & Behavioural Sciences*, *24*(1), 2805-2821. https://doi.org/10.15405/ejsbs.246

Goldstein, S. E., Boxer, P., & Rudolph, E. (2015). Middle school transition stress: Links with academic performance, motivation, and school experiences. *Contemporary School Psychology*, *19*(1), 21-29. https://doi.org/10.1007/s40688-014-0044-4

Gonski, D., Arcus, T., Boston, K., Gould, V., Johnson, W., O'Brien, L., Perry, L., & Roberts, M. (2018). *Through growth to achievement: Report of the review to achieve educational excellence in Australian schools.* Canberra: Commonwealth of Australia. https://www.dese.gov.au/download/4175/through-growth-achievement-report-review-achieve-educational-excellence-australian-schools/18692/document/pdf

Gouvernement du Québec. (2021). *List of all infographics related to the Prime Minister's announcements (COVID-19)*. https://www.quebec.ca/en/premier/premier/access-to-publications-related-to-the-premiers-announcements-concerning-covid-19/liste-de-toutes-les-infographies-en-lien-avec-les-annonces-du-premier-ministre-covid-19

Hafstad, G. S., Sætren, S. S., Wentzel-Larsen, T., & Augusti, E.-M. (2021). Adolescents' symptoms of anxiety and depression before and during the Covid-19 outbreak – A prospective population-based study of teenagers in Norway. *The Lancet Regional Health - Europe*, *5*, 100093. https://doi.org/10.1016/j.lanepe.2021.100093

Hammond, M. M., Murphy, C., & Demsky, C. A. (2020). Stress mindset and the work–family interface. *International Journal of Manpower*, *42*(1). 150-166. https://doi.org/10.1108/ijm-05-2018-0161

Hampel, P., & Petermann, F. (2006). Perceived stress, coping, and adjustment in adolescents. *Journal of Adolescent Health*, *38*(4), 409-415. https://doi.org/10.1016/j.jadohealth.2005.02.014

Heerde, J. A., & Hemphill, S. A. (2018). Examination of associations between informal help-seeking behavior, social support, and adolescent psychosocial outcomes: A meta-analysis. *Developmental Review*, *47*, 44-62. https://doi.org/10.1016/j.dr.2017.10.001

Higashi, T., Yamagata, K., Kato, Y., Ogawa, Y., Takano, K., Nakaaze, Y., . . . Ogawa, S. (2016). Methods for determination of fingernail steroids by LC/MS/MS and differences in their contents between right and left hands. *Steroids*, *109*, 60-65. https://doi.org/10.1016/j.steroids.2016.02.013

Hogue, C. M. (2019). The protective impact of a mental skills training session and motivational priming on participants' psychophysiological responses to performance stress. *Psychology of Sport and Exercise*, *45*, 101574. https://doi.org/10.1016/j.psychsport.2019.101574

Huettermann, H., & Bruch, H. (2019). Mutual gains? health-related HRM, collective well-being and organizational performance. *Journal of Management Studies*, *56*(6), 1045-1072. https://doi.org/10.1111/joms.12446

Iwamoto, K., Takehashi, H., & Taka, F. (2019). Reliability and validity of a Japanese translation of the Stress Mindset Measure (SMM-J). *Japanese Journal of Psychology*, *90*(6), 592-602. http://dx.doi.org/10.4992/jjpsy.90.18229

Iwamoto, K., Takehashi, H., Ozaki, Y., & Narita, N. (2020). Investigating effects of intelligence and stress mindsets on system engineer's mental health and learning motivations. *Japanese Journal of Motivational Studies: IMSAR Annual Report*, *9*(2), 9.

Jamieson, J. P., Crum, A. J., Goyer, J. P., Marotta, M. E., & Akinola, M. (2018). Optimizing stress responses with reappraisal and mindset interventions: an integrated model. *Anxiety, Stress & Coping*, *31*(3), 245-261. https://doi.org/10.1080/10615806.2018.1442615

Jamieson, J. P., Mendes, W. B., Blackstock, E., & Schmader, T. (2010). Turning the knots in your stomach into bows: Reappraising arousal improves performance on the GRE. *Journal of Experimental Social Psychology*, *46*(1), 208-212. https://doi.org/10.1016/j.jesp.2009.08.015

Jamieson, J. P., Nock, M. K., & Mendes, W. B. (2012). Mind over matter: Reappraising arousal improves cardiovascular and cognitive responses to stress. *Journal of Experimental Psychology: General*, *141*(3), 417-422. https://doi.org/10.1037/a0025719

Jiang, Y., Zhang, J., Ming, H., Huang, S. L., & Lin, D. H. (2019). Stressful life events and well-being among rural-to-urban migrant adolescents: The moderating role of the stress mindset and differences between genders. *Journal of Adolescence*, *74*, 24-32. https://doi.org/10.1016/j.adolescence.2019.05.005

Jose, P. E., Wilkins, H., & Spendelow, J. S. (2012). Does social anxiety predict rumination and co-rumination among adolescents? *Journal of Clinical Child & Adolescent Psychology*, *41*(1), 86-91. https://doi.org/10.1080/15374416.2012.632346

Journault, A., & Lupien, S. (2020). *Addendum to MATA's study: Stress mindset intervention*. https://doi.org/10.17605/OSF.IO/U4CMF

Karampas, K., Pezirkianidis, C., & Stalikas, A. (2020). Psychometric properties of the Stress Mindset Measure (SMM) in a Greek sample. *Psychology*, *11*(08), 1185. https://doi.org/10.4236/psych.2020.118079

Keech, J. J., Cole, K. L., Hagger, M. S., & Hamilton, K. (2020). The association between stress mindset and physical and psychological wellbeing: Testing a stress beliefs model in police officers. *Psychology & Health*, *35*(11), 1306-1325. https://doi.org/10.1080/08870446.2020.1743841

Keech, J. J., Hagger, M. S., & Hamilton, K. (2021). Changing stress mindsets with a novel imagery intervention: A randomized controlled trial. *Emotion*, *21*(1), 123-136. https://doi.org/10.1037/emo0000678

Keech, J. J., Hagger, M. S., O'Callaghan, F. V., & Hamilton, K. (2018). The infuence of university students' stress mindsets on health and performance outcomes. *Annals of Behavioral Medicine*, *52*(12), 1046-1059. https://doi.org/10.1093/abm/kay008

Keech, J. J., Orbell, S., Hagger, M. S., O'Callaghan, F. V., & Hamilton, K. (2021). Psychometric properties of the stress control mindset measure in university students from Australia and the UK. *Brain and Behavior*, *11*(2), e01963. https://doi.org/10.1002/brb3.1963

Kessler, R. C., Amminger, G. P., Aguilar-Gaxiola, S., Alonso, J., Lee, S., & Ustün, T. B. (2007). Age of onset of mental disorders: A review of recent literature. *Current Opinion in Psychiatry*, *20*(4), 359–364. https://doi.org/10.1097/YCO.0b013e32816ebc8c

Kim, J., Shin, Y., Tsukayama, E., & Park, D. (2020). Stress mindset predicts job turnover among preschool teachers. *Journal of School Psychology*, *78*, 13-22. https://doi.org/10.1016/j.jsp.2019.11.002

Lee, D. Y., Kim, E., & Choi, M. H. (2015). Technical and clinical aspects of cortisol as a biochemical marker of chronic stress. *BMB Reports*, *48*(4), 209–216. http://doi.org/10.5483/BMBRep.2015.48.4.275

Lee, H. Y., Jamieson, J. P., Miu, A. S., Josephs, R. A., & Yeager, D. S. (2019). An entity theory of intelligence predicts higher cortisol levels when high school grades are declining. *Child Development*, *90*(6), e849-e867. https://doi.org/10.1111/cdev.13116

Liang, L., Ren, H., Cao, R., Hu, Y., Qin, Z., Li, C., & Mei, S. (2020). The effect of COVID-19 on youth mental health. *Psychiatric Quarterly*, *91*(3), 841-852. https://doi.org/10.1007/s11126-020-09744-3

Liu, J. J. W., Ein, N., Gervasio, J., & Vickers, K. (2019). The efficacy of stress reappraisal interventions on stress responsivity: A meta-analysis and systematic review of existing evidence. *PLOS One*, *14*(2), e0212854-e0212854. https://doi.org/10.1371/journal.pone.0212854

Liu, P. L. (2020). COVID-19 information seeking on digital media and preventive behaviors: the mediation role of worry. *Cyberpsychology, Behavior, and Social Networking*, *23*(10), 677-682. https://doi.org/10.1089/cyber.2020.0250

Lowe, K., & Yunkaporta, T. (2013). The inclusion of Aboriginal and Torres Strait Islander content in the Australian National Curriculum: A cultural, cognitive and socio-political evaluation. *Curriculum Perspectives*, *33*(1), 1-14.

Lupien, S. J., King, S., Meaney, M. J., & McEwen, B. S. (2001). Can poverty get under your skin? Basal cortisol levels and cognitive function in children from low and high socioeconomic status. *Development and Psychopathology*, *13*(3), 653-676. https://doi.org/10.1017/S0954579401003133

Lupien, S. J., Maheu, F., Tu, M., Fiocco, A., & Schramek, T. E. (2007). The effects of stress and stress hormones on human cognition: Implications for the field of brain and cognition. *Brain and Cognition*, 65(3), 209-237. https://doi.org/10.1016/j.bandc.2007.02.007

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

Lupien, S. J., Ouellet-Morin, I., Trépanier, L., Juster, R. P., Marin, M. F., Francois, N., Sindi, S., Wan, N., Findlay, H., Durand, N., Cooper, L., Schramek, T., Andrews, J., Corbo, V., Dedovic, K., Lai, B., & Plusquellec, P. (2013). The DeStress for Success Program: Effects of a stress education program on cortisol levels and depressive symptomatology in adolescents making the transition to high school. *Neuroscience*, *249*, 74-87. https://doi.org/10.1016/j.neuroscience.2013.01.057

Ma, Z., Idris, S., Zhang, Y., Zewen, L., Wali, A., Ji, Y., Pan, Q., & Baloch, Z. (2021). The impact of COVID-19 pandemic outbreak on education and mental health of Chinese children aged 7-15 years: an online survey. *BMC pediatrics*, *21*(1), 95-95. https://doi.org/10.1186/s12887-021-02550-1

Maarsingh, B. M., Bos, J., Van Tuijn, C. F. J., & Renard, S. B. (2019). Changing stress mindset through Stressjam: A virtual reality game using biofeedback. *Games for Health*, *8*(5), 326-331. http://dx.doi.org/10.1089/g4h.2018.0145

Magson, N. R., Freeman, J. Y. A., Rapee, R. M., Richardson, C. E., Oar, E. L., & Fardouly, J. (2021). Risk and protective factors for prospective changes in adolescent mental health during the COVID-19 pandemic. *Journal of Youth and Adolescence*, *50*(1), 44-57. https://doi.org/10.1007/s10964-020-01332-9

Malooly, A. M., Flannery, K. M., & Ohannessian, C. M. (2017). Coping mediates the association between gender and depressive symptomatology in adolescence. *International Journal of Behavioral Development*, *41*(2), 185-197. https://doi.org/10.1177/0165025415616202

Maninger, N., Wolkowitz, O. M., Reus, V. I., Epel, E. S., & Mellon, S. H. (2009). Neurobiological and neuropsychiatric effects of dehydroepiandrosterone (DHEA) and DHEA sulfate (DHEAS). *Frontiers in Neuroendocrinology*, *30*(1), 65-91. https://doi.org/10.1016/j.yfrne.2008.11.002

McCrindle. (2021). *MyStrengths youth wellbeing report 2021*. https://s3.amazonaws.com/kajabi-storefronts-production/sites/163568/themes/2149125913/downloads/TnT1pVifTn62tOGicnyT_MyStrengths_Youth_Wellbeing_Report_2021.pdf

McEwen, B. S. (2017). Neurobiological and systemic effects of chronic stress. *Chronic Stress*, *1*, 2470547017692328. https://doi.org/10.1177/2470547017692328

McEwen, B. S. (2019). The good side of “stress”. *Stress*, *22*(5), 524-525. https://doi.org/10.1080/10253890.2019.1631794

McLaughlin, K. A., Costello, E. J., Leblanc, W., Sampson, N. A., & Kessler, R. C. (2012). Socioeconomic status and adolescent mental disorders. *American Journal of Public Health*, *102*(9), 1742-1750.

Meda, N., Pardini, S., Slongo, I., Bodini, L., Zordan, M. A., Rigobello, P., Visioli, F., & Novara, C. (2021). Students' mental health problems before, during, and after COVID-19 lockdown in Italy. *Journal of Psychiatric Research*, *134*, 69-77. https://doi.org/10.1016/j.jpsychires.2020.12.045

Ministère de la Santé et des services sociaux. (2021). *Historique du portrait quotidien des cas confirmés*. Quebec Retrieved from https://www.donneesquebec.ca/recherche/dataset/covid-19-portrait-quotidien-des-cas-confirmes/resource/d2cf4211-5400-46a3-9186-a81e6cd41de9

Morgan, C. A., 3rd, Southwick, S., Hazlett, G., Rasmusson, A., Hoyt, G., Zimolo, Z., & Charney, D. (2004). Relationships among plasma dehydroepiandrosterone sulfate and cortisol levels, symptoms of dissociation, and objective performance in humans exposed to acute stress. *Archives of General Psychiatry*, *61*(8), 819-825. https://doi.org/10.1001/archpsyc.61.8.819

Nguyen, T. T. T., Neff, L. A., & Williamson, H. C. (2020). The role of stress mindset in support provision. *Personal Relationships*. http://dx.doi.org/10.1111/pere.12302

Oldehinkel, A. J., & Bouma, E. M. C. (2011). Sensitivity to the depressogenic effect of stress and HPA-axis reactivity in adolescence: A review of gender differences. *Neuroscience & Biobehavioral Reviews*, *35*(8), 1757-1770. https://doi.org/10.1016/j.neubiorev.2010.10.013

Östberg, V., Almquist, Y. B., Folkesson, L., Låftman, S. B., Modin, B., & Lindfors, P. (2015). The complexity of stress in mid-adolescent girls and boys. *Child Indicators Research*, *8*(2), 403-423. https://doi.org/10.1007/s12187-014-9245-7

Park, D., Yu, A., Metz, S. E., Tsukayama, E., Crum, A. J., & Duckworth, A. L. (2018). Beliefs about stress attenuate the relation among adverse life events, perceived distress, and self-control. *Child Development*, *89*(6), 2059-2069. http://dx.doi.org/10.1111/cdev.12946

Park, H., & Hahm, S. (2019). Changes in stress mindset and EEG through E-healthcare based education. *IEEE Access*, *7*, 20163-20171, Article 8629068. https://doi.org/10.1109/ACCESS.2019.2895655

Petersen, A. C., Sarigiani, P. A., & Kennedy, R. E. (1991). Adolescent depression: Why more girls? *Journal of Youth and Adolescence*, *20*(2), 247-271. https://doi.org/10.1007/BF01537611

Phillips, R., Kraeuter, A. K., McDermott, B., Lupien, S., & Sarnyai, Z. (2021). Human nail cortisol as a retrospective biomarker of chronic stress: A systematic review. *Psychoneuroendocrinology*, *123*, 104903. https://doi.org/10.1016/j.psyneuen.2020.104903

Queensland Government. (2021). *Queensland COVID-19 statistics*. https://www.qld.gov.au/health/conditions/health-alerts/coronavirus-covid-19/current-status/statistics#casesummary

Ravens-Sieberer, U., Kaman, A., Otto, C., Adedeji, A., Devine, J., Erhart, M., Napp, A.-K., Becker, M., Blanck-Stellmacher, U., Löffler, C., Schlack, R., & Hurrelmann, K. (2020). Mental health and quality of life in children and adolescents during the COVID-19 pandemic-results of the Copsy Study. *Deutsches Arzteblatt international*, *117*(48), 828-829. https://doi.org/10.3238/arztebl.2020.0828

Reiss, F., Meyrose, A.-K., Otto, C., Lampert, T., Klasen, F., & Ravens-Sieberer, U. (2019). Socioeconomic status, stressful life situations and mental health problems in children and adolescents: Results of the German BELLA cohort-study. *PLOS One*, *14*(3), e0213700. https://doi.org/10.1371/journal.pone.0213700

Rogers, A. A., Ha, T., & Ockey, S. (2021). Adolescents' perceived socio-emotional impact of COVID-19 and implications for mental health: Results from a U.S.-based mixed-methods study. *Journal of Adolescent Health*, *68*(1), 43-52. https://doi.org/10.1016/j.jadohealth.2020.09.039

Romeo, R. D. (2013). The teenage brain: The stress response and the adolescent brain. *Current Directions in Psychological Science*, *22*(2), 140-145. https://doi.org/10.1177/0963721413475445

Sapolsky, R. M. (1996). Why Stress Is Bad for Your Brain. *Science*, *273*(5276), 749-750. https://doi.org/10.1126/science.273.5276.749

Smith, D. T., Mouzon, D. M., & Elliott, M. (2018). Reviewing the assumptions about men's mental health: An exploration of the gender binary. *American Journal of Men's Health*, *12*(1), 78-89. https://doi.org/10.1177/1557988316630953

Smith, E. N., Young, M. D., & Crum, A. J. (2020). Stress, mindsets, and success in Navy SEALs special warfare training. *Frontiers in Psychology*, *10*, 2962. https://doi.org/10.3389/fpsyg.2019.02962

Soroka, S., & McAdams, S. (2015). News, politics, and negativity. *Political Communication*, *32*(1), 1-22. https://doi.org/10.1080/10584609.2014.881942

Staufenbiel, S. M., Penninx, B. W., Spijker, A. T., Elzinga, B. M., & van Rossum, E. F. (2013). Hair cortisol, stress exposure, and mental health in humans: A systematic review. *Psychoneuroendocrinology*, *38*(8), 1220-1235. https://doi.org/10.1016/j.psyneuen.2012.11.015

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53-55. https://doi.org/10.5116/ijme.4dfb.8dfd

Thorisdottir, I. E., Asgeirsdottir, B. B., Kristjansson, A. L., Valdimarsdottir, H. B., Jonsdottir Tolgyes, E. M., Sigfusson, J., Allegrante, J. P., Sigfusdottir, I. D., & Halldorsdottir, T. (2021). Depressive symptoms, mental wellbeing, and substance use among adolescents before and during the COVID-19 pandemic in Iceland: a longitudinal, population-based study. *The Lancet Psychiatry*, *8*(8), 663-672. https://doi.org/10.1016/S2215-0366(21)00156-5

Warnock, F., McElwee, K., Seo, R. J., McIsaac, S., Seim, D., Ramirez-Aponte, T., . . . Young, A. H. (2010). Measuring cortisol and DHEA in fingernails: a pilot study. *Neuropsychiatric Disease and Treatment*, *6*, 1-7.

Warren, D., & Yu, M. (2016). Pubertal status and emotional, school and social functioning. *Annual statistical report 2015*, 127.

Wennig, R. (2000). Potential problems with the interpretation of hair analysis results. *Forensic Science International*, *107*(1-3), 5-12. https://doi.org/10.1016/s0379-0738(99)00146-2

White, B. P. (2014). The perceived stress scale for children: A pilot study in a sample of 153 children. *International Journal of Pediatrics and Child Health*, *2*(2), 45-52. http://dx.doi.org/10.12974/2311-8687.2014.02.02.4

Wight, R. G., Botticello, A. L., & Aneshensel, C. S. (2006). Socioeconomic context, social support, and adolescent mental health: A multilevel investigation. *Journal of Youth and Adolescence*, *35*(1), 109. https://doi.org/10.1007/s10964-005-9009-2

Wols, A., Poppelaars, M., Lichtwarck-Aschoff, A., & Granic, I. (2020). The role of motivation to change and mindsets in a game promoted for mental health. *Entertainment Computing*, *35*, 100371. https://doi.org/10.1016/j.entcom.2020.100371

World Health Organisation. (2021a). *Rolling updates on coronavirus disease (COVID-19)*. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen

Zhou, S.-J., Zhang, L.-G., Wang, L.-L., Guo, Z.-C., Wang, J.-Q., Chen, J.-C., Liu, M., Chen, X., & Chen, J.-X. (2020). Prevalence and socio-demographic correlates of psychological health problems in Chinese adolescents during the outbreak of COVID-19. *European Child & Adolescent Psychiatry*, *29*(6), 749-758. https://doi.org/10.1007/s00787-020-01541-4

Zorn, J. V., Schür, R. R., Boks, M. P., Kahn, R. S., Joëls, M., & Vinkers, C. H. (2017). Cortisol stress reactivity across psychiatric disorders: A systematic review and meta-analysis. *Psychoneuroendocrinology*, *77*, 25-36. https://doi.org/10.1016/j.psyneuen.2016.11.036

Appendix

Ethics Approval

This administrative form has been removed

Chapter 6 Author Contributions

The candidate's contribution to the work included the following:

- Research conception
- Data collection
- Data analysis
- Manuscript writing
- Manuscript revision
- Responsibility for the final content
- Approval of final manuscript

The nature of the co-author contribution is listed below in order of authorship:

Co-author	Affiliation	Contribution
Audrey-Ann Journault	Centre for Studies on Human Stress, Psychology Department, University of Montreal, Canada	• Research conception • Data collection • Data analysis • Manuscript revision • Responsibility for the final content • Approval of final manuscript
Rebecca Cernik	Centre for Studies on Human Stress, Psychiatry Department, University of Montreal, Canada	• Research conception • Data collection • Manuscript revision • Approval of final manuscript
Dr Paul Welch	College of Medicine and Dentistry, James Cook University, Townsville, Queensland, Australia	• Data collection • Manuscript revision • Approval of final manuscript
Professor Sonia Lupien	Centre for Studies on Human Stress, Psychiatry Department, University of Montreal, Canada	• Research conception • Manuscript revision • Approval of final manuscript
Professor Brett McDermott	College of Medicine and Dentistry, James Cook University, Townsville, Queensland, Australia	• Manuscript revision • Approval of final manuscript
Dr Joseph V Moxon	College of Medicine and Dentistry, James Cook University, Townsville, Queensland, Australia	• Manuscript revision • Approval of final manuscript
Professor Zoltan Sarnyai	Laboratory of Psychiatric Neuroscience, Australian Institute of Tropical Health and Medicine. College of Public Health, Medical, and Veterinary Sciences, James Cook University, Townsville, Queensland, Australia	• Manuscript revision • Approval of final manuscript

Declaration by co-authors

The undersigned hereby certify that:

- The above declaration correctly reflects the nature of the candidate's contribution to this work and the nature of the contribution of each of the co-authors.
- The authors listed here meet the criteria for authorship in that they have participated in the design, execution or interpretation of the work presented.
- The listed authors take public responsibility for their part in the thesis manuscript. The senior/ corresponding author, however, accepts overall responsibility for the publication.
- All authors have been included in the manuscript.
- The editor/publisher of the journal has been informed of the role of the funding source and any conflicts of interest.

Signatures:

Riana Marie

Professor Brett McDermott

Audrey-Ann Journault

Professor Sonia Lupien

Rebecca Cernik

Dr Joseph Moxon

Dr Paul Welch

Professor Zoltan Sarnyai

Chapter 7 Author Contributions

The candidate's contribution to the work included the following:

- Research conception
- Reviewed the literature
- Manuscript writing
- Manuscript revision
- Responsibility for the final content
- Approval of final manuscript

The nature of the co-author contribution is listed below in order of authorship:

Co-author	Affiliation	Contribution
Dr Ann-Katrin Kraeuter	Psychology Department, Northumbria University, Newcastle Upon Tyne	• Research conception • Quality assessment • Manuscript revision • Approval of final manuscript
Professor Brett McDermott	College of Medicine and Dentistry, James Cook University, Townsville, Queensland, Australia	• Manuscript revision • Approval of final manuscript
Professor Sonia Lupien	Centre for Studies on Human Stress, Psychiatry Department, University of Montreal, Canada	• Manuscript revision • Approval of final manuscript
Professor Zoltan Sarnyai	Laboratory of Psychiatric Neuroscience, Australian Institute of Tropical Health and Medicine College of Medicine and Dentistry, James Cook University, Townsville, Queensland, Australia	• Research conception • Manuscript revision • Approval of final manuscript

Declaration by co-authors

The undersigned hereby certify that:

- The above declaration correctly reflects the nature of the candidate's contribution to this work and the nature of the contribution of each of the co-authors.
- The authors listed here meet the criteria for authorship in that they have participated in the design, execution or interpretation of the work presented.
- The listed authors take public responsibility for their part in the thesis manuscript. The senior/ corresponding author, however, accepts overall responsibility for the publication.
- All authors have been included in the manuscript.
- The editor/publisher of the journal has been informed of the role of the funding source and any conflicts of interest.

Signatures:

Riana Marie

Professor Brett McDermott

Dr Ann-Katrin Kraeuter

Professor Sonia Lupien

Professor Zoltan Sarnyai