

**The Empathic Highly Sensitive Person: Investigating the Relationship between Sensory
Processing Sensitivity and Empathy through Behavioural, Self-Report, and Functional
Magnetic Resonance Imaging Measures**

by

Amanda M. McQuarrie

**A Thesis submitted to the
Faculty of Graduate and Postdoctoral Studies
of the University of Manitoba
in partial fulfilment of the requirements of the degree of**

Doctor of Philosophy

Department of Psychology

University of Manitoba

Winnipeg

Copyright © 2026 by Amanda M. McQuarrie

Abstract

Variations in levels of empathy (i.e., the process of identifying and sharing the affective state of the other person) exist across the general population, in part based on certain personality traits. Sensory processing sensitivity (SPS) is a personality trait associated with higher levels of empathy. SPS is defined by heightened sensitivity to one's environment and emotional reactivity. A more recent conceptualization of the trait breaks it into two components: a positive trait aspect (SPS+) capturing sensitivity to positive and subtle stimuli and aesthetic sensitivity; and a negative aspect (SPS-) which includes sensitivity to unpleasant stimuli and emotional reactivity. This manuscript explores the relationship between SPS (and its components) and empathy across three studies that investigate environmental factors associated with the relationship, and the neural correlates of SPS related to empathy in the resting brain and during an emotional contagion task. Across each study, the primary difference in the relationship between the SPS components and empathy related to the experience of personal distress while empathizing; specifically, SPS+ traits acted as a protective mechanism against the experience of personal distress while SPS- traits were linked to heightened distress. The experience of emotional abuse in childhood positively predicted levels of SPS, which then predicted variations in empathy, emphasizing the role of childhood environment in the development of SPS and empathy. Neuroimaging findings identified a deeper level of processing in the SPS brain, particularly in emotional and visual processing regions, as well as findings specific to each SPS component. Overall, the studies presented in this manuscript provide a detailed exploration into the relationship between SPS and empathy. Additionally, the findings contribute novel information regarding the conceptualization of SPS+ and SPS- components as well as their neural correlates, which have not previously been investigated.

Acknowledgments

I would like to express my gratitude to Drs. Lorna Jakobson and Stephen Smith, who have provided so much expertise and guidance as research supervisors throughout my studies. I would also like to thank the members of my Dissertation committee, Drs. Jennifer Kornelsen, Steven Greening, and Edward Johnson. Financial support for the studies included in this manuscript was provided by the Natural Sciences and Engineering Research Council of Canada, Postgraduate Scholarship – Doctoral.

Table of Contents

Abstract	2
Acknowledgments.....	3
List of Tables	9
List of Figures	11
List of Abbreviations	12
Chapter 1: General Introduction	13
Sensory Processing Sensitivity	13
Empathy	16
Links Between Emotional Contagion and Empathy	17
Sensory Processing Sensitivity and Empathy	20
The Current Studies	21
References.....	23
Chapter 2: Exploring the Links between Childhood Emotional Abuse and Empathy: The Mediating Roles of Alexithymia and Sensory Processing Sensitivity.....	30
Abstract	31
Introduction.....	32
Materials and Methods.....	36
Participants.....	36
General Procedure.....	36
Measures	37
Emotional Contagion Behavioural Task.....	37
Emotional Abuse Subscale of the Childhood Trauma Questionnaire–Short Form	37

Toronto Alexithymia Scale	37
Sensory Processing Sensitivity	38
Interpersonal Reactivity Index and Empathy Index	39
Analyses	39
Results	41
Emotional Contagion Profiles	41
Descriptive Statistics and Zero-Order Correlations	42
Mediation Analyses	44
Discussion	47
Links Between Childhood Emotional Abuse and Personality Traits	49
Alexithymia and Sensory Processing Sensitivity as Mediators	49
Limitations and Future Directions	52
Conclusion	54
Data Availability Statement	54
Contributions of Authors	55
References	56
Supplementary Material	65
References	67
Chapter 3: Resting-State Functional Connectivity Related to Empathy and Sensory Processing Sensitivity	72
Abstract	73
Highlights	74
Introduction	75

Methods.....	78
Participants.....	78
General Procedure.....	78
Scanning Parameters.....	79
Personality Questionnaires.....	79
Measures of SPS	79
Measures of Empathy	80
Analyses	81
Personality Questionnaires	81
Neuroimaging Analyses.....	82
Results.....	83
Self-Report Data	83
Functional Resting-State Analyses	83
Discussion.....	90
Enhanced Visual Processing and Deeper Processing	91
Heightened Interoceptive and Emotional Processing and Possible Links to Distress and Emotion Dysregulation	92
Limitations and Future Directions	95
Data Statement.....	96
Acknowledgements.....	96
Author Contributions	97
Informed Consent.....	97
Funding Sources.....	97

References	98
Chapter 4: Associations between Sensory Processing Sensitivity and Neural Activity During an Emotional Contagion Task	108
Abstract	109
Highlights	110
Introduction	111
Methods	114
Participants	114
Measures	115
Scanning Parameters	116
General Procedure	116
Analyses	119
Results	120
Self-Report and Behavioural Data	120
Neuroimaging Data	121
Discussion	126
Patterns of Brain Activity During Different Types of Emotional Contagion	126
Exploring Individual Differences in Emotional Contagion Neural Activity	128
Links Between SPS and Activity Specific to Contagious Amusement	128
Links Between SPS and Activity Specific to Contagious Fear	130
Links Between SPS and Activity Specific to Mixed-Valence Contagion	132
Limitations	133
Conclusions and Future Directions	133

Data Statement	135
Acknowledgements	135
Author Contributions	135
Informed Consent.....	136
Funding Sources.....	136
References	137
Chapter 5: General Conclusion	146
The Experience of Personal Distress	148
Clinical Implications and Treatment.....	149
Implications and Treatment of Empathy Deficits	149
Implications of Heightened Empathy	150
Potential Treatment for Heightened Empathy Associated with SPS- Traits	151
Concluding Remarks.....	153
References	155
Appendix: Consent Forms	160

List of Tables

Chapter 2: Exploring the Links between Childhood Emotional Abuse and Empathy: The Mediating Roles of Alexithymia and Sensory Processing Sensitivity

Table 1. Descriptive Statistics for Behavioural Task and Self-Report Measures	43
Table 2. Models Showing Significant Mediation between Childhood Emotional Abuse and Behavioural Measures of Emotional Contagion via Personality Variables	46
Table 3. Significant Mediations between Childhood Emotional Abuse and Self-Reported Empathy via Personality Variables	47
Supplementary Table S1. Film Names and Sources for Emotional Contagion Behavioural Task	69
Supplementary Table S2. Pearson Correlation Coefficients Measuring the Relationships between Behavioural and Self-Report Variables	71

Chapter 3: Resting-State Functional Connectivity Related to Empathy and Sensory Processing Sensitivity

Table 1. Descriptive Statistics for Sensory Processing Sensitivity and Empathy and Related Constructs	84
Table 2. Regression Analyses Showing Relationships between Sensory Processing Sensitivity and Empathy Subscales	85
Table 3. Brain Regions Showing Correlated Connectivity with the Positive Sensory Processing Sensitivity Trait Cluster	86
Table 4. Brain Regions Showing Correlated Connectivity with the Negative Sensory Processing Sensitivity Trait Cluster	88

Chapter 4: Associations between Sensory Processing Sensitivity and Neural Activity During an Emotional Contagion Task

Table 1. Demographic Information of Participants and Descriptive Statistics for Sensory Processing Sensitivity Trait Components	120
Table 2. Main Effects Comparing Neural Activity for Each Film Type	122
Table 3. Neural Activity Associated with Sensory Processing Sensitivity Positive Traits ...	123
Table 4. Neural Activity Associated with Sensory Processing Sensitivity Negative Traits .	125

List of Figures

Chapter 2: Exploring the Links between Childhood Emotional Abuse and Empathy: The Mediating Roles of Alexithymia and Sensory Processing Sensitivity

Figure 1. Mean Ratings of the Measured Emotions When Viewing the Four Film Types 42

Figure 2. The General Form of the Mediation Analyses 45

Chapter 3: Resting-State Functional Connectivity Related to Empathy and Sensory Processing Sensitivity

Figure 1. Neural Regions Functionally Connected with the Medial Prefrontal Cortex and Correlated with the Positive Sensory Processing Sensitivity Trait Cluster 87

Figure 2. Functional Connectivity Correlated with the Negative Sensory Processing Sensitivity Trait Cluster 89

Chapter 4: Associations between Sensory Processing Sensitivity and Neural Activity During an Emotional Contagion Task

Figure 1. Design of the Emotional Contagion Paradigm 118

Figure 2. Clusters of Neural Activation Associated with Sensory Processing Sensitivity Positive Traits 124

Figure 3. Clusters of Neural Activation Associated with Sensory Processing Sensitivity Negative Traits 126

List of Abbreviations

Abbreviation	Explanation
ANOVA	Analysis of variance
BC	Behavioural Contagion subscale of the Empathy Index
DMN	Default mode network
eaCTQ	Emotional Abuse subscale of the Childhood Trauma Questionnaire-Short Form
EC	Empathic Concern subscale of the Interpersonal Reactivity Index
EI	Empathy Index
EMP	Empathy subscale of the Empathy Index
FC	Functional connectivity
FDR	False discovery rate
fMRI	Functional magnetic resonance imaging
FS	Fantasy subscale of the Interpersonal Reactivity Index
FWE	Family-wise error
HSPS	Highly Sensitive Person Scale
IPL	Inferior parietal lobule
IFG	Inferior frontal gyrus
IRI	Interpersonal Reactivity Index
IRI/EI	Combined Interpersonal Reactivity Index and Empathy Index
LOC	Lateral occipital cortex
mPFC	Medial prefrontal cortex
MP-RAGE	Magnetization-prepared rapid gradient-echo
MRI	Magnetic resonance imaging
MTG	Middle temporal gyri
OS	Orienting Sensitivity subscale of the Adult Temperament Questionnaire
PD	Personal distress subscale of the Interpersonal Reactivity Index
PT	Perspective-taking subscale of the Interpersonal Reactivity Index
rsMRI	Resting-state functional magnetic resonance imaging
SD	Standard deviation
SPS	Sensory processing sensitivity
SPS+	Positive sensory processing sensitivity trait cluster
SPS-	Negative sensory processing sensitivity trait cluster
TAS-20	Toronto Alexithymia Scale

Chapter 1: General Introduction

The following chapter will introduce the main concepts of this dissertation manuscript, specifically, sensory processing sensitivity, empathy, and emotional contagion, and identify relationships across these variables. The three studies presented in this manuscript will then be briefly described.

Sensory Processing Sensitivity

Sensory processing sensitivity (SPS), conceptualized by Aron and Aron (1997), is a personality trait defined by increased sensitivities to one's internal and external environment, "deep" processing of information (i.e., in a more meaningful way to support encoding into long term memory; Craik & Lockhart, 1972), and heightened emotional reactivity (Aron et al., 2012). This personality trait is found in up to 30% of individuals (Lionetti et al., 2018). SPS is influenced almost equally by genetic and environmental factors (Assary et al., 2021).

The Highly Sensitive Person Scale (HSPS; Aron & Aron, 1997) is the most commonly used self-report measure of SPS. Items are grouped into three subscales (Smith et al., 2019; Smolewska et al., 2006). The first subscale is ease of excitation, measuring the ease with which one becomes over aroused by external stimuli. The second subscale measures discomfort related to sensory stimulation and is titled low sensory threshold. The final subscale, aesthetic sensitivity, measures one's sensitivity to subtle stimuli and the aesthetic qualities of one's environment. A critique of the HSPS is that its items focus mostly on the negative aspects of SPS and do not address depth of processing. To counter this, Aron et al. (2012) proposed that the HSPS should be administered alongside measures such as the Orienting Sensitivity subscale of the Adult Temperament Questionnaire (OS; Evans & Rothbert, 2007) to fully capture the trait of

SPS. The OS measures sensitivity to subtle stimuli and engagement in internally driven processes such as creative problem-solving and dreaming.

As part of the creation of a new measure of SPS, De Gucht and others (2022) identified higher-order factors of “positive” and “negative” SPS traits within their own measure of SPS. Their positive higher-order factor strongly correlated with the aesthetic sensitivity subscale of the HSPS and the OS subscales, and their negative higher-order factor correlated strongly with the low sensory threshold and ease of excitation subscales of the HSPS (De Gucht et al., 2022). The positive SPS (SPS+) factor included subscales measuring sensitivity to pleasant and subtle stimuli, aesthetic sensitivity, and social-affective sensitivity. The negative SPS (SPS-) factor included subscales measuring emotional and physiological reactivity and sensitivity to uncomfortable stimuli.

Additional evidence for the existence of distinct SPS+ and SPS- trait clusters came from the work of Attary and Ghazizadeh (2021), who found that the aesthetic sensitivity subscale of the HSPS related more strongly to Big Five traits such as openness, conscientiousness, extraversion, and agreeableness, and that the low sensory threshold and ease of excitation subscales of the HSPS related more strongly to traits such as autism, alexithymia, anxiety, depression, shyness, and neuroticism. In a follow-up study, Jakobson et al. (2024) expanded on this work by showing that the aesthetic sensitivity subscale of the HSPS and the three subscales of the OS loaded on the SPS+ factor, and that the low sensory threshold and ease of excitation subscales of the HSPS loaded on the SPS- factor.

These three recent studies have motivated a new body of research that has explored how SPS+ and SPS- traits relate to a range of other variables including, for example, professional quality of life (McQuarrie & Jakobson, 2025); interoceptive accuracy and awareness (Jakobson

et al., 2026); fantasizing (Jakobson et al., 2024); and Big Five personality factors and clinical outcomes (De Gucht et al., 2022). A key goal of the research described in this dissertation was to apply this approach to the study of individual differences in empathy and related processes.

Another area of research into SPS that has expanded in recent years involves investigations into its neural underpinnings. A systematic review of functional magnetic resonance imaging (fMRI) studies identified increased activity associated with SPS in the precentral gyrus, ventral tegmental area, substantia nigra, hypothalamus, periacqueductal gray area, inferior frontal gyrus, insula, temporal parietal junction, and prefrontal cortex during affective and perceptual tasks (Acevedo et al., 2018). Additionally, Schaefer et al. (2022) found increased activity in the posterior insula associated with SPS during the experience of touch. These results indicate alterations in activity with SPS in neural regions associated with physiological control, reward processing, awareness, and self-other processing (Acevedo et al., 2018).

The neural substrates of SPS have also been investigated using resting-state fMRI. This technique involves measuring correlated activity in spatially disparate groups of neurons (Raichle, 2015). Some examples of altered functional connectivity associated with SPS include: reduced connectivity between the hippocampus and inferior parietal lobule, insula, and precuneus; reduced connectivity between the periacqueductal gray area and the amygdala and cingulate gyrus; increased connectivity between the insula and inferior parietal lobule; and increased connectivity between the middle frontal gyrus and the anterior cingulate cortex, precuneus, and inferior parietal lobule (Acevedo et al., 2021; Zhou et al., 2025). Overall, these findings indicate that activity in highly-sensitive brains differs from that seen in individuals who are not highly sensitive, even when participants are not performing a cognitive task.

To date, no imaging studies have attempted to determine if the neural correlates of SPS+ and SPS- traits differ. Additionally, SPS-related activity specific to empathy and emotional contagion have not been investigated. The present research sought to explore these two questions. The following section will provide background information about these important functions.

Empathy

Empathy is the process of identifying and sharing another person's affective state (Cuff et al., 2016). Although there are a number of competing definitions of empathy, a meta-review focusing on defining empathy identified four main themes across the literature: "understanding" or knowing about the target's emotions, thoughts, motivations, etc.; "feeling" or experiencing an emotion that is appropriate to the target's situation; "sharing" or feeling an emotion that is similar to the target's emotion; and "self-other distinction" or recognizing that the emotion one is experiencing belongs to the other person (Håkansson Eklund & Summer Meranius, 2021). Empathy involves both automatic/bottom-up processes encompassing the feeling and sharing definition themes (often also referred to as "affective empathy"), and conscious/top-down processes encompassing the understanding and self-other distinction definition themes (also referred to as "cognitive empathy"). These processes combine to produce *a shared affective state that is identified as belonging to the other person* (Cuff et al., 2016; Håkansson Eklund & Summer Meranius, 2021).

There are many constructs related to empathy and involved in the empathic experience. Although these have often been presented as separate from the experience of empathy, the empathy definition themes described by Håkansson Eklund and Summer Meranius (2021) illustrate how these related constructs contribute to the overarching experience of empathy. For

example, perspective-taking involves adopting the point of view of the other person (fitting into the understanding definition theme), whereas sympathy and compassion or empathic concern (terms often used synonymously) involve feeling bad for another person who is in a difficult situation (fitting into the feeling definition theme) (Cuff et al., 2016; Davis, 1983; Jordan et al., 2016).

Empathy can prompt one to take action (Cuff et al., 2016). However, the behaviours evoked by feelings of empathy may not always benefit others or society (i.e., be prosocial). Jordan and colleagues (2016) found that sharing another person's feelings may not lead to altruistic behaviour if one experiences high levels of personal distress, as this can lead to a desire to flee and protect oneself rather than supporting others. It is feeling concern or caring for the other person (Jordan et al., 2016) and sympathizing with them (Maibom, 2012) that are stronger predictors of prosocial actions, overall.

Links Between Emotional Contagion and Empathy

Our understanding of the emotional and mental state of the empathy target arises from cues provided by that person (e.g., body language, tone of voice, speech, etc.), contextual information from the environment, and inferential reasoning based on the empathizer's past experiences and knowledge. But it is also influenced by the extent to which the empathizer experiences an emotional response that mimics the target's or is appropriate to the situation (e.g., feeling sorrow or concern for another in need; Coll et al., 2017; Håkansson Eklund & Summer Meranius, 2021). This emotional response involves the associated process of emotional contagion.

Emotional contagion is considered a building block of empathy and is an important construct investigated in the following studies. It has traditionally been defined as the automatic

mimicry of eye and body movements, expressions, and vocalizations of another person, which allows for a shared emotional experience that allows the receiver to gain important information about the sender's emotional state and associated thoughts (Hatfield et al., 1993, 2014).

Examining the components of this definition provides more nuanced information about the process of emotional contagion. First, emotional contagion is considered automatic in the sense that it can be induced without conscious control (Kelly et al., 2016; Prochazkova & Kret, 2017; Wróbel & Imbir, 2019). It should be noted, however, that (as with empathy) there can also be top-down, conscious influences on this emotional response (Huntsinger et al., 2009; Schoenewolf, 1990). For example, Huntsinger et al. (2009) found that, after being told that the person with whom they were about to interact was in a positive or negative mood, participants rated their own mood going into the interaction as more positive or negative, respectively—especially when they were motivated for the interaction to be successful (Huntsinger et al., 2009). Therefore, while emotional contagion is often considered a bottom-up process, it can also be shaped by top-down memories of past experiences and motivation.

A second note regarding the traditional definition of emotional contagion provided above is that, although it is generally believed to involve the receiver mimicking the sender, there is continued debate about this in the literature. The majority of mimicry research has investigated facial mimicry through electromyography recordings of facial muscles involved in smiling and frowning. Although facial mimicry of observed expressions has been frequently observed (e.g., Deng & Hu, 2018; Dezechache et al., 2013), some studies have found a relationship between facial mimicry and self-reported levels of emotional contagion (e.g., Olszanowski et al., 2020), while others have not (e.g., Hess & Blairy, 2001). A recent meta-analysis investigating the

relationship between facial mimicry and empathy found that empathy and facial mimicry were significantly correlated, but with a small effect size (Holland et al., 2021).

The Neurocognitive Model of Emotional Contagion (Prochazkova & Kret, 2017) may help to resolve debate in the literature regarding the role of mimicry in emotional contagion and empathy. The authors expand upon Hatfield's (1993) focus on the mimicry of facial expressions, speech, body posture and movements (titled "motor mimicry") by also including "autonomic mimicry," which is defined as physiological mimicry of changes in certain hormones, pupil dilation/constriction, heart rate, breathing, and blushing (Prochazkova & Kret, 2017). The Neurocognitive Model proposes that activation of both the mirror neuron system (for motor mimicry) and of the amygdala and hypothalamic-pituitary-adrenal axis (for autonomic mimicry) allows one to generate a prediction, and that feedback from both types of automatic mimicry allows one to reduce prediction errors (Hatfield et al., 2014; Prochazkova & Kret, 2017). The multilevel response that is generated (via the anterior insula) underlies the experience of emotional contagion and contributes to the experience of empathy (Prochazkova & Kret, 2017). The important takeaway here is that an individual who shows strong autonomic mimicry may experience strong emotional contagion and empathy, even if motor mimicry is minimal. Continued investigation is required to fully explore links between emotional contagion and empathic experience.

The final important aspect of the definition Hatfield et al. (1993, 2014) provided for emotional contagion is that the outcome of (successful) emotional contagion is that one experiences the *same* emotion as the sender. However, a key distinction between emotional contagion and empathy is that only the latter requires recognition of the fact that this shared

emotional state originates from the empathy target (i.e., that a self-other distinction is made; Bird & Viding, 2014; Cuff et al., 2016).

The experience of empathy and emotional contagion are related to factors such as depression and anxiety (Di Tella et al., 2020; Yan et al., 2021). Empathy can also be associated with personality factors such as narcissism (Chukwuorji et al., 2020). As discussed in the next section, SPS is another personality trait that has been associated with empathy and emotional contagion.

Sensory Processing Sensitivity and Empathy

There are few studies to date investigating the relationships between SPS and empathy/emotional contagion. We previously investigated this relationship, measuring empathy and emotional contagion through self-report and behavioural testing (McQuarrie et al., 2023). SPS positively predicted both self- and other-oriented aspects of empathy, as well as the strength of the primary (strongest) emotional response elicited by viewing emotional film clips, the number of emotions experienced during film viewing, and how strongly the participants felt that the emotions they experienced while viewing the films matched those experienced by the main characters in the films. Therefore, we concluded that individuals scoring higher in SPS believe that they are more empathic because they feel emotions more strongly and are more confident that their feelings match those of the empathy target(s) (McQuarrie et al., 2023). More recently, Laros-van Gorkom et al. (2025) also explored the relationship between SPS and empathy, finding that the overarching trait of SPS was positively linked to empathy, including both its affective component (similar to emotional contagion) and its cognitive component (similar to perspective-taking).

The Current Studies

The three studies presented in this manuscript represent a detailed investigation into links between environmental factors (specifically the experience of childhood emotional abuse) and both SPS and empathy (Chapter 2), the neural correlates of SPS at rest (Chapter 3), and neural activity seen during the completion of an emotional contagion behavioural task (Chapter 4). The research is based, in part, on the theoretical model of SPS in the context of environmental sensitivity and emotions, presented by Lionetti and Pluess (2024). This model states that SPS directly influences both emotion perception and processing, and one's emotional response. SPS also influences emotional reactivity, emotion regulation, and overall well-being indirectly through its connection with emotion perception and processing. The environment is included in as an overarching factor influencing every aspect of the model.

Interestingly, Lionetti and Pluess (2024) state that the influence of SPS on overall well-being depends on whether the individual is highly sensitive to positive experiences (leading to better emotion regulation and better well-being), negative experiences, or a combination of both positive and negative experiences. It can be hypothesized that sensitivity to positive and negative experiences, respectively, may align closely with the strength of SPS+ and SPS- trait clusters presented by De Gucht et al. (2022) and Jakobson et al. (2024). In the following studies, these two trait clusters are studied separately to gain insight into how each relates to the domains listed above.

The first study presented in this manuscript represents an investigation into the relationship between environmental factors, SPS, and empathy. A mediation model was tested linking the experience of childhood emotional abuse to empathy through SPS. The personality trait of alexithymia, characterized by difficulties identifying and expressing one's emotions and a

more concrete, externally-oriented thinking style, was also included in this model as a mediator (Preece & Gross, 2023). This was done because alexithymia and SPS frequently co-occur in the general population, and are related, particularly through the negative SPS trait cluster (Attary & Ghazizadeh, 2021; Jakobson & Rigby, 2021; Jakobson et al., 2024).

The second and third studies included in this manuscript investigate the neural correlates of SPS+ and SPS- traits, specifically within the context of their relationship to empathy and emotional contagion. Chapter 3 presents correlations between resting-state functional connectivity and SPS, focusing on connectivity between empathy-related neural regions and the rest of the brain. Chapter 4 presents neural activity related to SPS during an emotional contagion behavioural task. These two studies were designed specifically to explore similarities and differences in functional connectivity and neural activity between SPS+ and SPS- traits.

Please note that, due to the fact that this is a sandwich thesis (i.e., one that includes a collection of manuscripts that are published, in-press, or submitted/prepared-for-submission), there will be some repetition in the presentation of concepts and measures across the three studies. The first study has been published, and the second and third studies have been prepared for submission. As the submissions have been co-authored, details of the authors' contributions are included at the end of each study, prior to the Reference section; these follow the Contributor Role Taxonomy (CRediT; <https://credit.niso.org/>).

References

- Acevedo, B. P., Aron, E., Pospos, S., & Jessen, D. (2018). The functional highly sensitive brain: A review of the brain circuits underlying sensory processing sensitivity and seemingly related disorders. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 373(20170161). <https://doi.org/10.1098/rstb.2017.0161>.
- Acevedo, B. P., Santander, T., Marhenke, R., Aron, A., & Aron, E. (2021). Sensory processing sensitivity predicts individual differences in resting-state functional connectivity associated with depth of processing. *Neuropsychobiology*, 80, 185–199. <https://doi.org/10.1159/000513527>.
- Aron, E. N., & Aron, A. (1997). Sensory-processing sensitivity and its relation to introversion and emotionality. *Journal of Personality and Social Psychology*, 73(2), 345–368. <https://doi.org/10.1037/0022-3514.73.2.345>.
- Aron, E. N., Aron, A., & Jagiellowicz, J. (2012). Sensory processing sensitivity: A review in the light of the evolution of biological responsivity. *Personality and Social Psychology Review*, 16(3), 262–282. <https://doi.org/10.1177/1088868311434213>.
- Assary, E., Zavos, H. M. S., Krapohl, E., Keers, R., & Pluess, M. (2021). Genetic architecture of Environmental Sensitivity reflects multiple heritable components: A twin study with adolescents. *Molecular Psychiatry*, 26(9), 4896–4904. <https://doi.org/10.1038/s41380-020-0783-8>.
- Attary, T., & Ghazizadeh, A. (2021). Localizing sensory processing sensitivity and its subdomains within its relevant trait space: A data-driven approach. *Scientific Reports*, 11(20343). <https://doi.org/10.1038/s41598-021-99686-y>.

- Bird, G., & Viding, E. (2014). The self to other model of empathy: Providing a new framework for understanding empathy impairments in psychopathy, autism, and alexithymia. *Neuroscience and Biobehavioral Reviews*, 47, 520–532. <https://doi.org/10.1016/j.neubiorev.2014.09.021>.
- Chukwuorji, J. C., Uzuegbu, C. N., Agbo, F., Ifeagwazi, C. M., & Ebulum, G. C. (2020). Different slopes for different folks: Gender moderates the relationship between empathy and narcissism. *Current Psychology*, 39(5), 1808–1818. <https://doi.org/10.1007/s12144-018-9881-z>.
- Coll, M. P., Viding, E., Rütgen, M., Silani, G., Lamm, C., Catmur, C., & Bird, G. (2017). Are we really measuring empathy? Proposal for a new measurement framework. *Neuroscience and Biobehavioral Reviews*, 83, 132–139. <https://doi.org/10.1016/j.neubiorev.2017.10.009>.
- Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, 11(6), 671–684. [https://doi.org/10.1016/S0022-5371\(72\)80001-X](https://doi.org/10.1016/S0022-5371(72)80001-X).
- Cuff, B. M. P., Brown, S. J., Taylor, L., & Howat, D. J. (2016). Empathy: A review of the concept. *Emotion Review*, 8(2), 144–153. <https://doi.org/10.1177/1754073914558466>.
- Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, 44(1), 113–126. <https://doi.org/10.1037//0022-3514.44.1.113>.
- De Gucht, V., Woestenburg, D. H. A., & Wilderjans, T. F. (2022). The different faces of (high) sensitivity, toward a more comprehensive measurement instrument. Development and validation of the Sensory Processing Sensitivity Questionnaire (SPSQ). *Journal of*

- Personality Assessment*, 104(6), 784–799.
<https://doi.org/10.1080/00223891.2022.2032101>.
- Deng, H., & Hu, P. (2018). Matching your face or appraising the situation: Two paths to emotional contagion. *Frontiers in Psychology*, 8(2278).
<https://doi.org/10.3389/fpsyg.2017.02278>.
- Dezecache, G., Conty, L., Chadwick, M., Philip, L., Soussignan, R., Sperber, D., & Grèzes, J. (2013). Evidence for unintentional emotional contagion beyond dyads. *PLoS ONE*, 8(6).
<https://doi.org/10.1371/journal.pone.0067371>.
- Di Tella, M., Adenzato, M., Catmur, C., Miti, F., Castelli, L., & Ardito, R. B. (2020). The role of alexithymia in social cognition: Evidence from a non-clinical population. *Journal of Affective Disorders*, 273, 482–492. <https://doi.org/10.1016/j.jad.2020.05.012>.
- Evans, D. E., & Rothbart, M. K. (2007). Developing a model for adult temperament. *Journal of Research in Personality*, 41(4), 868–888. <https://doi.org/10.1016/j.jrp.2006.11.002>.
- Håkansson Eklund, J., & Summer Meranius, M. (2021). Toward a consensus on the nature of empathy: A review of reviews. *Patient Education and Counseling*, 104(2), 300–307.
<https://doi.org/10.1016/j.pec.2020.08.022>.
- Hatfield, E., Bensman, L., Thornton, P. D., & Rapson, R. L. (2014). New perspectives on emotional contagion: A review of classic and recent research on facial mimicry and contagion. *Interpersona: An International Journal on Personal Relationships*, 8(2), 159–179. <https://doi.org/10.5964/ijpr.v8i2.162>.
- Hatfield, E., Cacioppo, J. T., & Rapson, R. L. (1993). Emotional contagion. *Psychological Science*, 2(3), 96–99. <https://doi.org/10.1111/1467-8721.ep10770953>.

- Hess, U., & Blairy, S. (2001). Facial mimicry and emotional contagion to dynamic emotional facial expressions and their influence on decoding accuracy. *International Journal of Psychophysiology*, 40, 129-141.
- Holland, A. C., O'Connell, G., & Dziobek, I. (2021). Facial mimicry, empathy, and emotion recognition: a meta-analysis of correlations. *Cognition and Emotion*, 35(1), 150–168. <https://doi.org/10.1080/02699931.2020.1815655>.
- Huntsinger, J. R., Lun, J., Sinclair, S., & Clore, G. L. (2009). Contagion without contact: Anticipatory mood matching in response to affiliative motivation. *Personality and Social Psychology Bulletin*, 35(7), 909–922. <https://doi.org/10.1177/0146167209335299>.
- Jakobson, L. S., Pearson, P. M., & Rigby, S. N. (2026). Links between facets of alexithymia, self-rated interoception, and social perception. *Frontiers in Psychology*, 16(1669056). <https://doi.org/10.3389/fpsyg.2025.1669056>.
- Jakobson, L. S., McQuarrie, A. M. M., Van Landeghem, C. V., & Smith, S. D. (2024). Traits linked to sensory processing sensitivity mediate the relationship between externally oriented thinking and fantasizing. *Frontiers in Psychology*, 15(1354120). <https://doi.org/10.3389/fpsyg.2024.1354120>.
- Jakobson, L. S., & Rigby, S. (2021). Alexithymia and sensory processing sensitivity: Areas of overlap and links to sensory processing styles. *Frontiers in Psychology*, 12(583786). <https://doi.org/10.3389/fpsyg.2021.583786>.
- Jordan, M. R., Amir, D., & Bloom, P. (2016). Are empathy and concern psychologically distinct? *Emotion*, 16(8), 1107–1116. <https://doi.org/10.1037/emo0000228>.

- Kelly, J. R., Iannone, N. E., & McCarty, M. K. (2016). Emotional contagion of anger is automatic: An evolutionary explanation. *British Journal of Social Psychology*, 55(1), 182–191. <https://doi.org/10.1111/bjso.12134>.
- Laros-van Gorkom, B., Damatac, C., Stevelmans, I., & Greven, C. (2025). Relationships of sensory processing sensitivity with creativity and empathy in an adult sample. *Frontiers in Psychology*, 15(1465407). <https://doi.org/10.3389/fpsyg.2024.1465407>.
- Lionetti, F., Aron, A., Aron, E. N., Burns, G. L., Jagiellowicz, J., & Pluess, M. (2018). Dandelions, tulips and orchids: Evidence for the existence of low-sensitive, medium-sensitive and high-sensitive individuals. *Translational Psychiatry*, 8(1). <https://doi.org/10.1038/s41398-017-0090-6>.
- Lionetti, F., & Pluess, M. (2024). The role of environmental sensitivity in the experience and processing of emotions: Implications for well-being. *Philosophical Transactions B*, 379(20230244). <https://doi.org/10.1098/rstb.2023.0244>.
- Maibom, H. L. (2012). The many faces of empathy and their relation to prosocial action and aggression inhibition. *Wiley Interdisciplinary Reviews: Cognitive Science*, 3(2), 253–263. <https://doi.org/10.1002/wcs.1165>.
- McQuarrie, A. M. M., & Jakobson, L. S. (2025). Exploring links between sensory processing sensitivity, professional quality of life, and negative affectivity in clinical and counselling psychologists. *PLoS Mental Health*, 2(7). <https://doi.org/10.1371/journal.pmen.0000362>.
- McQuarrie, A. M. M., Smith, S. D., & Jakobson, L. S. (2023). Alexithymia and sensory processing sensitivity account for unique variance in the prediction of emotional contagion and empathy. *Frontiers in Psychology*, 14(1072783). <https://doi.org/10.3389/fpsyg.2023.1072783>.

- Olszanowski, M., Wróbel, M., & Hess, U. (2020). Mimicking and sharing emotions: A re-examination of the link between facial mimicry and emotional contagion. *Cognition and Emotion*, 34(2), 367–376. <https://doi.org/10.1080/02699931.2019.1611543>.
- Preece, D. A., & Gross, J. J. (2023). Conceptualizing alexithymia. *Personality and Individual Differences*, 215(112375). <https://doi.org/10.1016/j.paid.2023.112375>.
- Prochazkova, E., & Kret, M. E. (2017). Connecting minds and sharing emotions through mimicry: A neurocognitive model of emotional contagion. *Neuroscience and Biobehavioral Reviews*, 80, 99–114. <https://doi.org/10.1016/j.neubiorev.2017.05.013>.
- Raichle, M. (2015). The restless brain: How intrinsic activity organizes brain function. *Philosophical Transactions B*, 370(1668). <https://doi.org/10.1098/rstb.2014.0172>.
- Schaefer, M., Kühnel, A., & Gärtner, M. (2022). Sensory processing sensitivity and somatosensory brain activation when feeling touch. *Scientific Reports*, 12(1). <https://doi.org/10.1038/s41598-022-15497-9>.
- Schoenewolf, G. (1990). Emotional contagion: Behavioral induction in individuals and groups. *Modern Psychoanalysis*, 15(1), 49–61.
- Smith, H. L., Sriken, J., & Erford, B. T. (2019). Clinical and research utility of the Highly Sensitive Person Scale. *Journal of Mental Health Counseling*, 41(3), 221–241. <https://doi.org/10.17744/mehc.41.3.03>.
- Smolewska, K. A., McCabe, S. B., & Woody, E. Z. (2006). A psychometric evaluation of the Highly Sensitive Person Scale: The components of sensory-processing sensitivity and their relation to the BIS/BAS and “Big Five.” *Personality and Individual Differences*, 40(6), 1269–1279. <https://doi.org/10.1016/j.paid.2005.09.022>.

- Wróbel, M., & Imbir, K. K. (2019). Broadening the perspective on emotional contagion and emotional mimicry: The correction hypothesis. *Perspectives on Psychological Science*, 14(3), 437–451. <https://doi.org/10.1177/1745691618808523>.
- Yan, Z., Zeng, X., Su, J., & Zhang, X. (2021). The dark side of empathy: Meta-analysis evidence of the relationship between empathy and depression. *PsyCh Journal*, 10(5), 794–804. <https://doi.org/10.1002/pchj.482>.
- Zhou, L., Xu, T., & Feng, T. (2025). The hippocampus–IPL connectivity links to ADHD traits through sensory processing sensitivity. *Cerebral Cortex*, 35. <https://doi.org/10.1093/cercor/bhaf063>.

Chapter 2: Exploring the Links between Childhood Emotional Abuse and Empathy: The Mediating Roles of Alexithymia and Sensory Processing Sensitivity

The following study is published, and the citation is provided below. Minor adjustments have been made to the text to allow for consistent formatting within this manuscript.

McQuarrie, A. M. M., Smith, S. D., & Jakobson, L. S. (2025). Exploring the links between childhood emotional abuse and empathy: The mediating roles of alexithymia and sensory processing sensitivity. *Acta Psychologica*, 255(104903).
<http://doi.org/10.1016/j.actpsy.2025.104903>.

Abstract

Exposure to childhood emotional abuse amplifies the personality traits of alexithymia and sensory processing sensitivity (SPS) and impacts empathy. This study investigated if alexithymia, SPS positive traits, and/or SPS negative traits mediate the relationship between childhood emotional abuse and both emotional contagion measured behaviourally and self-reported empathy. A sample of 190 university students ($M_{age} = 19.92$ years) completed self-report measures of empathy and a behavioural task measuring emotional contagion elicited by viewing affective films. Multiple parallel mediation analyses were run to determine if the personality variables mediated the links between abuse and empathy-related outcome measures. The relationship between childhood emotional abuse and each of the self-report empathy subscales was mediated by personality, although the strength and direction of the effects varied across the three trait clusters. In the behavioural task, aspects of SPS mediated the relationships between emotional abuse and the strength of the primary emotion felt during viewing of positive and negative films; and alexithymia mediated the relationship between emotional abuse the number of discrete emotions felt during viewing of negative films. The findings provide important insights into how childhood exposure to emotional abuse can impact personality development and, indirectly, the development of empathy. They also highlight the importance of considering the relative strength of specific traits associated with both alexithymia and SPS when trying to predict individual differences in empathy. The results may inform the development of individualized intervention programs targeting empathic deficits.

Keywords: Childhood emotional abuse; Empathy; Emotional contagion; Alexithymia; Sensory Processing Sensitivity

Introduction

Childhood emotional abuse involves repeated patterns of caregiver behaviour directed toward a child that negatively impact the child's self-worth, make the child feel flawed or unloved, and/or humiliate and demean the child (Bernstein et al., 2003; Chamberland et al., 2011). In their review of meta-analytic studies, Stoltenborgh et al. (2015) found that prevalence estimates for this type of abuse were similar across continents and fell at 36.3 % globally, based on self-report data. This raises serious concerns, as the experience of such abuse has been associated with negative outcomes in adulthood, including an increased risk for depression and anxiety (Van Landeghem & Jakobson, 2024), poor self-esteem, maladaptive substance use, and interpersonal difficulties (Chamberland et al., 2011).

One interpersonal domain that may be impacted by childhood emotional abuse is empathy. This is a multidimensional construct, underpinned by emotional contagion (Prochazkova & Kret, 2017). We use the term *empathy* here to refer to a range of processes, including not only the ability to identify and feel the same emotion as another person, but to feel a related emotion (such as sympathy or concern) that is appropriate to the situation (Håkansson Eklund & Summer Meranius, 2021). Findings from a recent meta-analysis suggest that the experience of emotional abuse in childhood is related to a reduced ability to identify another's emotions (Zhang et al., 2024) and an increased tendency to experience personal distress when confronted with tense or uncomfortable interpersonal situations (Benz et al., 2023). These outcomes could negatively impact one's ability to empathize with and act compassionately toward others (Jordan et al., 2016).

A variety of factors could account for the association between childhood emotional abuse and empathy. In this paper, we test the novel proposal that early experiences of emotional abuse

shape the development or expression of certain personality traits characterized by atypicalities in emotional awareness and emotion regulation, and that these traits, in turn, impact empathic processes. The work was inspired by a model proposed by Smith et al. (2018) that was developed to explain how emotional experiences unfold and reach awareness. This model acknowledges the important, and interacting, roles that both cognitive habits (which are shaped by life experiences) and personality traits with an innate component play in emotional awareness. The two personality traits we focused on were alexithymia and sensory processing sensitivity (SPS). As described below, expression of these frequently co-occurring traits has been shown to be impacted by exposure to early adversity and to contribute to individual differences in empathy.

Alexithymia is a trait characterized by difficulties identifying and describing one's own emotions, and by an externally oriented thinking style (Bagby et al., 1994; Preece & Gross, 2023; Sifneos, 1973). Exposure to childhood abuse or maltreatment is associated with stronger expression of alexithymia, potentially (in part) because emotionally abusive parents fail to provide proper modeling and reinforcement of emotion expression and regulation (Ditzer et al., 2023; Khan & Jaffee, 2022). This could impact a child's ability to develop healthy emotion processing. Alexithymia is associated with weaknesses in other-oriented empathy processes such as perspective taking and empathic concern, and with experiencing greater personal distress when in tense interpersonal situations (e.g., Di Tella et al., 2020; McQuarrie et al., 2023). As such, it may be that alexithymia helps to explain the deficits in these processes that are seen in those who were emotionally abused in childhood.

SPS is associated with increased sensitivity to one's environment, a tendency to engage in "deep" processing (i.e., encoding and processing information in a meaningful and elaborate way; Craik & Lockhart, 1972), strong fantasizing tendencies, and heightened emotional

reactivity (Aron & Aron, 1997; Aron et al., 2012). Recent work has shown that these and other features of SPS can be grouped into two broad clusters (Attary & Ghazizadeh, 2021; De Gucht et al., 2022; Jakobson et al., 2024). Positive aspects of SPS (SPS+) include sensitivity to subtle internal, external, and interpersonal stimuli, sensitivity to pleasurable forms of stimulation (sensory comfort), and heightened appreciation of environmental aesthetics, art, and music (i.e., aesthetic sensitivity). Negative aspects of SPS (SPS-) include strong emotional and physiological reactivity and sensitivity to sensory discomfort (De Gucht et al., 2022). Strong expression of the negative features, in particular, may place highly sensitive individuals who were exposed to early adversity at an increased risk for developing internalizing symptoms or psychopathology (Aron et al., 2005, 2012; Karaca Dinç et al., 2021; Lionetti et al., 2024). Both aspects of SPS may also shape the development of empathic tendencies. Indeed, SPS has been found to predict both “self-oriented” processes (awareness of feelings of personal distress and of the fact that one’s feelings or actions mirror those of another) and “other-oriented” processes (empathic concern and perspective taking) related to empathy (McQuarrie et al., 2023; Schaefer et al., 2022). Given this, it seems possible that SPS could also help explain the relationship between childhood emotional abuse and empathy.

When studying alexithymia or SPS, it is important to note that these traits frequently co-occur (Jakobson et al., 2024; Van Landeghem & Jakobson, 2024), with alexithymia showing the strongest relationship to the SPS- trait cluster (Attary & Ghazizadeh, 2021). Individual differences in the relative strength of these personality variables appear to contribute to individual differences in one’s sensory processing style (Jakobson & Rigby, 2021) and cognitive style (Jakobson et al., 2024). Given this and the relationships each trait has with both childhood abuse and empathy, it is important to tease apart the unique roles that each might play in

mediating the relationship between the experience of childhood emotional abuse and levels of empathy assessed in adulthood—yet this is seldom done. Instead, most researchers study alexithymia *or* SPS without considering the overlap, thereby introducing a confound. For this reason, in the current study we treated alexithymia, SPS+ traits, and SPS- traits as parallel mediators. Our empathy-related outcomes were measured through both self-report and behavioural testing. The self-report measure utilized in this study included subscales measuring perspective-taking, empathic concern, the tendency to identify with fictional characters, personal distress, and awareness of both emotional and behavioural contagion (Davis, 1983; Jordan et al., 2016). The behavioural task involved measurement of emotional contagion elicited by viewing affective film clips. Emotional contagion is considered to be a building block of empathy (Prochazkova & Kret, 2017). It arises from automatic motor and physiological mimicry of other people, and awareness of it supports the feeling that one is sharing another's emotional state (Hatfield et al., 1993).

Based on the research described above, the present study was designed to use mediation analysis to test a proposed causal pathway linking our study variables. Our design also allowed us to control for overlap between different facets of SPS and alexithymia, and to tease apart the unique contributions each makes to the prediction of empathic processes. We expected that self-reported exposure to childhood emotional abuse would predict stronger expression of alexithymia and of both the positive and negative facets of SPS in adults. Higher levels of alexithymia were then hypothesized to predict lower levels of perspective taking, empathic concern and contagion, and stronger feelings of distress in tense interpersonal situations, and to impact participants' emotional response to affective film clips. Higher levels of SPS were expected to predict higher levels of empathy and stronger emotional contagion elicited by

viewing affective film clips; however, whether the positive or negative facets would prove to be equally strong predictors of the various outcomes was unclear.

Materials and Methods

Participants

Participants were a convenience sample of adult university students enrolled in an Introduction to Psychology course. To minimize cultural influences or language barriers, participation was restricted to Canadian citizens and those with English as a first language. Exclusion criteria included having a self-reported history of neurological disorders or significant head injury. Participants received credit toward a research participation option for taking part in the study. After data cleaning (see the Analyses section, below), the final sample included 190 participants (51.0 % female), with a mean age of 19.9 years ($SD = 4.7$). This exceeded the sample size needed to detect a medium effect with power of 0.80 and an alpha of 0.05, as determined a priori using G*Power 3.1 (Faul et al., 2009). All participants provided informed consent prior to participation.

General Procedure

The data for this study were collected online using the Qualtrics survey platform. Participants answered questions regarding demographic variables (age, sex, and gender) and completed self-report measures of childhood emotional abuse, alexithymia, SPS, and empathy, along with several other measures used in a separate investigation. Participants also completed a behavioural task assessing emotional contagion. Although the methods described bear some similarity to those in other published reports, there were important differences which we have outlined in the Supplementary Materials. Ethical approval was granted by the university research ethics board (protocol number HE2022-0210, approval granted November 2022).

Measures

Emotional Contagion Behavioural Task

Film clips for the behavioural task were compiled from affective film libraries created by Maffei and Angrilli (2019) and Samson et al. (2016) (see supplementary materials, Table S1, for a list of the film clips). Participants watched 12 positive, 12 negative, 12 mixed-valence, and 12 neutral clips, presented in a random order. Each clip was approximately eight seconds in length and played without audio. After viewing each clip, participants rated how strongly they personally felt the emotions of amusement, repulsion, fear, boredom, and embarrassment. These ratings were made using a five-point Likert scale ranging from 1 (do not agree at all) to 5 (strongly agree).

Emotional Abuse Subscale of the Childhood Trauma Questionnaire–Short Form

The Emotional Abuse subscale of the Childhood Trauma Questionnaire–Short Form (eaCTQ; Bernstein et al., 2003) measures the level of emotional abuse experienced in childhood. Five items are rated on a five-option Likert scale ranging from 1 (*never true*) to 5 (*very often true*). After reverse-scoring appropriate items, a sum is calculated to create a total score. The reliability of this subscale in the present sample was good ($\alpha = 0.85$).

Toronto Alexithymia Scale

The Toronto Alexithymia Scale (TAS-20) measures three main facets of alexithymia: difficulties identifying feelings, difficulties describing feelings, and externally oriented thinking (Bagby et al., 1994). The twenty items are rated on a five-option Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). After reverse-scoring where indicated, ratings are summed to produce a total score that can range from 20 to 100. The reliability of the TAS-20 total score in the current study was good ($\alpha = 0.82$).

Sensory Processing Sensitivity

SPS is commonly measured using the Highly Sensitive Person Scale (HSPS; Aron & Aron, 1997); however, Aron et al. (2012) recommend supplementing the HSPS with the Orienting Sensitivity subscale of the Adult Temperament Questionnaire (OS; Evans & Rothbart, 2007) to capture the features of SPS more fully. This approach was followed in the present study. The HSPS includes three subscales that measure the tendency to become overwhelmed by busy sensory environments and multi-tasking demands (Ease of Excitation), sensitivity to unpleasant stimulation (Low Sensory Threshold), and sensitivity to subtle, aesthetic qualities of one's environment (Aesthetic Sensitivity; see Smolewska et al., 2006). The 27 items that comprise this scale are rated on a seven-option Likert scale ranging from 1 (*not at all*) to 7 (*extremely*). The subscales of the OS measure awareness of subtle environmental cues (Neutral Perceptual Sensitivity) and of emotional responses to subtle, non-social stimuli (Affective Perceptual Sensitivity), along with tendencies to engage in cognitive processes such as imagery that are not driven by sensory stimulation (Associative Sensitivity). The OS has 15 items, which are rated on a seven-point Likert scale ranging from 1 (*extremely untrue*) to 7 (*extremely true*).

We have recently shown that the Aesthetic Sensitivity subscale of the HSPS and the three subscales of the OS load onto one factor, and that the Low Sensory Threshold and Ease of Excitation subscales of the HSPS load onto another (Jakobson et al., 2024). Following De Gucht et al. (2022) and Attary and Ghazizadeh (2021), we referred to the former factor as capturing a positive SPS trait cluster, and the latter as capturing a negative SPS trait cluster. In the current study, the mean of the Aesthetic Sensitivity subscale of the HSPS and the three subscales of the OS was calculated to produce a composite “SPS+” score and the mean of the Low Sensory Threshold and Ease of Excitation subscales of the HSPS was calculated to produce a composite

“SPS-” score. In our sample, the reliability of both the SPS+ ($\alpha = 0.84$) and SPS- ($\alpha = 0.90$) composite scores were good.

Interpersonal Reactivity Index and Empathy Index

The Interpersonal Reactivity Index (IRI; Davis, 1983) and Empathy Index (Jordan et al., 2016) were combined into a 42-item measure of empathy and related constructs (the IRI/EI). The IRI includes four subscales: perspective-taking (PT), measuring the ability to adopt the point of view of another; empathic concern (EC), measuring the ability to feel concern for another in need; fantasy (FS), measuring the tendency to imagine scenarios described in narrative works and how the characters might feel; and personal distress (PD), measuring the tendency to feel uncomfortable in tense interpersonal situations. The EI adds two subscales: empathy (EMP), measuring awareness of emotional contagion (i.e., the mirroring of another’s emotional state); and behavioural contagion (BC), measuring awareness that one is mimicking the behaviours or actions of another. Each item is rated on a five-option Likert scale from 0 (*does not describe me well*) to 4 (*describes me very well*). Each subscale includes seven items and the ratings are summed. Five of the subscales showed adequate reliability in the current sample ($\alpha \geq 0.68$). The exception was the BC subscale, which had a reliability coefficient of $\alpha = 0.62$. Because the reliability of this subscale was questionable (George & Mallery, 2003), it was not included in the analyses.

Analyses

Prior to analysis, the data were cleaned. If a given individual completed the study more than once, only the first set of responses was retained. The remaining data were checked to ensure that participants had completed all subscales of a given measure and that proper reverse-scoring and coding had been applied. The data were also checked for outliers and possible

violations of normality. After confirming that missing data were missing completely at random, missing values were imputed using an Estimation-Maximization algorithm. Linearity between the independent and dependent variables was confirmed. Statistical analyses were conducted using IBM SPSS Statistics for Microsoft, Version 28.

Two measures were extracted for each participant from the ratings collected in the behavioural task. First, we computed the mean rating for each emotion, for each film type. These mean ratings were subsequently entered into a repeated measures analysis of variance (ANOVA) that allowed us to identify the strongest or “primary” emotion(s) elicited by each film type in the sample as a whole. Second, we computed a “dispersion” score for each film type by finding the average number of emotions that received a rating greater than one. These scores could range from zero to five and provided a measure of the purity of the emotional response to each type of film. A repeated measures ANOVA was also run with the dispersion score for each film type to determine if these scores differed significantly across film types.

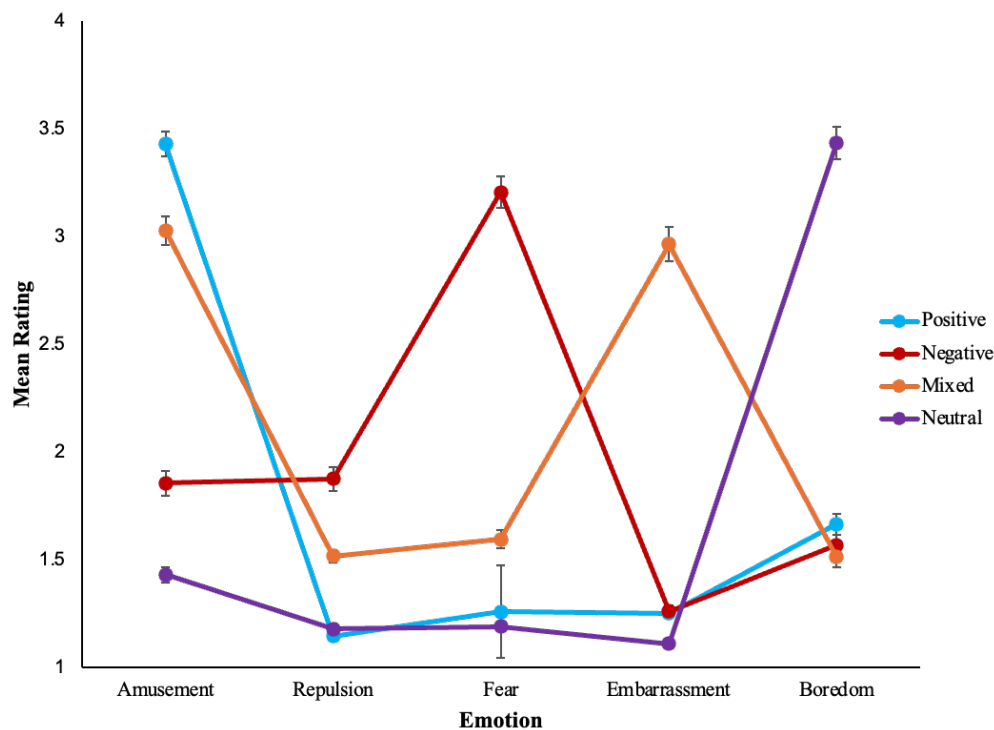
Multiple parallel mediation analyses were run using model 4 in the PROCESS macro (Hayes, 2022) to determine if links between childhood emotional abuse and any of the outcome measures (i.e., the strength of the primary emotions and the number of discrete emotions elicited by each type of film used in the behavioural task, and scores on the subscales of the IRI/EI) were mediated by the personality variables. For each mediation analysis, percentile bootstrap confidence intervals were calculated using 5000 bootstrapped samples. Following contemporary thinking regarding mediation analyses (Hayes, 2022), we did not consider establishing a simple association between our predictor and outcome variables a precondition for testing mediation.

Results

Emotional Contagion Profiles

A 4 (Film Type) X 5 (Emotion) repeated measures ANOVA conducted on mean emotion ratings produced main effects of film type, $F_{(2.26, 427.18)} = 222.78, p < .001, \eta_p^2 = 0.54$, and emotion, $F_{(2.51, 475.15)} = 156.47, p < .001, \eta_p^2 = 0.45$, but it also produced a significant interaction between these variables, $F_{(4.30, 811.74)} = 539.98, p < .001, \eta_p^2 = 0.74$ (see Figure 1). Planned tests of the simple main effect of emotion confirmed that the primary emotions elicited by the positive, negative, and neutral films were amusement, fear, and boredom, respectively. In the case of mixed valence films, amusement and embarrassment were the two most strongly endorsed emotions. As such, the mean of these ratings served as an index of the strength of the primary emotion blend elicited by these films. These results were expected based on film content and support the view that, rather than experiencing non-specific increases in arousal, viewers experienced emotional contagion from cues produced by the characters in the films.

The repeated measures ANOVA comparing dispersion scores produced a significant main effect of film type, $F_{(2.54, 479.03)} = 319.99, p < .001, \eta_p^2 = 0.63$. Pairwise comparisons indicated that the dispersion scores across the four film types differed significantly from one another. As shown in Table 1, Mixed films produced the greatest amount of dispersion in emotion ratings, followed by Negative and Positive film types, and finally Neutral films.

Figure 1*Mean Ratings of the Measured Emotions When Viewing the Four Film Types*

Note. Error bars indicate standard errors.

Descriptive Statistics and Zero-Order Correlations

Descriptive statistics for all study variables are presented in Table 1. Using cut-off scores identified by Bernstein and Fink (1998), 53.2% of participants had experienced none-to-minimal emotional abuse, 20.0% had experienced low-to-moderate levels of abuse, 12.1% had experienced moderate-to-severe levels of abuse, and 14.7% had experienced severe-to-extreme levels of emotional abuse.

Zero-order correlations between all study variables are shown in Supplementary Table S2. To reduce the risk of Type 1 errors when testing multiple correlations, the Benjamini-Hochberg procedure was used with a False Discovery Rate of 0.05; this procedure was chosen as

it is less conservative than the Bonferroni correction, therefore allowing for improved power.

Generally speaking: (a) the behavioural measures were more strongly correlated with one another than with the self-report measures, and vice versa; (b) fear elicited by negative films was the behavioural variable most strongly linked to SPS and to IRI/EI scores; (c) boredom elicited by neutral films was the behavioural variable least strongly linked to SPS and to IRI/EI scores; and (d) exposure to emotional abuse in childhood was most strongly related to alexithymia, SPS, FS, and PD scores, although all of these effect sizes were small.

Table 1

Descriptive Statistics for Behavioural Task and Self-Report Measures

	Behavioural Measures of Emotion Contagion								
Film Type	Primary emotion (range 1 to 5)				Dispersion (range 0 to 5)				
	Positive	Mixed	Negative	Neutral	Positive	Mixed	Negative	Neutral	
<i>M</i>	3.4	3.0	3.2	3.4	1.6	2.5	2.2	1.4	
<i>SD</i>	0.8	0.7	1.0	1.0	0.6	0.8	0.9	0.7	
	Self-Report Measures								
	TAS-20	SPS+	SPS-	EC	PT	FS	PD	EMP	eaCTQ
<i>M</i>	52.6	4.6	4.1	19.0	17.4	16.1	11.5	13.2	9.8
<i>SD</i>	11.3	0.8	1.1	4.7	4.3	5.3	4.9	5.3	4.9

Note. The primary emotions for the positive, mixed, negative, and neutral film types used in the behavioural task were amusement, an amusement/embarrassment blend, fear, and boredom, respectively. TAS-20, Toronto Alexithymia Scale; SPS+ and SPS-, positive and negative traits associated with sensory processing sensitivity; eaCTQ, Emotional Abuse subscale of the Childhood Trauma Questionnaire. Subscales of the Interpersonal Reactivity Index/Empathy Index: EC, Empathic Concern; PT, Perspective Taking; FS, Fantasy; PD, Personal Distress; EMP, Empathy/Emotional Contagion.

Mediation Analyses

To determine whether the personality variables mediated links between childhood emotional abuse and empathic processes, we ran two sets of mediation analyses. The general form of the mediation analyses is illustrated in Figure 2. The first set of two planned analyses included the primary emotion and the dispersion scores elicited by different types of films as the outcome variables. The second set of five planned analyses included the IRI/EI subscales as the outcome variables. Note that paths from the predictor to the personality traits that served as mediators were common to all models tested. As expected, greater exposure to emotional abuse in childhood predicted higher TAS-20 ($a_1: b = 0.61, p < .001$), SPS+ ($a_2: b = 0.03, p < .01$), and SPS- ($a_3: b = 0.04, p < .05$) scores.

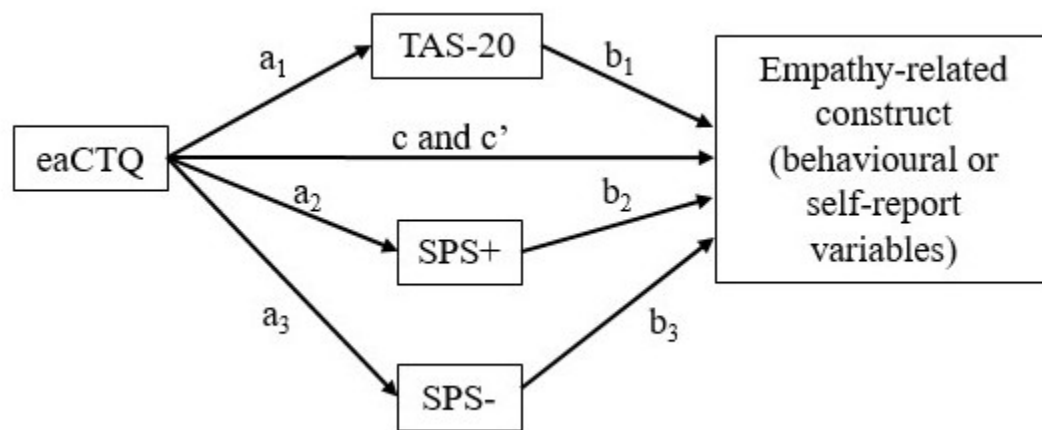
Table 2 shows the unstandardized coefficients in the models predicting behavioural measures in which mediation was supported. SPS+ scores fully mediated the link between eaCTQ scores and amusement elicited by positive films. SPS- scores fully mediated the link between eaCTQ scores and fear elicited by negative films. Finally, alexithymia emerged as a significant mediator of the link between eaCTQ scores and dispersion scores for the negative films.

Table 3 shows the unstandardized coefficients in the models predicting IRI/EI scores. Based on measured direct and indirect effects, full mediation via at least two of the mediators was supported in each model tested. Higher TAS-20 scores predicted lower self-rated EC and PT, and stronger ratings of PD, but were unrelated to scores on the FS and EMP subscales. Stronger expression of SPS+ traits predicted higher self-ratings of EC, PT, FS, and EMP, and lower ratings of PD. Finally, stronger expression of SPS- traits predicted higher scores on all of the IRI/EI subscales except for PT. Examination of the 95% CIs for indirect effect contrasts

confirmed that: (a) SPS+ and SPS- were stronger mediators of EC than TAS-20 scores; (b) SPS+ was a stronger mediator of PT than TAS-20; (c) SPS+ and SPS- traits were equally strong mediators of FS and EMP scores; and (d) SPS- and TAS-20 were both stronger mediators of PD than SPS+ scores.

Figure 2

The General Form of the Mediation Analyses



Note. The predictor was the score on the Emotional Abuse subscale of the Childhood Trauma Questionnaire (eaCTQ). The mediators included the total score on the Toronto Alexithymia Scale-20 (TAS-20), a composite score for positive traits associated with sensory processing sensitivity (SPS+), and a composite score for negative traits associated with sensory processing sensitivity (SPS-). The outcome variable was either a behavioural measure of emotion contagion or a self-report measure tapping into one of the empathic processes captured by the Interpersonal Reactivity Index or the Empathy Index.

Table 2*Models Showing Significant Mediation between Childhood Emotional Abuse and Behavioural**Measures of Emotional Contagion via Personality Variables*

DV	Film type	M	Effect of M on DV b [95% CI]	Direct effect c' [95% CI]	Indirect effect ab [Boot95% CI]	Total effect c [95% CI]
Primary emotion	Positive	TAS-20	-0.01 [-0.02, 0.004]	-0.01 [-0.04, 0.01]	-0.004 [-0.01, 0.002]	-0.01 [-0.03, 0.01]
		SPS+	0.17 [0.01, 0.33]		0.006 [0.0001, 0.01]	
		SPS-	0.04 [-0.09, 0.18]		0.002 [-0.004, 0.01]	
	Negative	TAS-20	-0.01 [-0.02, 0.005]	-0.01 [-0.04, 0.02]	-0.01 [-0.01, 0.003]	-0.01 [-0.04, 0.02]
		SPS+	-0.01 [-0.21, 0.18]		-0.0004 [-0.01, 0.01]	
		SPS-	0.34 [0.19, 0.50]		0.01 [0.002, 0.03]	
Dispersion	Negative	TAS-20	0.01 [0.002, 0.03]	0.002 [-0.03, 0.03]	0.01 [0.002, 0.02]	0.01 [-0.02, 0.04]
		SPS+	0.08 [-0.10, 0.25]		0.003 [-0.003, 0.01]	
		SPS-	-0.09 [-0.23, 0.06]		-0.003 [-0.01, 0.002]	

Note. 95% confidence intervals (CIs) shown in bold are significant. Percentile bootstrap (Boot)

CIs for the indirect effects were calculated using 5000 bootstrapped samples. DV, dependent variable; M, mediator; TAS-20, Toronto Alexithymia Scale; SPS+ and SPS-, positive and negative trait clusters associated with sensory processing sensitivity.

Table 3

Significant Mediations between Childhood Emotional Abuse and Self-Reported Empathy via Personality Variables

DV	M	Effect of M on DV b [95% CI]	Direct effect c' [95% CI]	Indirect effect ab [Boot95% CI]	Total effect c [95% CI]
EC	TAS-20	-0.14 [-0.20, -0.08]	-0.01 [-0.14, 0.11]	-0.08 [-0.15, -0.03]	0.01 [-0.13, 0.15]
	SPS+	1.37 [0.53, 2.22]		0.05 [0.01, 0.10]	
	SPS-	1.60 [0.91, 2.29]		0.06 [0.01, 0.13]	
PT	TAS-20	-0.12 [-0.18, -0.06]	0.06 [-0.06, 0.18]	-0.07 [-0.13, -0.03]	0.05 [-0.07, 0.18]
	SPS+	1.52 [0.70, 2.34]		0.05 [0.01, 0.10]	
	SPS-	0.49 [-0.18, 1.15]		0.02 [-0.01, 0.06]	
FS	TAS-20	0.01 [-0.05, 0.08]	0.06 [-0.07, 0.19]	0.01 [-0.03, 0.06]	0.21 [0.06, 0.37]
	SPS+	2.71 [1.84, 3.57]		0.09 [0.02, 0.16]	
	SPS-	1.37 [0.66, 2.08]		0.05 [0.01, 0.11]	
EMP	TAS-20	-0.001 [-0.06, 0.06]	0.01 [-0.12, 0.14]	-0.001 [-0.04, 0.04]	0.14 [-0.01, 0.30]
	SPS+	1.04 [1.17, 1.91]		0.03 [0.003, 0.08]	
	SPS-	2.54 [1.83, 3.25]		0.10 [0.02, 0.18]	
PD	TAS-20	0.07 [0.01, 0.13]	0.11 [-0.01, 0.24]	0.04 [0.003, 0.09]	0.21 [0.07, 0.35]
	SPS+	-1.09 [-1.93, -0.25]		-0.04 [-0.08, -0.004]	
	SPS-	2.36 [1.67, 3.04]		0.09 [0.02, 0.17]	

Note. 95% confidence intervals (CIs) shown in bold are significant. Percentile bootstrap (Boot)

CIs for the indirect effects were calculated using 5000 bootstrapped samples. DV, dependent variable; M, mediator; TAS-20, Toronto Alexithymia Scale; SPS+ and SPS-, positive and negative trait clusters associated with sensory processing sensitivity. Subscales of the Interpersonal Reactivity Index/Empathy Index: EC, Empathic Concern; PT, Perspective Taking; FS, Fantasy; PD, Personal Distress; EMP, Empathy/Emotional Contagion.

Discussion

The findings from the current study are consistent with the view that emotional abuse in childhood can exacerbate certain personality traits that shape empathic tendencies in later life. The findings from the IRI/EI also clearly highlight the importance of considering the *relative*

strengths of particular traits or trait clusters when trying to predict individual differences in self-reported empathy. SPS+ and SPS- traits were equally strong, positive mediators of the links between childhood emotional abuse and both FS and EMP scores. The same pattern was seen in the model predicting EC, although in this case alexithymia emerged as an additional, weaker, negative mediator. Whereas SPS+ traits were associated with enhanced ability to see things from another's perspective, alexithymia was (more weakly) associated with a reduced ability to do so. Finally, although all three personality variables mediated the link between childhood emotional abuse and experiencing personal distress in tense situations, the direction and strength of these effects varied. SPS+ traits predicted lower levels of distress; in contrast, alexithymia and SPS- traits predicted higher levels of distress, with these two variables being the strongest mediators of PD overall.

In the behavioural task, SPS positively mediated the strength of participants' primary emotional responses to the film clips, with stronger expression of SPS+ traits being linked to heightened feelings of amusement when watching people in positively-valenced film clips, and stronger expression of SPS- traits predicting greater fear when watching people in negatively-valenced clips. Additionally, alexithymia emerged as a positive mediator of the number of emotions participants felt while watching people in negatively-valenced clips. Overall, the findings support previous claims that alexithymia generally interferes with empathic processes (Aaron et al., 2015; Banzhaf et al., 2018; Brewer et al., 2019; Butera et al., 2023; Decety & Moriguchi, 2007; Di Tella et al., 2020; McQuarrie et al., 2023; Patil & Silani, 2014a, 2014b), while SPS generally promotes them (McQuarrie et al., 2023; Schaefer et al., 2022).

Links Between Childhood Emotional Abuse and Personality Traits

Our finding that childhood emotional abuse was associated with increased levels of alexithymia is consistent with the results of two recent meta-analyses (Ditzer et al., 2023; Khan & Jaffee, 2022). Effect size estimates between childhood emotional abuse and alexithymia in both meta-analyses ($r = .21$) are similar to the effect size estimate reported in the present study (Table S2, $r = .26$). One possible explanation for this positive relationship is that children who experience emotional abuse from caregivers may be less likely to observe and be reinforced for displaying positive examples of emotion regulation and expression. As a result, these children may grow up to display the emotion processing difficulties characteristic of alexithymia (Ditzer et al., 2023).

Exposure to childhood emotional abuse also appears to exacerbate the tendencies to be hypersensitive to both unpleasant stimuli (an SPS- trait) and to subtle internal, interpersonal, and contextual cues, regardless of their valence (SPS+ traits). This is consistent with neuroimaging research demonstrating that the experience of adversity in childhood is associated with increased neural activity during the viewing of emotional stimuli in regions involved with emotional processing, including the insula and anterior cingulate cortex (Ganzel et al., 2013; Peters et al., 2019). These neural regions have also been shown to be overactive in individuals with SPS (Acevedo et al., 2014). Although possessing strong SPS- traits could increase distress and anxiety in emotionally traumatized children, these difficulties may be mitigated to some extent in those who also strongly express SPS+ traits (c.f. Gulla & Golonka, 2021).

Alexithymia and Sensory Processing Sensitivity as Mediators

The following section will explore potential explanations for why the personality traits of alexithymia and SPS mediated the relationships between childhood emotional abuse and

empathic processes. Our data suggest that the traits differ in the roles they played in mediating these relationships.

The two SPS trait clusters acted as positive mediators influencing: (a) the primary reactions viewers had to the film clips in the behavioural task; (b) the EMP scores, which reflect awareness that one is experiencing emotional contagion; and (c) the FS scores, which reflect the tendency to mentally project oneself into scenarios depicted in narratives. More specifically, the positive aspect of SPS predicted subjective ratings of amusement elicited by positively-valenced films, and the SPS- aspect predicted subjective ratings of fear elicited by negatively-valenced films. Both SPS trait clusters also positively mediated awareness that one is experiencing emotional contagion (i.e., the EMP ratings of the IRI/EI). Consciously experiencing strong reactions in response to another would make events more salient, prompting deeper processing (Aron et al., 2012). We have argued elsewhere that this might explain why SPS is linked to higher FS scores. If individuals with SPS find events unfolding in narratives that trigger strong emotional reactions highly salient, this may prompt them to use their imagination and to draw on their own past experiences to help them understand how they would think, feel, or act in circumstances like those being faced by the characters (Jakobson et al., 2024).

Our findings suggest that the relative strength of SPS+ and alexithymic traits help to explain individual differences in PT. These findings replicate past results (McQuarrie et al., 2023). Being more sensitive or attuned to subtle interpersonal cues could help an individual scoring higher in SPS+ traits identify the thoughts and feelings of another. However, this ability may be diminished in those who also score high on alexithymia given that the ability to identify what another person may be feeling depends, in part, on the ability to accurately identify emotions in oneself (Smith et al., 2018). Interestingly, in the current study and in a prior study

(McQuarrie et al., 2023), individuals scoring higher in alexithymia experienced a greater number of emotions (i.e., more dispersion) when viewing emotional film clips—especially those with negative valence. This lack of emotional granularity may contribute to the difficulties they experience with emotional appraisal and PT.

Finally, consider the fact that all three mediators predicted both PD and EC, albeit in different ways. Stronger expression of SPS- traits predicted higher scores on both subscales. In contrast, whereas stronger expression of alexithymia predicted lower EC but higher PD, stronger expression of SPS+ traits did the reverse. These findings may help to explain why the ability to *feel for* someone does not necessarily predict how one might *act toward* that person in real life (Jordan et al., 2016). If someone scores high on alexithymia and SPS- traits, their heightened sensitivity to negative stimuli may increase the salience of unpleasant events, promoting longer (e.g., Luminet et al., 2021) and deeper (e.g., Jakobson et al., 2024) processing of threatening or distressing situations. If this leads to greater PD, it may make it more difficult for these individuals to regulate their emotions effectively. Indeed, both alexithymia and the Ease of Excitation SPS subscale, which belongs to the SPS- trait cluster (Jakobson et al., 2024), have been linked to the use of emotion suppression, which is considered to be a maladaptive form of emotion regulation (Eşkisu et al., 2022; Preece et al., 2023).

Alexithymia has also been associated with other maladaptive emotion regulation strategies such as behavioural withdrawal and ignoring, and with reduced use of adaptive strategies such as cognitive reappraisal, approaching problems, and seeking social support (Preece et al., 2023). It is possible that individuals scoring high on alexithymia, in particular, may experience high levels of distress in tense interpersonal situations due to these emotion regulation difficulties. Experiencing high levels of personal distress without corresponding high

levels of sympathy or concern for another may then impact one's desire to act in a prosocial manner (Maibom, 2019). These effects could be partially offset, however, in those who also score high on SPS+ traits, which were linked with lower levels of PD and higher EC in the current study. This buffering effect may reflect the successful application of adaptive emotion regulation strategies. In support of this, Aesthetic Sensitivity (which belongs to the SPS+ trait cluster; Jakobson et al., 2024) has been linked to greater use of cognitive reappraisal—considered an adaptive strategy of emotion regulation (Eşkisu et al., 2022).

Limitations and Future Directions

As mentioned previously, the reliability of the BC subscale of the IRI/EI was poor and so this subscale was not included in our analyses. Future research should be directed at improving the reliability of this subscale so that it can be used to investigate how awareness of one's motor mimicry contributes to empathy and relates to childhood emotional abuse and various personality traits. Some research utilizing physiological measures of motor mimicry (e.g., facial electromyography) suggests that those scoring high on alexithymia exhibit less spontaneous mimicry of others' facial expressions than those scoring low on this trait (Franz et al., 2021). Whether the strength of this effect varies as a function of individual differences in the expression of SPS is unknown, although it seems likely that SPS would be linked to stronger mimicry and body awareness.

This study used a brief self-report measure of emotional abuse requiring adult participants to reflect on their childhood experiences. This may have limited the reliability of the reports of abuse; however, it should be noted that subscale scores of the CTQ have been found to significantly predict abuse ratings made by professionals (Bernstein et al., 2003). The eaCTQ does not, however, provide information about the onset, duration, or frequency of exposure to

emotional abuse. It will be important to gather this information in future studies, as these variables could impact the strength of observed relationships. We also relied exclusively on self-report measures of personality. Use of structured interviews or multi-method assessment would be beneficial in future work examining these variables; nonetheless, the personality measures selected have been found to be both valid and reliable (Aron & Aron, 1997; Bagby et al., 2020; Evans & Rothbart, 2007).

Mediation analysis assumes that a causal chain exists, wherein the independent variable affects the mediator, which then affects the outcome variable. However, one cannot rule out the possibility that the variables under study are merely correlated with one another. As such, the use of a cross-sectional study design in the present study does not provide the strongest possible test of the proposal that childhood emotional abuse exacerbates the expression of alexithymia and SPS, or that these personality traits directly influence the development of empathy, as predicted. Confirmation could only come from studies employing longitudinal designs.

Future research could also explore how the present results relate to attachment styles. Children learn socio-emotional skills through interactions with their environment and caregivers. Attachment theory (Bowlby, 1969, 1973) provides explanations for the impact these early relationships can have on social and emotional functioning. Therefore, attachment theory can provide insights into potential mechanisms of empathy development. A secure attachment style has been shown to be positively correlated with empathy (Xu et al., 2022), perhaps because responsive caregiving allows for either the modeling of empathic responses or the proper development of emotion regulation skills that can then be employed in interpersonal interactions (Troyer & Greitemeyer, 2018). A negative relationship has also been found between an avoidant attachment style and empathy, as individuals with an avoidant attachment style develop negative

beliefs about the needs of others and avoid close interactions (Mikulincer et al., 2001; Xu et al., 2022). Additionally, both SPS and alexithymia have been positively related to an insecure, anxious attachment style (Besharat & Khajavi, 2013; Şengül-İnal et al., 2018). Therefore, the development of an insecure attachment style may help explain the mediating effects of SPS and alexithymia on empathy as shown in the present study and why these relationships deserve further attention from researchers.

Conclusion

The present findings suggest a potential mechanism through which childhood emotional abuse may impact the development of a range of empathic processes in adulthood. We propose that: (a) experiences of emotional abuse exacerbate features of both SPS and alexithymia; (b) being highly sensitive makes emotional events more salient and promotes deeper processing of them; (c) being highly sensitive to feelings of personal discomfort (an SPS- trait) and experiencing a lack of emotional granularity (a feature of alexithymia) disproportionately interfere with the processing of negative emotions in oneself or others, negatively impacting the development of empathic concern and perspective-taking and increasing feelings of personal distress when faced with others' suffering; and (d) strong expression of SPS+ traits can help one manage feelings of personal distress, potentially allowing one to act toward others with greater compassion. These findings are important for theory building and may inform the development of individualized interventions for those displaying empathy deficits, low levels of prosocial behaviour, and/or antisocial tendencies.

Data Availability Statement

The dataset for this study can be found in the "Abuse and Empathy" repository
<https://doi.org/10.5683/SP3/MKSTPY>

Contributions of Authors

Amanda M. McQuarrie was involved in the Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, and Writing – review and editing. Stephen D. Smith and Lorna S. Jakobson were involved in Conceptualization, Formal analysis, Funding acquisition, Methodology, Supervision, Validation, and Writing – review and editing.

References

- Aaron, R. V., Benson, T. L., & Park, S. (2015). Investigating the role of alexithymia on the empathic deficits found in schizotypy and autism spectrum traits. *Personality and Individual Differences*, 77, 215–220. <https://doi.org/10.1016/j.paid.2014.12.032>
- Acevedo, B. P., Aron, E. N., Aron, A., Sangster, M. D., Collins, N., & Brown, L. L. (2014). The highly sensitive brain: An fMRI study of sensory processing sensitivity and response to others' emotions. *Brain and Behavior*, 4(4), 580–594. <https://doi.org/10.1002/brb3.242>
- Aron, E. N., & Aron, A. (1997). Sensory-processing sensitivity and its relation to introversion and emotionality. *Journal of Personality and Social Psychology*, 73(2), 345–368. <https://doi.org/10.1037/0022-3514.73.2.345>
- Aron, E. N., Aron, A., & Davies, K. M. (2005). Adult shyness: The interaction of temperamental sensitivity and an adverse childhood environment. *Personality and Social Psychology Bulletin*, 31(2), 181–197. <https://doi.org/10.1177/0146167204271419>
- Aron, E. N., Aron, A., & Jagiellowicz, J. (2012). Sensory processing sensitivity: A review in the light of the evolution of biological responsivity. *Personality and Social Psychology Review*, 16(3), 262–282. <https://doi.org/10.1177/1088868311434213>
- Attary, T., & Ghazizadeh, A. (2021). Localizing sensory processing sensitivity and its subdomains within its relevant trait space: A data-driven approach. *Scientific Reports*, 11(1). <https://doi.org/10.1038/s41598-021-99686-y>
- Bagby, R. M., Parker, J. D. A., & Taylor, G. J. (1994). The twenty-item Toronto Alexithymia Scale-I: Item selection and cross-validation of the factor structure. *Journal of Psychosomatic Research*, 38(1), 23–32. [https://doi.org/10.1016/0022-3999\(94\)90005-1](https://doi.org/10.1016/0022-3999(94)90005-1)

- Bagby, R. M., Parker, J. D. A., & Taylor, G. J. (2020). Twenty-five years with the 20-item Toronto Alexithymia Scale. *Journal of Psychosomatic Research, 131*(109940).
<https://doi.org/10.1016/j.jpsychores.2020.109940>
- Banzhaf, C., Hoffmann, F., Kanske, P., Fan, Y., Walter, H., Spengler, S., Schreiter, S., Singer, T., & Berman, F. (2018). Interacting and dissociable effects of alexithymia and depression on empathy. *Psychiatry Research, 270*, 631–638.
<https://doi.org/10.1016/j.psychres.2018.10.045>
- Benz, A. B. E., Dimitroff, S. J., Jeggle, C., Gaertner, R. J., Meier, M., Unternaehrer, E., Bentele, U. U., Denk, B. F., Klink, E. S. C., & Pruessner, J. C. (2023). Increased empathic distress in adults is associated with higher levels of childhood maltreatment. *Scientific Reports, 13*(1). <https://doi.org/10.1038/s41598-023-30891-7>
- Bernstein, D., & Fink, L. (1998). *Childhood Trauma Questionnaire. A retrospective self-report questionnaire and manual*. The Psychological Corporation.
- Bernstein, D. P., Stein, J. A., Newcomb, M. D., Walker, E., Pogge, D., Ahluvalia, T., Stokes, J., Handelsman, L., Medrano, M., Desmond, D., & Zule, W. (2003). Development and validation of a brief screening version of the Childhood Trauma Questionnaire. *Child Abuse & Neglect, 27*, 169–190. [https://doi.org/10.1016/S0145-2134\(02\)00541-0](https://doi.org/10.1016/S0145-2134(02)00541-0)
- Besharat, M. A., & Khajavi, Z. (2013). The relationship between attachment styles and alexithymia: Mediating role of defense mechanisms. *Asian Journal of Psychiatry, 6*(6), 571–576. <https://doi.org/10.1016/j.ajp.2013.09.003>
- Bowlby, J. (1969). *Attachment and loss: Vol. 1. Attachment*. Basic Books.
- Bowlby, J. (1973). *Attachment and loss: Vol. 2. Separation: Anxiety and anger*. Basic Books.

- Brewer, R., Cook, R., Cardi, V., Treasure, J., Catmur, C., & Bird, G. (2019). Alexithymia explains increased empathic personal distress in individuals with and without eating disorders. *Quarterly Journal of Experimental Psychology*, 72(7), 1827–1836.
<https://doi.org/10.1177/1747021818816051>
- Butera, C. D., Harrison, L., Kilroy, E., Jayashankar, A., Shipkova, M., Pruyser, A., & Aziz-Zadeh, L. (2023). Relationships between alexithymia, interoception, and emotional empathy in autism spectrum disorder. *Autism*, 27(3), 690–703.
<https://doi.org/10.1177/13623613221111310>
- Chamberland, C., Fallon, B., Black, T., & Trocmé, N. (2011). Emotional maltreatment in Canada: Prevalence, reporting and child welfare responses (CIS2). *Child Abuse & Neglect*, 35(10), 841–854. <https://doi.org/10.1016/j.chiabu.2011.03.010>
- Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, 11(6), 671–684.
[https://doi.org/10.1016/S0022-5371\(72\)80001-X](https://doi.org/10.1016/S0022-5371(72)80001-X)
- Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, 44(1), 113–126. <https://doi.org/10.1037//0022-3514.44.1.113>
- De Gucht, V., Woestenburg, D. H. A., & Wilderjans, T. F. (2022). The different faces of (high) sensitivity, toward a more comprehensive measurement instrument. Development and validation of the Sensory Processing Sensitivity Questionnaire (SPSQ). *Journal of Personality Assessment*, 104(6), 784–799.
<https://doi.org/10.1080/00223891.2022.2032101>

- Decety, J., & Moriguchi, Y. (2007). The empathic brain and its dysfunction in psychiatric populations: Implications for intervention across different clinical conditions. *BioPsychoSocial Medicine, 1*, 1–21. <https://doi.org/10.1186/1751-0759-1-22>
- Di Tella, M., Adenzato, M., Catmur, C., Miti, F., Castelli, L., & Ardito, R. B. (2020). The role of alexithymia in social cognition: Evidence from a non-clinical population. *Journal of Affective Disorders, 273*, 482–492. <https://doi.org/10.1016/j.jad.2020.05.012>
- Ditzer, J., Wong, E. Y., Modi, R. N., Behnke, M., Gross, J. J., & Talmon, A. (2023). Child maltreatment and alexithymia: A meta-analytic review. *Psychological Bulletin, 149*(5–6), 311–329. <https://doi.org/10.1037/bul0000391.supp>
- Eşkisü, M., Ağırkan, M., Çelik, O., Yalçın, R. Ü., & Haspolat, N. K. (2022). Do the highly sensitive people tend to have psychological problems because of low emotion regulation and dysfunctional attitudes? *Journal of Rational-Emotive and Cognitive-Behavior Therapy, 40*(4), 683–706. <https://doi.org/10.1007/s10942-021-00436-w>
- Evans, D. E., & Rothbart, M. K. (2007). Developing a model for adult temperament. *Journal of Research in Personality, 41*(4), 868–888. <https://doi.org/10.1016/j.jrp.2006.11.002>
- Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*(4), 1149–1160. <https://doi.org/10.3758/BRM.41.4.1149>
- Franz, M., Nordmann, M. A., Rehagel, C., Schäfer, R., Müller, T., & Lundqvist, D. (2021). It is in your face—Alexithymia impairs facial mimicry. *Emotion, 21*(7), 1537–1549. <https://doi.org/10.1037/emo0001002>

- Ganzel, B. L., Kim, P., Gilmore, H., Tottenham, N., & Temple, E. (2013). Stress and the healthy adolescent brain: Evidence for the neural embedding of life events. *Development and Psychopathology*, 25, 879–889. <https://doi.org/10.1017/S0954579413000242>
- George, D., & Mallery, P. (2003). *SPSS for Windows step by step: A simple guide and reference* (11.0 update (4th ed.)). Allyn & Bacon.
- Gulla, B., & Golonka, K. (2021). Exploring protective factors in wellbeing: How sensory processing sensitivity and attention awareness interact with resilience. *Frontiers in Psychology*, 12(751679). <https://doi.org/10.3389/fpsyg.2021.751679>
- Håkansson Eklund, J., & Summer Meranius, M. (2021). Toward a consensus on the nature of empathy: A review of reviews. *Patient Education and Counseling*, 104(2), 300–307. <https://doi.org/10.1016/j.pec.2020.08.022>
- Hatfield, E., Cacioppo, J. T., & Rapson, R. L. (1993). Emotional contagion. *Psychological Science*, 2(3), 96–99. <https://doi.org/10.1111/1467-8721.ep10770953>
- Hayes, A. F. (2022). *Introduction to mediation, moderation, and conditional process analysis* (3rd ed.). Guilford Press.
- Jakobson, L. S., McQuarrie, A. M., Van Landeghem, C., & Smith, S. D. (2024). Traits linked to sensory processing sensitivity mediate the relationship between externally oriented thinking and fantasizing. *Frontiers in Psychology*, 15(1354120). <https://doi.org/10.3389/fpsyg.2024.1354120>
- Jakobson, L. S., & Rigby, S. N. (2021). Alexithymia and sensory processing sensitivity: Areas of overlap and links to sensory processing styles. *Frontiers in Psychology*, 12(583786). <https://doi.org/10.3389/fpsyg.2021.583786>

- Jordan, M. R., Amir, D., & Bloom, P. (2016). Are empathy and concern psychologically distinct? *Emotion, 16*(8), 1107–1116. <https://doi.org/10.1037/emo0000228>
- Karaca Dinç, P., Oktay, S., & Durak Batıgün, A. (2021). Mediation role of alexithymia, sensory processing sensitivity and emotional-mental processes between childhood trauma and adult psychopathology: A self-report study. *BMC Psychiatry, 21*(1), 1–10. <https://doi.org/10.1186/s12888-021-03532-4>
- Khan, A. N., & Jaffee, S. R. (2022). Alexithymia in individuals maltreated as children and adolescents: A meta-analysis. *Journal of Child Psychology and Psychiatry, 63*(9), 963–972. <https://doi.org/10.1111/jcpp.13616>
- Lionetti, F., Dumpfrey, R. S. C., Richetin, J., Fasolo, M., Nocentini, A., Penolazzi, B., Pluess, M., Santona, A., Spinelli, M., & Preti, E. (2024). Is environmental sensitivity a unique trait? A multi-sample study on the association between sensitivity, personality, and psychological adjustment. *Personality and Individual Differences, 217*(112463). <https://doi.org/10.1016/j.paid.2023.112463>
- Luminet, O., Nielson, K. A., & Ridout, N. (2021). Cognitive-emotional processing in alexithymia: An integrative review. *Cognition and Emotion, 35*(3), 449–487. <https://doi.org/10.1080/02699931.2021.1908231>
- Maffei, A., & Angrilli, A. (2019). E-MOVIE - Experimental MOVies for Induction of Emotions in neuroscience: An innovative film database with normative data and sex differences. *PLOS ONE, 14*(10), e0223124. <https://doi.org/10.1371/journal.pone.0223124>
- Maibom, H. L. (2019). Empathy and emotion regulation. *Philosophical Topics, 47*(2), 149–163. <https://doi.org/10.5840/philtopics201947220>

McQuarrie, A. M., Smith, S. D., & Jakobson, L. S. (2023). Alexithymia and sensory processing sensitivity account for unique variance in the prediction of emotional contagion and empathy. *Frontiers in Psychology, 14*(1072783).

<https://doi.org/10.3389/fpsyg.2023.1072783>

Mikulincer, M., Gillath, O., Halevy, V., Avihou, N., Avidan, S., & Eshkoli, N. (2001).

Attachment theory and reactions to others' needs: Evidence that activation of the sense of attachment security promotes empathic responses. *Journal of Personality and Social Psychology, 81*(6), 1205–1224. <https://doi.org/10.1037/0022-3514.81.6.1205>

Patil, I., & Silani, G. (2014a). Alexithymia increases moral acceptability of accidental harms. *Journal of Cognitive Psychology, 26*(5), 597–614.

<https://doi.org/10.1080/20445911.2014.929137>

Patil, I., & Silani, G. (2014b). Reduced empathic concern leads to utilitarian moral judgments in trait alexithymia. *Frontiers in Psychology, 5*(501), 1–12.

<https://doi.org/10.3389/fpsyg.2014.00501>

Peters, A. T., Burkhouse, K. L., Kinney, K. L., & Luan Phan, K. (2019). The roles of early-life adversity and rumination in neural response to emotional faces amongst anxious and depressed adults. *Psychological Medicine, 49*(13), 2267–2278.

<https://doi.org/10.1017/S0033291718003203>

Preece, D. A., & Gross, J. J. (2023). Conceptualizing alexithymia. *Personality and Individual Differences, 215*(112375). <https://doi.org/10.1016/j.paid.2023.112375>

Preece, D. A., Mehta, A., Petrova, K., Sikka, P., Bjureberg, J., Becerra, R., & Gross, J. J. (2023). Alexithymia and emotion regulation. *Journal of Affective Disorders, 324*, 232–238.

<https://doi.org/10.1016/j.jad.2022.12.065>

- Prochazkova, E., & Kret, M. E. (2017). Connecting minds and sharing emotions through mimicry: A neurocognitive model of emotional contagion. *Neuroscience and Biobehavioral Reviews*, 80, 99–114. <https://doi.org/10.1016/j.neubiorev.2017.05.013>
- Samson, A. C., Kreibig, S. D., Soderstrom, B., Wade, A. A., & Gross, J. J. (2016). Eliciting positive, negative and mixed emotional states: A film library for affective scientists. *Cognition and Emotion*, 30(5), 827–856. <https://doi.org/10.1080/02699931.2015.1031089>
- Schaefer, M., Kühnel, A., & Gärtner, M. (2022). Sensory processing sensitivity and somatosensory brain activation when feeling touch. *Scientific Reports*, 12(1). <https://doi.org/10.1038/s41598-022-15497-9>
- Şengül-İnal, G., Kirimer-Aydinli, F., & Sümer, N. (2018). The role of attachment insecurity and big five traits on sensory processing sensitivity. *The Journal of Psychology*, 152(7), 497–514. <https://doi.org/10.1080/00223980.2018.1482255>
- Sifneos, P. E. (1973). *Short-term psychotherapy and emotional crisis*. Harvard University Press.
- Smith, R., Killgore, W. D. S., & Lane, R. D. (2018). The structure of emotional experience and its relation to trait emotional awareness: A theoretical review. *Emotion*, 18(5), 670–692. <https://doi.org/10.1037/emo0000376>
- Smolewska, K. A., McCabe, S. B., & Woody, E. Z. (2006). A psychometric evaluation of the Highly Sensitive Person Scale: The components of sensory-processing sensitivity and their relation to the BIS/BAS and “Big Five.” *Personality and Individual Differences*, 40(6), 1269–1279. <https://doi.org/10.1016/j.paid.2005.09.022>
- Stoltenborgh, M., Bakermans-Kranenburg, M. J., Alink, L. R. A., & van IJzendoorn, M. H. (2015). The prevalence of child maltreatment across the globe: Review of a series of meta-analyses. *Child Abuse Review*, 24(1), 37–50. <https://doi.org/10.1002/car.2353>

- Troyer, D., & Greitemeyer, T. (2018). The impact of attachment orientations on empathy in adults: Considering the mediating role of emotion regulation strategies and negative affectivity. *Personality and Individual Differences, 122*, 198–205.
<https://doi.org/10.1016/j.paid.2017.10.033>
- Van Landeghem, C., & Jakobson, L. S. (2024). Isolating unique variance in mental health outcomes attributable to personality variables and childhood emotional abuse. *Frontiers in Psychology, 15*(1330483). <https://doi.org/10.3389/fpsyg.2024.1330483>
- Xu, X., Liu, Z., Gong, S., & Wu, Y. (2022). The relationship between empathy and attachment in children and adolescents: Three-level meta-analyses. *International Journal of Environmental Research and Public Health, 19*(3).
<https://doi.org/10.3390/ijerph19031391>
- Zhang, H., Gao, X., Liang, Y., Yao, Q., & Wei, Q. (2024). Does child maltreatment reduce or increase empathy? A systematic review and meta-analysis. *Trauma, Violence, and Abuse, 25*(1), 166–182. <https://doi.org/10.1177/15248380221145734>

Supplementary Material

As features of the present study are similar to features of some previously published reports, we wish to outline some key differences that set the present study apart. Jakobson et al. (2024) performed secondary analyses of data collected in three previous studies: Study 1 incorporated data from Jakobson and Rigby (2021) and McQuarrie et al. (2023); and Study 2 incorporated data from Van Landeghem et al. (2019). The main goals of the secondary analyses were: (a) to add to the literature contrasting “positive” and “negative” features of SPS; (b) to examine the distribution of these trait clusters in a young adult sample and to explore their links to alexithymia; and (c) to test the proposal that SPS might mediate the link between one specific facet of alexithymia—externally oriented thinking—and impaired fantasy, as measured by the Fantasizing subscale of the Interpersonal Reactivity Index (IRI; Davis, 1983). Neither emotional abuse suffered in childhood nor emotional contagion were examined in this report.

The present study is more closely related to one of the papers mentioned above: McQuarrie et al. (2023). In that paper, it was reported that—when *controlling for* SPS and alexithymia—childhood emotional abuse did not emerge as a predictor of emotional contagion in a behavioural task, nor did it predict self- or other-oriented dimensions of empathy captured by factor scores derived from subscales of the IRI and Jordan et al.’s (2016) Empathy Index (EI). We wanted to follow up on that surprising result in the present study by determining whether SPS and/or alexithymia might *mediate* the link between childhood emotional abuse and empathy-related constructs. However, there are several features of the methods employed in the present study that distinguish it from those used in McQuarrie et al. (2023). First, although university students were recruited for both studies, there was no overlap in the samples. Second, our film rating task included more film clips (48 vs. 10) obtained from multiple sources (2 vs. 1),

which were of shorter duration (~8 s vs. ~ 30 s) and were rated on fewer dimensions (5 vs. 9 emotions) compared to those used in McQuarrie et al. (2023). We also had only a single “mixed valence” category in the present study, rather than distinguishing between mixed valence films depicting situations that would cause embarrassment and those that would cause humiliation. Third, consistent with several recent reports (Attary & Ghazizadeh, 2021; De Gucht et al., 2022; Jakobson et al., 2024), we distinguished in the present work between “SPS+” and “SPS-” trait clusters. Finally, rather than grouping IRI/EI subscales into two clusters as in McQuarrie et al. (2023), we treated each of the four IRI and two EI subscales as a separate dependent variable to get a more fine-grained look at how our predictor and mediator variables related to specific empathy-related processes measured through self-report.

References

- Attary, T. and Ghazizadeh, A. (2021). Localizing sensory processing sensitivity and its subdomains within its relevant trait space: a data-driven approach. *Sci Rep*, 11:20343. <https://doi.org/10.1038/s41598-021-99686-y>.
- Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, 44(1), 113–126. <https://doi.org/10.1037//0022-3514.44.1.113>.
- De Gucht, V., Woestenburg, D. H. A., & Wilderjans, T. F. (2022). The different faces of (high) sensitivity, toward a more comprehensive measurement instrument. Development and validation of the Sensory Processing Sensitivity Questionnaire (SPSQ). *Journal of Personality Assessment*, 104(6), 784–799. <https://doi.org/10.1080/00223891.2022.2032101>.
- Jakobson, L. S., McQuarrie, A. M., Van Landeghem, C., & Smith, S. D. (2024). Traits linked to sensory processing sensitivity mediate the relationship between externally oriented thinking and fantasizing. *Frontiers in Psychology*, 15(1354120). <https://doi.org/10.3389/fpsyg.2024.1354120>.
- Jakobson, L. S., & Rigby, S. N. (2021). Alexithymia and sensory processing sensitivity: Areas of overlap and links to sensory processing styles. *Frontiers in Psychology*, 12(583786). <https://doi.org/10.3389/fpsyg.2021.583786>.
- Jordan, M. R., Amir, D., & Bloom, P. (2016). Are empathy and concern psychologically distinct? *Emotion*, 16(8), 1107–1116. <https://doi.org/10.1037/emo0000228>.
- McQuarrie, A. M., Smith, S. D., & Jakobson, L. S. (2023). Alexithymia and sensory processing sensitivity account for unique variance in the prediction of emotional contagion and

empathy. *Frontiers in Psychology*, 14(1072783).

<https://doi.org/10.3389/fpsyg.2023.1072783>.

Van Landeghem, C., Jakobson, L. S., & Keough, M. (2019). Risk of exercise dependence in university students: A subtyping study utilizing latent profile analysis. *Psychology of Sport and Exercise*, 45(101575). <https://doi.org/10.1016/j.psychsport.2019.101575>.

Supplementary Table S1*Film Names and Sources for Emotional Contagion Behavioural Task*

Film type	Film name	Brief film description	Source
Positive	Baby controls cheers	Baby puts hands in air and crowd also puts hands in air and cheers after baby	Samson et al. 2016
	Baby dance Beyonce	Baby is dancing to a Beyoncé music video	Samson et al. 2016
	Baby dancing to RnB	Little boy dancing at a wedding	Samson et al. 2016
	Baby dance 50 Cent	Baby dances to 50 Cent	Samson et al. 2016
	Babys hiccup and laugh	Twin babies, one laughs while the other hiccups	Samson et al. 2016
	Bride laughing during vows	Bride can't stop laughing	Samson et al. 2016
	Cat suckles air	Cat suckles the air	Samson et al. 2016
	Escalator spinning	Spinning on an escalator	Samson et al. 2016
	Girl thrown into basketball hoop	Girl does a flip and goes through basketball hoop	Samson et al. 2016
	Lamb can't find owner	Lamb bounding from room to room	Samson et al. 2016
	Man gets hurt tubing	Man tubing	Samson et al. 2016
Negative	Thirsty baby drinks	Baby struggles to drink from hose	Samson et al. 2016
	Bull wrong target	Bull tramples person in crowd	Samson et al. 2016
	Car hits skater	Skateboarder is hit by a car	Samson et al. 2016
	Croc bites man	Man sticks arm in crocodile's mouth and is bit	Samson et al. 2016
	Deep Red	Creepy eye and hanging doll	Maffei & Angrilli, 2019
	Deep Red 2	Lights go out mysteriously	Maffei & Angrilli, 2019
	Deep Red 3	Woman being stalked	Maffei & Angrilli, 2019
	Gothika	Woman running away	Maffei & Angrilli, 2019
	Gothika 2	Woman running through empty hallways and is caught	Maffei & Angrilli, 2019
	Silence of the Lambs 1	Woman backing away with a gun in the dark	Maffei & Angrilli, 2019
	Silence of the Lambs 2	Woman walking in the dark and a hand grabs her	Maffei & Angrilli, 2019
	Vacancy 1	Couple running into a man with a mask	Maffei & Angrilli, 2019
	Vacancy 2	Woman trying to escape	Maffei & Angrilli, 2019

Film type	Film name	Brief film description	Source
Mixed	Boy faints at wedding	Boy faints at wedding	Samson et al. 2016
	Boy falls off diving board	Boy slips on diving board and falls into pool	Samson et al. 2016
	Bride falls in water	Best man slips and pushes bride into pond	Samson et al. 2016
	Bride loses teeth drinking	Bride loses fake teeth drinking at wedding	Samson et al. 2016
	Car handstand	Man doing handstand on car breaks windshield	Samson et al. 2016
	Dancers break table	Table breaks while people are dancing in it	Samson et al. 2016
	Guy breaks glass copying butt	Man photocopying his bottom breaks the glass	Samson et al. 2016
	Man crashes into glass door	Man chooses wrong glass door and crashes into it	Samson et al. 2016
	Man rope swing fail	Man crashes while rope swinging	Samson et al. 2016
	Skier crash into snow	Skier skies into pile of snow	Samson et al. 2016
Neutral	Wedding photographer fails	Photographer falls into fountain	Samson et al. 2016
	Woman ruins wedding with pole	Woman dances on a pole	Samson et al. 2016
	Cable car	Riding in a cable car	Samson et al. 2016
	Central Station NY	People walking through train station	Samson et al. 2016
	Denver train	Travelling in a subway	Samson et al. 2016
	Diving II	Diving into a pool	Samson et al. 2016
	In the kitchen	Opening a can	Samson et al. 2016
	Knitting	Knitting	Samson et al. 2016
	Origami 4	Folding origami	Samson et al. 2016
	Planting a veggie garden	Planting seeds in the dirt	Samson et al. 2016
	Riding horse	Woman riding a horse	Samson et al. 2016
	Snow	Shovelling snow	Samson et al. 2016
	Swimming laps	Person swimming laps	Samson et al. 2016
	Treadmill	Walking on a treadmill	Samson et al. 2016

Supplementary Table S2

Pearson Correlation Coefficients Measuring the Relationships between Behavioural and Self-Report Variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Primary emotions	1. Positive	--															
	2. Neutral	.07	--														
	3. Mixed	.55**	.36**	--													
	4. Negative	.53**	.17*	.55**	--												
Dispersion scores	5. Positive	-.11	.22**	.20*	.14	--											
	6. Neutral	.02	.10	.12	.12	.75**	--										
	7. Mixed	.08	.23**	.46**	.36**	.77**	.64**	--									
	8. Negative	.06	.29**	.40**	.27**	.74**	.65**	.80**	--								
Self-report measures	9. TAS-20	-.10	.08	.06	.04	.10	.07	.13	.15	--							
	10. SPS+	.19*	-.08	.07	.16	-.06	-.03	.08	.02	.02	--						
	11. SPS-	.09	.04	.14	.32**	-.06	-.09	.07	.004	.41**	.49**	--					
	12. EC	.34**	-.03	.05	.31**	-.26**	-.17*	-.07	-.13	-.18*	.41**	.35**	--				
	13. PT	.19*	-.04	-.04	.16	-.22**	-.16	-.12	-.09	-.24**	.36**	.15	.55**	--			
	14. FS	.18*	-.02	.05	.24**	-.11	-.02	.01	-.06	.17*	.57**	.51**	.46**	.24**	--		
	15. PD	.06	-.07	-.04	.23**	-.06	-.02	.07	-.06	.40**	.10	.52**	.27**	-.01	.34**	--	
	16. EMP	.22**	-.05	.17*	.45**	-.03	.04	.12	.07	.22**	.42**	.61**	.55**	.29**	.49**	.59**	--
	17. eaCTQ	-.06	.03	.04	-.03	.13	.09	.11	.06	.26**	.19*	.17*	.01	.06	.20*	.21*	.13

Note. Yellow, orange, and red fills indicate small, medium, and large effect sizes, respectively. The primary emotions for the positive, neutral, mixed, and negative film types were amusement, boredom, an amusement/embarrassment blend, and fear, respectively. TAS-20, Toronto Alexithymia Scale; SPS+ and SPS-, positive and negative trait clusters associated with sensory processing sensitivity; eaCTQ, Emotional Abuse subscale of the Childhood Trauma Questionnaire. Subscales of the Interpersonal Reactivity Index/Empathy Index: EC, Empathic Concern; PT, Perspective Taking; FS, Fantasy; PD, Personal Distress; EMP, Empathy/Emotional Contagion.

* $p < .05$ (2-tailed); ** $p < .01$ (2-tailed)

Chapter 3: Resting-State Functional Connectivity Related to Empathy and Sensory Processing Sensitivity

The following study is the preprint version of a manuscript that was subsequently accepted for publication after some changes were made to address reviewers' comments. The citation for the final, published version appears below. Minor adjustments have been made to the text to allow for consistent formatting within this manuscript.

McQuarrie, A. M. M., Jakobson, L. S., & Smith, S. D. (in press). Resting-state functional connectivity related to empathy and sensory processing sensitivity. *Frontiers in Human Neuroscience*.

Abstract

Sensory processing sensitivity (SPS) is a personality trait that has both positive features (SPS+) such as sensitivity to subtle cues, and negative features (SPS-) such as sensitivity to unpleasant stimuli or situations. In a sample of university students ($N = 172$), we identified links between these facets and multiple aspects of empathy, measured via self-report. Subsequently, resting-state functional magnetic resonance imaging scans from 40 of these participants ($M_{age} = 21.10$ years; 22 females) were analyzed, using neural regions associated with empathy as seeds. Second-level correlation analyses identified associations between functional connectivity (FC) for each seed-to-voxel connection and each facet of SPS. SPS+ was associated with increased FC between medial prefrontal cortex (mPFC) and left superior parietal lobule, right intracalcarine cortex, and bilateral lateral occipital cortex (LOC). SPS- was associated with increased FC between the left inferior frontal gyrus and right frontal pole; right insula and primary somatosensory cortex; mPFC and left LOC; and precuneus and left frontal pole. SPS- was also associated with decreased FC between the left inferior frontal gyrus (IFG) and left LOC; left insula and brainstem; precuneus and left occipital pole; and precuneus and right cerebellum. These patterns may relate to specific features of SPS including enhanced visual processing, deeper processing of information, and heightened interoceptive and emotional processing, which may contribute to the strong feelings of empathy reported by individuals with SPS, and to emotion dysregulation that may exacerbate feelings of personal distress in those possessing strong SPS- traits when witnessing others' suffering.

Keywords: sensory processing sensitivity, empathy, personal distress, functional connectivity, resting-state magnetic resonance imaging

Highlights

- Sensory processing sensitivity (SPS) is a multi-faceted trait linked to empathy.
- It relates to functional connectivity (FC) between empathy seeds and other regions.
- Strong FC with the mPFC seed was associated with positive and negative SPS facets.
- Altered FC with IFG, insula, and precuneus seeds were linked to negative facets.
- Possible links between altered FC and processes related to empathy are discussed.

Introduction

The personality trait of sensory processing sensitivity (SPS) is characterized by heightened sensitivity to the internal and external environment, strong emotional reactivity, and processing stimuli at a deeper level¹ (Aron et al., 2012; Aron & Aron, 1997). SPS can be found in approximately 30% of the general population (Lionetti et al., 2018). The overarching trait can be divided into positive and negative components (Attary & Ghazizadeh, 2021; De Gucht et al., 2022; Jakobson et al., 2024). The positive component of SPS (SPS+) encompasses one's sensitivity to interpersonal cues, aesthetic qualities of the environment, and subtle stimuli (e.g., scents and textures), as well as one's awareness of how these cues affect one at an emotional level (e.g., how the weather affects one's mood). This component is associated with the Big Five personality traits of openness and conscientiousness (Attary & Ghazizadeh, 2021), and with adaptive forms of self-regulation such as cognitive appraisal (Eşkisu et al., 2022). The negative SPS trait cluster (SPS-) includes sensitivity to unpleasant stimuli (e.g., loud noises) and being prone to overstimulation. This trait cluster is associated with neuroticism, shyness, alexithymia, anxiety and depression (Attary & Ghazizadeh, 2021; Jakobson et al., 2024), as well as maladaptive forms of emotion regulation such as emotion suppression (Eşkisu et al., 2022). Problems with emotion regulation have been found to mediate the relationship between SPS and negative mood (Brindle et al., 2015). Based on these results, there is a clear connection between SPS and alterations in affective processing.

Both the SPS+ and SPS- components are linked to facets of empathy—the process of identifying and feeling the same emotion as another person, while recognizing that the emotion

¹ “Deep” processing, as originally described by Craik and Lockhart (1972), refers to encoding and processing information in a meaningful and elaborate way that supports long-term memory. It may involve things such as the formation of mental images and/or the linking of current information to previous knowledge.

belongs to the empathy target (Cuff et al., 2016; Håkansson Eklund & Summer Meranius, 2021; McQuarrie et al., 2023, 2025). Thus, both predict higher levels of perspective taking, empathic concern, fantasizing abilities, and emotional contagion (McQuarrie et al., 2025). However, the two trait clusters differ with regard to their links to the experience of personal distress while empathizing, with SPS+ traits predicting lower levels of distress and SPS- traits predicting higher levels (McQuarrie et al., 2025). It may be that individuals who express high levels of SPS are better able to empathize with others because they feel emotions more strongly (Aron et al., 2012; McQuarrie et al., 2023), but whether they act with compassion may depend on how well they can regulate feelings of personal distress (e.g., Jordan et al., 2016)—an ability that may depend, directly or indirectly, on the relative strength of SPS+ and SPS- traits.

Despite the strong links between SPS and empathy, there has been relatively little research examining the neural substrates of this association. One neuroimaging technique that may be particularly useful in this regard is resting-state functional magnetic resonance imaging (rsMRI), a measure of neural activity that occurs while an individual is not performing a cognitive or motoric task. rsMRI measures functional connectivity (FC), a value representing the degree of correlated neural activity between two or more topographically disparate regions of the brain (Biswal et al., 1995; Lee et al., 2013). Using this technique, Acevedo et al. (2021) found that SPS as an overarching trait was associated with increased FC in regions involved in attention (e.g., middle frontal gyrus and anterior cingulate cortex) and memory (e.g., precuneus and hippocampus). Associations between SPS and reduced limbic system connectivity (e.g., between the amygdala, periaqueductal gray and insula) were also identified (Acevedo et al., 2021). Another study investigating associations between FC, SPS, and attention deficits identified increased FC between the rostral hippocampus and the inferior parietal lobule (Zhou et

al., 2025). SPS was found to mediate the relationship between the FC of these two regions and attention deficits. The authors hypothesized that the increased FC between the hippocampus and inferior parietal lobule may explain attention deficits related to SPS through heightened processing of sensory stimuli, which could potentially lead to overstimulation (Zhou et al., 2025). These two studies provide some evidence of the neural underpinnings of SPS as a whole trait, although the specific neural connections between SPS (in particular, the SPS- and SPS+ components) and empathy have not been yet explored.

In the current study, neural regions commonly involved in empathy were used as seeds when analyzing rsMRI data. Meta-analyses of neuroimaging studies involving empathy-specific tasks have identified the midcingulate/anterior cingulate cortex and anterior insula as forming a “core” empathy network (Fan et al., 2011; Jauniaux et al., 2019; Timmers et al., 2018). Other neural regions commonly associated with empathy tasks include the inferior frontal gyrus (IFG), medial prefrontal cortex (mPFC), precuneus, and temporoparietal junction (Jauniaux et al., 2019; Kogler et al., 2020; Timmers et al., 2018). Empathy is also reflected in the resting brain, particularly with connectivity between the mPFC and posterior cingulate cortex, insula, precuneus, and anterior cingulate cortex (Kim et al., 2017; Li et al., 2014; Takeuchi et al., 2014; Tremblay et al., 2022).

Specific objectives of the current study included: 1) to replicate prior findings supporting the relationship between SPS and self-reported empathy; 2) to identify FC associated with SPS+ between the seeds mentioned above and the rest of the brain; and 3) to measure FC associated with SPS- between the seeds and the rest of the brain. Given the relationships between SPS and empathy, it was hypothesized that both components of SPS would be associated with alterations in FC between the empathy-related seeds and other regions.

Methods

Participants

There were two phases to this experiment. Initially, 186 adult participants were recruited from an undergraduate psychology class for phase I. After cleaning (described below), the final sample included 172 participants (102 men, 67 women, 2 transgender men, 1 non-binary individual; $M_{age} = 21.85$ years, $SD_{age} = 5.39$ years). Data obtained from these participants were used to assess the reliability of the self-report measures and to address our first study objective.

Based on eligibility criteria and availability, 41 participants (19 men, 22 women; age range 18-34) were then selectively recruited from this sample to complete an MRI scanning session in phase II. Exclusion criteria included: non-Canadian citizenship (to reduce the risk of cultural effects on emotional responses); inability to understand instructions presented in English; a self-reported history of neurological disorders or significant head injury (to reduce potential confounding variables); and not having normal or corrected-to-normal vision (relevant for a task-based scan not included in the present study). Inclusion criteria included completing and passing an MRI screening questionnaire.

Participants received credit toward a research participation option for taking part in this study. Individuals who took part in the scanning session also received \$20 CDN in monetary compensation to cover travel costs to and from the scanning location, and a complimentary copy of their structural brain scan.

General Procedure

Ethical approval was received from the university research ethics boards. Participants provided informed consent prior to participation. In phase I, participants completed self-report measures of SPS, empathy, and an MRI screening questionnaire (as well as additional self-report

measures not relevant to the current study) online via the Qualtrics survey platform (RRID: SCR_016728). A subset of the participants who were eligible to complete the MRI scanning session (as determined by the MRI screening questionnaire) were contacted for phase II to book their session. Participants completed a 5-minute structural scan and then an 11-minute resting-state functional scan, where they were asked to lie completely still, focus on a fixation cross, and stay awake.

Scanning Parameters

MRI scans were conducted using a 3 Tesla Siemens Verio MRI scanner (Siemens Healthineers, Erlangen, Germany). Three-dimensional high-resolution T1-weighted gradient-echo anatomical MRI structural scans were used with a magnetization-prepared rapid gradient-echo (MP-RAGE) sequence. Structural scans used the following parameters: slices of 1-mm thickness, 0 gap, TR/TE = 1900/2.2 ms, in-plane resolution .94 x .94 mm, 256 x 256 matrix, with a field of view of 24 cm.

A whole-brain echo-planar imaging sequence was used to acquire functional data. Functional scans included the following parameters: slice thickness of 3-mm, 0 gap, TR/TE = 3000/30msec, flip angle 90°, 64 x 64 matrix, also with a field of view of 24 cm.

Personality Questionnaires

Measures of SPS

The overarching concept of SPS was captured using two measures based on the recommendation by Aron et al. (2012): the Highly Sensitive Person Scale (HSPS; Aron & Aron, 1997) and the Orienting Sensitivity (OS) subscale of the Adult Temperament Questionnaire (Evans & Rothbart, 2007). The HSPS contains 27 items rated on a seven-option Likert scale from 1 (not at all) to 7 (extremely). The HSPS has three subscales: ease of excitation, which

contains 12 items measuring the extent to which one becomes over-aroused by external stimuli; low sensory threshold, containing six items measuring discomfort related to sensory stimulation; and aesthetic sensitivity, with seven items measuring sensitivity to subtle stimuli and the aesthetic environment. HSPS subscale and total scores are found by calculating the mean of relevant items.

The OS adds to the HSPS by addressing sensitivity to subtle stimuli, and the richness of an individual's inner life (Aron et al., 2012; Evans & Rothbart, 2007). The OS includes three five-item subscales: affective perceptual sensitivity, a measure of the emotional impact of low intensity stimuli; neutral perceptual sensitivity, measuring general awareness of low intensity internal and external stimuli; and associative sensitivity, measuring spontaneous cognitive processes such as imagery, intuition, and dreaming. Each of the 15 items is rated on a seven-point Likert scale, from 1 (*extremely untrue*) to 7 (*extremely true*), as well as an X (*not applicable*) option. Subscale scores are calculated by finding the mean of relevant items.

In the current study, the mean of the aesthetic sensitivity subscale of the HSPS and the three OS subscales was calculated to produce an SPS+ composite score, and the mean of the low sensory threshold and ease of excitation subscales of the HSPS served as an SPS- composite score (Jakobson et al., 2024). The Cronbach's alpha was 0.83 for the SPS+ composite score and 0.89 for the SPS- composite, indicating good internal consistency.

Measures of Empathy

Empathy and its related concepts were measured using the combined Interpersonal Reactivity Index (Davis, 1983) and Empathy Index (Jordan et al., 2016). Together, these two measures include 42 items with a five-option Likert scale from 0 (*does not described me well*) to 4 (*describes me very well*). The four subscales from the Interpersonal Reactivity Index include:

Perspective Taking, adopting the viewpoint of another person; Personal Distress, the level of personal feelings of distress experienced when in tense interpersonal situations; Empathic Concern, feeling concern or sympathy for another; and Fantasy, adopting the feelings and actions of fictitious characters. The two additional subscales comprising the Empathy Index include: Behavioural Contagion, awareness of the extent to which one mimics the behaviours of those around them; and Empathy, awareness of emotional contagion, or the extent to which observing another's emotions triggers similar feelings in oneself. Each subscale includes seven items, with responses summed to produce the subscale score. In the current sample, reliability of five of the six subscales was acceptable ($\alpha \geq 0.72$); however, the Behavioural Contagion subscale had an unacceptable reliability coefficient of $\alpha = 0.54$ (Tavakol & Dennick, 2011). As such, the scores on this subscale were not included in the analyses.

Analyses

Personality Questionnaires

To address our first objective, we assessed relationships between the two facets of SPS and self-reported empathy in the full sample ($N = 172$). This step was important for replication purposes but also to justify the use of the SPS composite scores as covariates in the rsMRI analyses and to aid in the interpretation of those analyses. The data were first cleaned by checking for duplicates (retaining the first completion for duplicate entries), outliers, and abnormal participant response patterns. Next, Little's Missing Completely at Random test was run to determine if data were missing at random and, as this was the case, an expectation-maximization algorithm was used to estimate missing values. Following this, the subscale or composite scores for the self-report measures were computed and the distributions of these scores were checked for normality. Multiple linear regressions were run with the SPS trait

cluster scores entered as predictors and the empathy subscales entered as outcome variables. Individual coefficients were estimated using 95% percentile confidence intervals estimated based on 1000 bootstrap samples. Statistical analyses of the self-report measures were conducted using IBM SPSS Statistics for Microsoft, Version 28.

Neuroimaging Analyses

For the neuroimaging data, the structural and functional neuroimaging files were converted into NifTI files through the NifTI creator function of SPM version 12 (<http://www.fil.ion.ucl.ac.uk/spm>). This allowed the rsMRI data to be analysed using the CONN functional connectivity toolbox (Whitfield-Gabrieli & Nieto-Castanon, 2012). Structural MRI data were centred to the coordinates (0,0,0), segmented into white matter, gray matter, and cerebrospinal fluid, and normalized to a standard brain atlas with Montreal Neurological Institute coordinates. Artifacts from head motion were regressed out (three translation and three rotation parameters). Functional data were also centred, segmented into white matter, gray matter, and cerebrospinal fluid, and normalized to a standard brain atlas. These data also underwent slice time correction and spatial smoothing utilizing an 8mm Gaussian filter. Again, artifact interference was removed and denoising was performed utilizing the default .008 to .09 Hz bandpass filter. The structural and functional scans for each participant were co-registered.

First-level whole-brain analyses were run to examine the strength of the FC between the key seeds and the rest of the brain. Second-level correlation analyses were then conducted with the SPS composite scores entered individually as covariates of interest. The associations between FC of each seed-to-voxel connection and the SPS+ and SPS- scores were measured first with all seeds entered into the general linear model as an initial, general test of significance. Post-hoc analyses then investigated the associations between an SPS trait cluster and connectivity of each

seed individually. False discovery rate-controlling procedures were used, with a cluster-threshold $p < .05$. Voxel threshold was set at $p < .001$ (uncorrected).

Results

Self-Report Data

Descriptive statistics of the self-report measures for the full sample ($N = 172$) are presented in Table 1. The results of the regression analyses run on these data (see Table 2) replicated many of the findings of McQuarrie et al. (2025). More specifically, as predicted: (a) participants reporting stronger SPS+ also reported stronger perspective-taking, feelings of concern, and ability to feel with fictitious characters, and weaker feelings of personal distress in response to witnessing others' suffering; and (b) participants scoring higher on SPS- reported higher levels of awareness of emotional contagion and experienced more personal distress when empathizing with others. The fact that one or both SPS trait clusters significantly predicted each of the five self-report empathy measures justified our use of the SPS composite scores as covariates in the rsMRI analyses.

Functional Resting-State Analyses

The scan from one participant was removed due to image distortion. Thus, resting-state scans from 40 participants were analysed (18 men, 22 women; $M_{age} = 21.10$ years, $SD_{age} = 4.09$ years). Examination of descriptive statistics confirmed that mean scores for the SPS composite and Interpersonal Reactivity Index/Empathy Index subscale scores for this subgroup of individuals were comparable to those seen in the full sample of individuals who had participated in phase I; as well, the scores on these variables for the scanned participants covered the full range of scores seen in the full sample. These observations suggest that the group who underwent imaging were representative of the larger sample.

With the SPS+ trait cluster entered as a covariate, an omnibus F -test was first conducted including all seed regions. The general linear model produced positively correlated activity with a cluster located in the posterior inferior temporal gyrus (27 voxels, $p = .03$). Post-hoc analyses showed the mPFC as the only seed that produced significantly correlated connectivity. SPS+ scores were positively associated with FC between the mPFC and a cluster in the left superior parietal lobule and two separate clusters in the right intracalcarine cortex. Significant positive associations were also identified with FC between the mPFC and three separate but adjacent clusters in the left superior lateral occipital cortex (LOC): one extending into the cuneal cortex; one extending to the precuneus; and one solely within the left superior LOC. A final cluster within the right superior LOC was also significant. These associations are shown in Table 3 and Figure 1.

Table 1

Descriptive Statistics for Sensory Processing Sensitivity and Empathy and Related Constructs

	SPS+	SPS-	PT	EC	FS	EMP	PD
Mean/Sum	4.75	3.80	17.72	19.41	16.58	11.93	10.35
SD	0.77	1.06	4.98	4.45	5.39	4.87	5.02
Minimum	3.00	1.00	4.00	9.00	4.00	0.00	0.00
Maximum	6.70	6.38	28	28.00	27.00	23.00	22.00

Note. Statistics calculated from the full sample ($N = 172$). SPS+, positive trait cluster of sensory processing sensitivity; SPS-, negative trait cluster of sensory processing sensitivity. Subscales of the Interpersonal Reactivity Index and Empathy Index: PT, perspective-taking; EC, empathic concern; FS, fantasy; EMP, empathy; PD, personal distress. SD, standard deviation.

Table 2

Regression Analyses Showing Relationships between Sensory Processing Sensitivity and Empathy Subscales

Dependent variable	Predictor	B	Standard error	Bootstrapped 95% confidence interval		<i>p</i> -value (2-tailed)
				Lower	Upper	
PT	SPS+	3.16	0.52	2.12	4.19	< .001
	SPS-	-0.81	0.38	-1.51	0.03	.04
EC	SPS+	2.31	0.44	1.45	3.15	< .001
	SPS-	0.44	0.37	-0.29	1.11	.25
FS	SPS+	2.67	0.55	1.49	3.66	< .001
	SPS-	0.93	0.38	0.22	1.71	.02
EMP	SPS+	1.20	0.47	0.27	2.14	.02
	SPS-	2.07	0.34	1.44	2.73	< .001
PD	SPS+	-2.10	0.38	-2.81	-1.31	< .001
	SPS-	3.09	0.32	2.45	3.70	< .001

Note. Regression analyses calculated from the full sample ($N = 172$). B, unstandardized

coefficient; values shown in bold are significant at $p < .01$. 95% percentile confidence intervals were calculated using 1000 bootstrap samples. SPS+ and SPS-, positive and negative trait clusters associated with sensory processing sensitivity. Subscales of the Interpersonal Reactivity Scale and Empathy Scale: PT, perspective-taking; EC, empathic concern; FS, fantasy; EMP, empathy; PD, personal distress.

The general linear model F -test with the SPS- trait cluster entered as the covariate showed positively correlated connectivity in the left superior LOC, right frontal pole, precuneus, cerebellum Crus I, cerebellum lobule VI, and posterior inferior temporal gyrus. Post-hoc analyses investigating each seed individually produced significant associations between this trait cluster and connectivity with multiple seeds. Connectivity positively associated with SPS- scores included: between the left IFG pars triangularis and the right frontal pole; between the right insula and the right primary somatosensory cortex extending into the anterior division of the

supramarginal gyrus; between the mPFC and the left inferior LOC; and between the precuneus and the left frontal pole extending into the left paracingulate gyrus and right frontal pole (see Table 4 and Figure 2).

Table 3

Brain Regions Showing Correlated Connectivity with the Positive Sensory Processing Sensitivity

Trait Cluster

Brain region (hemisphere)	Cluster size	<i>p</i> -value (FDR)	Peak coordinates		
			<i>x</i>	<i>y</i>	<i>z</i>
Seed: mPFC					
Superior parietal lobule (L)	66	.001	-28	-52	+54
LOC, superior division (L)	43	.009	-26	-74	+24
Cuneal cortex (L)					
Intracalcarine cortex (R)					
Lingual gyrus (R)	35	.018	+18	-62	+08
Precuneus					
LOC, superior division (L)	32	.021	-16	-84	+38
Precuneus					
LOC, superior division (L)	27	.030	-28	-84	+22
Intracalcarine cortex (R)	27	.030	+16	-78	+06
LOC, superior division (R)	23	.049	+20	-78	+46

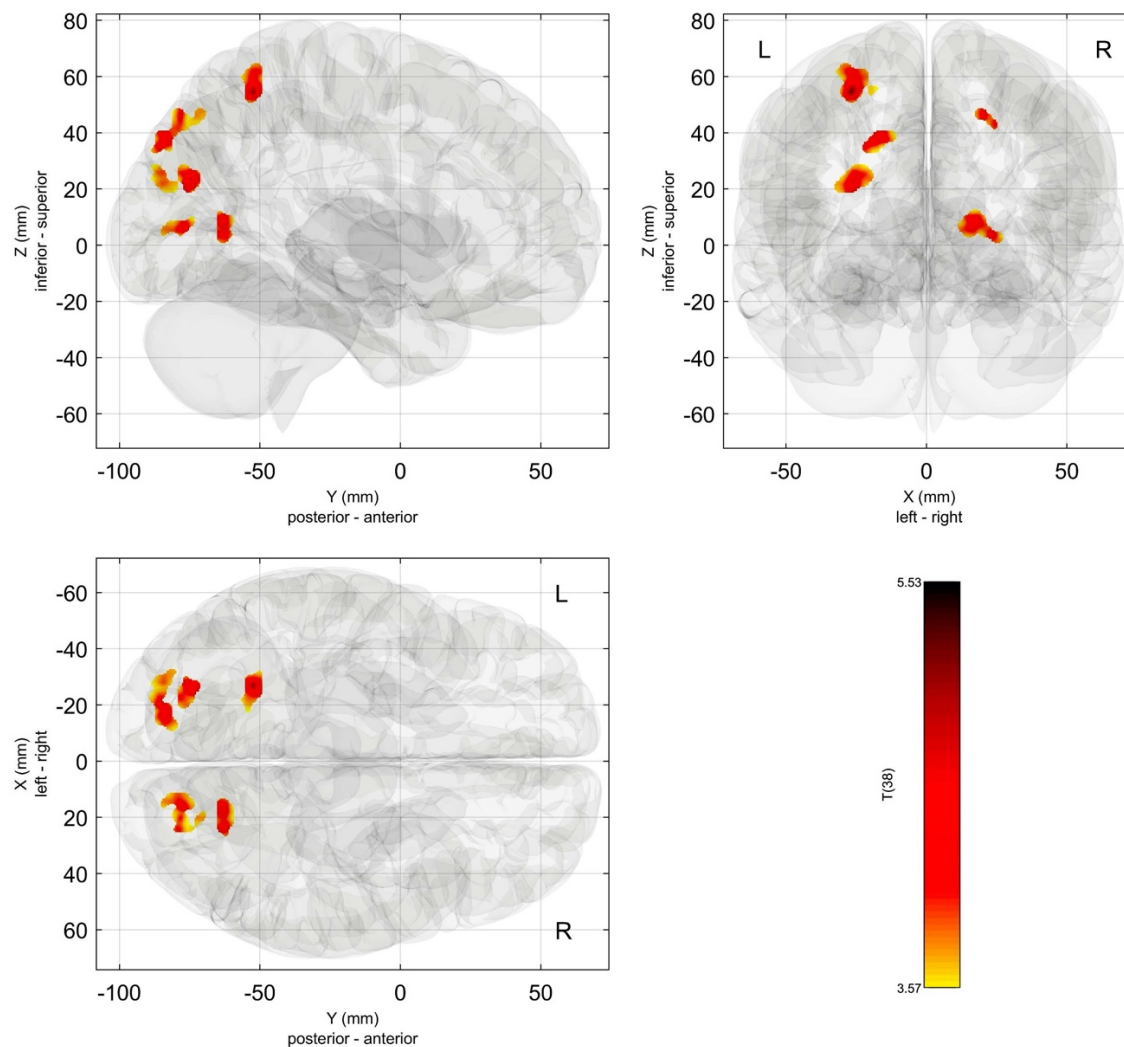
Note. All correlations were in the positive direction. FDR, false discovery rate corrected *p*-value.

mPFC, medial prefrontal cortex. LOC, lateral occipital cortex. L = left; R = right.

FC negatively associated with SPS- scores included: between the left IFG pars triangularis and the left superior LOC; between the left insula and the brainstem; between the precuneus and the left occipital pole; between the precuneus and the right cerebellum Crus I extending into lobule VI and fusiform gyrus; and a separate cluster between the precuneus and right cerebellum lobule VI extending into the fusiform gyrus (see Table 4 and Figure 2).

Figure 1

Neural Regions Functionally Connected with the Medial Prefrontal Cortex and Correlated with the Positive Sensory Processing Sensitivity Trait Cluster

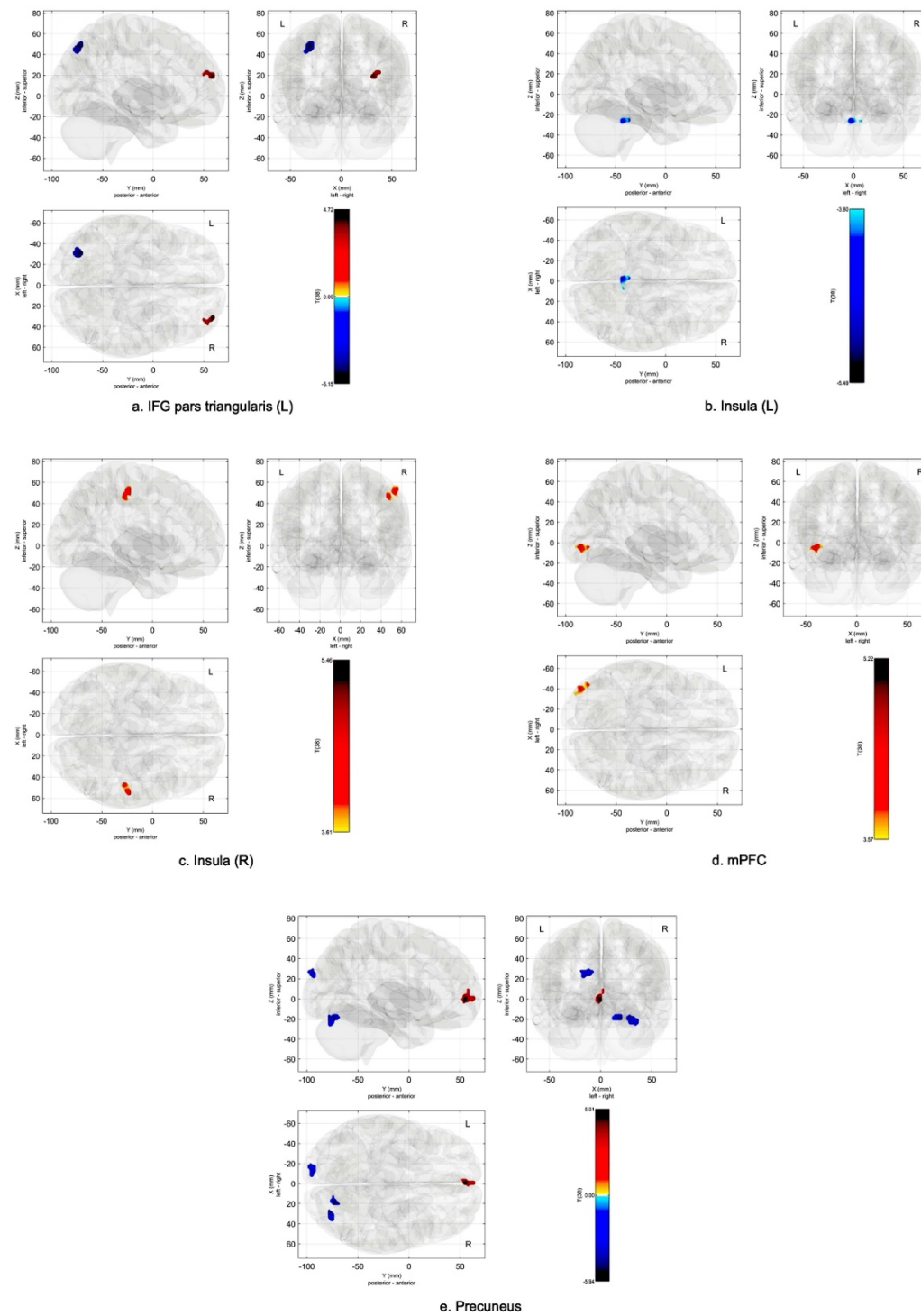


Note. Highlighted clusters functionally connected with the medial prefrontal cortex and positively correlated with the positive sensory processing sensitivity trait cluster include the left superior parietal lobule, right intracalcarine cortex (two separate clusters), left superior lateral occipital cortex (three separate clusters), and right superior lateral occipital cortex.

Table 4*Brain Regions Showing Correlated Connectivity with the Negative Sensory Processing**Sensitivity Trait Cluster*

Brain region (hemisphere)	Correlation	Cluster size	<i>p</i> -value (FDR)	Peak coordinates		
				<i>x</i>	<i>y</i>	<i>z</i>
Seed: IFG, pars triangularis (L)						
LOC, superior division (L)	-	52	.004	-32	-72	+48
Frontal pole (R)	+	29	.050	+32	+58	+20
Seed: Insula (L)						
Brainstem	-	37	.036	-02	-42	-26
Seed: Insula (R)						
Primary somatosensory cortex (R)						
Supramarginal gyrus, anterior division (R)	+	43	.015	+54	-24	+52
Seed: mPFC						
LOC, inferior division (L)	+	37	.036	-40	-84	-04
Seed: Precuneus						
Occipital pole (L)	-	46	.007	-12	-94	+26
Cerebellum Crus I (R)						
Cerebellum VI (R)	-	43	.007	+28	-78	-18
Fusiform gyrus (R)						
Cerebellum VI (R)	-	29	.033	+18	-72	-18
Fusiform gyrus (R)						
Frontal pole (L)						
Paracingulate gyrus (L)	+	41	.007	-02	+56	+00
Frontal pole (R)						

Note. FDR, false discovery rate corrected *p*-value. IFG, inferior frontal gyrus. mPFC, medial prefrontal cortex. LOC, lateral occipital cortex. L = left; R = right.

Figure 2*Functional Connectivity Correlated with the Negative Sensory Processing Sensitivity Trait**Cluster*

Note. Functional connectivity correlated with the negative trait cluster include: the (a) left inferior frontal gyrus (IFG) pars triangularis and right frontal pole and left superior lateral occipital cortex; (b) left insula and brainstem; (c) right insula and right primary somatosensory cortex; (d) medial prefrontal cortex and left inferior lateral occipital cortex; and (e) precuneus and left occipital pole, right cerebellum Crus I, right cerebellum lobule VI, and left frontal pole.

Discussion

In the current study we investigated correlations between SPS+ and SPS- traits and resting-state FC, with a focus on seeds previously identified as being involved in empathic processing. As this study used correlational analyses, causal assumptions cannot be made. Therefore, the possible explanations regarding the functions of neural regions provided below are considered speculative, although they are informed by prior research (Poldrack, 2006).

The focus on empathic processing was motivated by previous research findings regarding relationships between SPS and self-reported empathy (McQuarrie et al., 2025). The majority of these results were replicated in the current study. Specifically, reporting stronger SPS+ traits predicted scoring higher on perspective-taking, empathic concern, and fantasy, and lower on personal distress; and reporting stronger SPS- traits predicted scoring higher on emotional contagion and personal distress. These results support the view that individuals with SPS perceive themselves to be highly empathic, but that the degree to which they experience personal distress while empathizing varies as a function of how strongly they express SPS+ and SPS- traits, which are linked to lower and higher risk of personal distress, respectively.

In general, the functional connectivity results support and extend the findings of Acevedo et al., (2021). We will now discuss these results as they relate to several key features of SPS:

enhanced sensory processing (specifically visual), deeper processing, heightened interoceptive and emotional processing, and problems with emotion regulation.

Enhanced Visual Processing and Deeper Processing

The mPFC is involved in a number of higher-level cognitive functions, including self- and other-related processing, empathy/social cognition, emotion regulation, and decision-making (Denny et al., 2012; Etkin et al., 2011; Lieberman et al., 2019). The variety of functions is due in part to the numerous connections between the mPFC and other regions such as the anterior cingulate cortex, insula, temporoparietal junction, and amygdala (Coley et al., 2021; Denny et al., 2012; Lieberman et al., 2019; Simon et al., 2021). In the present study, mPFC showed increased FC with the right intracalcarine cortex in those scoring high in SPS+ traits, and increased FC with LOC that was positively correlated with both SPS trait clusters (indicating that individuals with higher overall levels of SPS tend to show stronger connectivity between these regions). The intracalcarine cortex houses the primary visual cortex, and the LOC is involved in higher-order visual functions including processing of objects (Lacey et al., 2009; MacLean et al., 2023) and integrating visual information about objects and actions (Ay & Demiralp, 2024). As such, the stronger FC we observed between mPFC and these regions associated with SPS may reflect a bottom-up approach to empathy, whereby information gathered from visual stimuli influences empathic processing, self-reflective processing, and decision-making. These results are consistent with findings from a magnetoencephalography study by Hamada et al. (2022) comparing brain activity of high empathizers versus low empathizers while participants watched films of social interactions. In this study, the high empathy group had greater activity in occipitotemporal regions (including LOC) than the low empathy group when they began viewing the social interaction films. The researchers inferred

that participants with greater empathy paid more attention to the faces and bodies of characters in the films (Hamada et al., 2022). Because individuals with SPS display greater empathy, and because FC between neural regions can reflect task-based neural activity (Bressler & Menon, 2010), the stronger FC we observed between mPFC and these regions may relate to the fact that individuals with SPS pay more attention to visual stimuli (including interpersonal and contextual cues) and process these stimuli deeply to gain insight into others' feelings (Aron et al., 2012; Aron & Aron, 1997).

A complementary explanation for the increased FC between the mPFC and both the LOC and left superior parietal lobule associated with features of SPS involves the trait's link to mental imagery, which is considered to be a weak form of perception (Pearson et al., 2015). Jakobson et al. (2024) argued that individuals scoring high on SPS, who are fantasy prone and emotionally reactive, are more likely than less sensitive individuals to utilize imagery-based strategies to help them understand the thoughts and feelings of others, and to empathize with them. Both the LOC and superior parietal lobule are activated during tasks involving visual mental imagery (Lacey et al., 2009; Liu et al., 2022; Stokes et al., 2009). Therefore, the increased FC between the mPFC and these regions may reflect the frequent application of mental imagery during the deep processing that is thought to underpin heightened empathy in individuals scoring high on SPS traits.

Heightened Interoceptive and Emotional Processing and Possible Links to Distress and Emotion Dysregulation

As previously described, personal distress was the main empathy-related construct sampled by the self-report empathy measure used in the current study that varied in its relationships to SPS+ and SPS- traits. Specifically, SPS+ was associated with experiencing low

levels of personal distress, while SPS- was associated with experiencing high levels of personal distress. This suggests that previously described associations between SPS and both low tolerance to distress and emotion dysregulation (Brindle et al., 2015), may be largely accounted for by stronger expression of the SPS- trait cluster, specifically. We propose that heightened personal distress and emotion dysregulation experienced by individuals scoring high in SPS- traits when empathizing may explain, in part, a number of the rsMRI results found in the current study.

The insula is involved in many functions; of particular interest to the current study are its roles in interoception and emotion processing, which are vital to empathy (Singer et al., 2009; Uddin et al., 2017). Connectivity between the right insula and primary somatosensory cortex was associated with stronger expression of SPS- traits. A study by Straube and Miltner (2011) found increased brain activity in the right (posterior) insula and primary somatosensory cortex when participants were instructed to reflect on their own emotional experience while viewing threatening emotional pictures. Given this, the enhancement in FC we observed between these regions could suggest a neural mechanism that explains how sensitivity to unpleasant sensations in the body triggered by seeing others' suffering may be translated into increased emotional reactivity and feelings of personal distress in those scoring high on SPS-.

The insula also works in conjunction with brainstem structures to integrate emotional and sensory information and autonomic responses through afferent and efferent connections (Sklerov et al., 2019). SPS- traits were associated with reduced FC between the left insula and the brainstem. This may contribute to ineffective integration of emotional, sensory, and autonomic information in individuals scoring high on SPS-, which could play into the ease with which these individuals become distressed and overwhelmed by unpleasant sensory and emotional stimuli.

Reduced FC between the left IFG pars triangularis and LOC was associated with SPS- traits. As previously described, the LOC is involved in higher-order visual processing (Lacey et al., 2009) and the left LOC, specifically, is activated during the processing of visual information related to emotion valence (Kuniecki et al., 2018). The left IFG, in contrast, is activated during emotion regulation, potentially due to the use of inner speech to label the experienced emotion (Morawetz et al., 2016). Given these findings, the decreased FC between the left IFG and LOC related to SPS- traits may reflect reduced regulation of emotions triggered by visual stimuli. Poor emotion regulation during arousing situations could exacerbate feelings of distress experienced by those scoring high on SPS-, potentially interfering with their ability to act with compassion.

Stronger FC between the left IFG and right frontal pole was also correlated with strong expression of SPS- traits. These regions are coactivated during episodic and working memory tasks (Bludau et al., 2014). When empathizing with others in difficult circumstances, we draw on episodic memory to assist with envisioning how they might be feeling (Gaesser & Schacter, 2014). Although this can evoke feelings of concern for the other person, it can also increase feelings of personal distress (Gregory et al., 2024). Although they did not distinguish between SPS- and SPS+ trait clusters in their work, Acevedo et al. (2021) proposed that SPS may be associated with heightened episodic memory due to enhanced FC between the hippocampus and left precuneus. An additional study by Acevedo et al. (2023) found greater improvements in visual memory in high- versus low-SPS individuals after a four-week cognitive training program. We did not find links between SPS- traits and FC of the precuneus and hippocampus specifically; however, we did observe stronger FC between the precuneus seed and the left frontal pole in those scoring higher on this trait cluster. The precuneus is a major node of the default mode network, involved in self-reflective processing, rumination, and episodic memory

(Dadario & Sughrue, 2023). A recent study by Kawakami et al. (2024) found that increased FC between the precuneus and frontal pole is associated with overestimation of depression symptom severity due to greater ruminative thinking and self-reflection. This is significant as SPS- traits have been found to be positively associated with neuroticism (Attary & Ghazizadeh, 2021), which is related to ruminative thinking (Kawakami et al., 2024). Given this, the stronger FC we observed between the precuneus and frontal pole (as well as the heightened FC between the IFG and frontal pole) in those scoring higher on SPS- traits may reflect their stronger engagement in rumination, episodic memory, and other self-referential processes that could exacerbate feelings of distress.

Finally, the relationship between SPS- traits and feelings of personal distress may also be partially explained by reduced FC between the precuneus and both the left occipital pole and the right cerebellum Crus I and lobule VI. These findings are interesting given that these alterations in FC might contribute to disrupted processing of emotionally-salient stimuli (Halbertsma et al., 2020; Stoodley & Schmahmann, 2009, 2010; Van Overwalle et al., 2020), potentially leading those scoring high in SPS- traits to feel overwhelmed and distressed in tense interpersonal situations. For example, lobule VI and Crus 1 in the cerebellum have been linked with both the processing of emotionally salient information and empathy (Stoodley & Schmahmann, 2009, 2010). The reduced FC between these regions and the precuneus may reflect impaired emotional processing, emphasizing feelings of distress in individuals with high SPS- traits.

Limitations and Future Directions

Although the current study provides new information about the relationship between functional connectivity, SPS, and empathy, there are some limitations that must be addressed in future research. Participants were undergraduate psychology students, which limits the

generalizability of results. Although the current sample size was acceptable by current standards in neuroimaging research, it was not a large enough sample to find small effects. With a larger sample size, future research may benefit from incorporating covariates such as alexithymia, anxiety, or depression when investigating neural bases of SPS.

This research provides novel insights into the neural substrates underpinning the strong links that have been described between facets of SPS and empathy. We measured SPS+ and SPS- facets using averages of subscale scores across two SPS measures, as suggested in a comprehensive review on measuring SPS (Aron et al., 2012) and findings from a recent factor analysis (Jakobson et al., 2024). Recently, De Gucht et al. (2022) created a self-report measure of SPS that includes a broader range of SPS+ traits. Future research may benefit from utilizing this new measure in comparison to the combined SPS measures used in the current study.

Finally, the results provide important new information that may shed light on why scoring high on SPS- traits may increase one's vulnerability to the experience of personal distress while empathizing. In particular, strong expression of SPS- traits was linked to alterations in the FC between multiple neural regions that could contribute to emotion dysregulation. Future research should be directed at exploring why strong expression of SPS+ traits appears to offer some protection against becoming overwhelmed by these feelings.

Data Statement

The data files are available upon request from the corresponding author.

Acknowledgements

AMM was supported by a doctoral scholarship from the Natural Sciences and Engineering Council of Canada. The authors would like to thank Dr. Jennifer Kornelsen and Lydia Chu for their assistance with this study.

Author Contributions

Amanda M. McQuarrie: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Visualization, Writing – original draft, and Writing – review and editing. **Lorna S. Jakobson:** Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review and editing. **Stephen D. Smith:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Supervision, Writing – review and editing.

Informed Consent

Ethical approval was received from the university research ethics boards (protocol number HE2021-0192, approval granted February 2022, and Multisite HE2021-0192, approval granted July 2023) and the health authority research approval committee (protocol number: SH2021:201, approval granted November 2023). Participants provided informed consent prior to participation.

Funding Sources

This work was supported by grants from the Natural Sciences and Engineering Council (NSERC) of Canada [grant numbers: RGPIN-2019-05485 and RGPIN-2023-03443].

References

- Acevedo, B. P., Dattatri, N., & Marhenke, R. (2023). Sensory processing sensitivity, memory and cognitive training with neurofeedback. *Behavioural Brain Research*, 452(114601). <https://doi.org/10.1016/j.bbr.2023.114601>.
- Acevedo, B. P., Santander, T., Marhenke, R., Aron, A., & Aron, E. (2021). Sensory processing sensitivity predicts individual differences in resting-state functional connectivity associated with depth of processing. *Neuropsychobiology*, 80, 185–199. <https://doi.org/10.1159/000513527>.
- Aron, E. N., & Aron, A. (1997). Sensory-processing sensitivity and its relation to introversion and emotionality. *Journal of Personality and Social Psychology*, 73(2), 345–368. <https://doi.org/10.1037/0022-3514.73.2.345>.
- Aron, E. N., Aron, A., & Jagiellowicz, J. (2012). Sensory processing sensitivity: A review in the light of the evolution of biological responsivity. *Personality and Social Psychology Review*, 16(3), 262–282. <https://doi.org/10.1177/1088868311434213>.
- Attary, T., & Ghazizadeh, A. (2021). Localizing sensory processing sensitivity and its subdomains within its relevant trait space: A data-driven approach. *Scientific Reports*, 11(1). <https://doi.org/10.1038/s41598-021-99686-y>.
- Ay, U., & Demiralp, T. (2024). Intrinsic functional connectivity patterns of the object-selective visual areas. *Archives of Neuropsychiatry*, 62(2), 100–108. <https://doi.org/10.29399/npa.28795>.
- Biswal, B., Yetkin, F. Z., Haughton, V. M., & Hyde, J. S. (1995). Functional connectivity in the motor cortex of resting human brain using echo-planar MRI. *Journal of Magnetic Resonance in Medicine*, 34(4), 537–541. <https://doi.org/10.1002/mrm.1910340409>.

- Bludau, S., Eickhoff, S. B., Mohlberg, H., Caspers, S., Laird, A. R., Fox, P. T., Schleicher, A., Zilles, K., & Amunts, K. (2014). Cytoarchitecture, probability maps and functions of the human frontal pole. *NeuroImage*, *93*, 260–275.
<https://doi.org/10.1016/j.neuroimage.2013.05.052>.
- Bressler, S. L., & Menon, V. (2010). Large-scale brain networks in cognition: Emerging methods and principles. *Trends in Cognitive Sciences*, *14*(6), 277–290.
<https://doi.org/10.1016/j.tics.2010.04.004>.
- Brindle, K., Moulding, R., Bakker, K., & Nedeljkovic, M. (2015). Is the relationship between sensory-processing sensitivity and negative affect mediated by emotional regulation? *Australian Journal of Psychology*, *67*(4), 214–221. <https://doi.org/10.1111/ajpy.12084>.
- Coley, A. A., Padilla-Coreano, N., Patel, R., & Tye, K. M. (2021). Valence processing in the PFC: Reconciling circuit-level and systems-level views. In *International Review of Neurobiology* (Vol. 158, pp. 171–212). Academic Press Inc.
<https://doi.org/10.1016/bs.irn.2020.12.002>.
- Craik, F. I. M., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior*, *11*(6), 671–684.
[https://doi.org/10.1016/S0022-5371\(72\)80001-X](https://doi.org/10.1016/S0022-5371(72)80001-X).
- Cuff, B. M. P., Brown, S. J., Taylor, L., & Howat, D. J. (2016). Empathy: A review of the concept. *Emotion Review*, *8*(2), 144–153. <https://doi.org/10.1177/1754073914558466>.
- Dadario, N. B., & Sughrue, M. E. (2023). The functional role of the precuneus. *Brain*, *146*(9), 3598–3607. <https://doi.org/10.1093/brain/awad181>.

- Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, 44(1), 113–126.
- De Gucht, V., Woestenburg, D. H. A., & Wilderjans, T. F. (2022). The different faces of (high) sensitivity, toward a more comprehensive measurement instrument. Development and validation of the Sensory Processing Sensitivity Questionnaire (SPSQ). *Journal of Personality Assessment*, 104(6), 784–799.
<https://doi.org/10.1080/00223891.2022.2032101>.
- Denny, B. T., Kober, H., Wager, T. D., & Ochsner, K. N. (2012). A meta-analysis of functional neuroimaging studies of self-and other judgments reveals a spatial gradient for mentalizing in medial prefrontal cortex. *Journal of Cognitive Neuroscience*, 24(8), 1742–1752. https://doi.org/10.1162/jocn_a_00233.
- Eşkisü, M., Ağırkan, M., Çelik, O., Yalçın, R. Ü., & Haspolat, N. K. (2022). Do the highly sensitive people tend to have psychological problems because of low emotion regulation and dysfunctional attitudes? *Journal of Rational-Emotive and Cognitive-Behavior Therapy*, 40(4), 683–706. <https://doi.org/10.1007/s10942-021-00436-w>.
- Etkin, A., Egner, T., & Kalisch, R. (2011). Emotional processing in anterior cingulate and medial prefrontal cortex. *Trends in Cognitive Sciences*, 15(2), 85–93.
<https://doi.org/10.1016/j.tics.2010.11.004>.
- Evans, D. E., & Rothbart, M. K. (2007). Developing a model for adult temperament. *Journal of Research in Personality*, 41(4), 868–888. <https://doi.org/10.1016/j.jrp.2006.11.002>.

- Fan, Y., Duncan, N. W., de Greck, M., & Northoff, G. (2011). Is there a core neural network in empathy? An fMRI based quantitative meta-analysis. *Neuroscience and Biobehavioral Reviews*, 35(3), 903–911. <https://doi.org/10.1016/j.neubiorev.2010.10.009>.
- Gaesser, B., & Schacter, D. L. (2014). Episodic simulation and episodic memory can increase intentions to help others. *Proceedings of the National Academy of Sciences*, 111(12), 4415–4420. <https://doi.org/10.1073/pnas.1402461111>.
- Gregory, A. J. P., Bartz, J. A., O'Connor, B. B., & Sheldon, S. (2024). From memory to motivation: Probing the relationship between episodic simulation, empathy, and helping intentions. *Emotion*, 24(3), 703–717. <https://doi.org/10.1037/emo0001294>.
- Håkansson Eklund, J., & Summer Meranius, M. (2021). Toward a consensus on the nature of empathy: A review of reviews. *Patient Education and Counseling*, 104(2), 300–307. <https://doi.org/10.1016/j.pec.2020.08.022>.
- Halbertsma, H. N., Elshout, J. A., Bergsma, D. P., Norris, D. G., Cornelissen, F. W., van den Berg, A. V., & Haak, K. V. (2020). Functional connectivity of the precuneus reflects effectiveness of visual restitution training in chronic hemianopia. *NeuroImage: Clinical*, 27(102292). <https://doi.org/10.1016/j.nicl.2020.102292>.
- Hamada, M., Matsubayashi, J., Tanaka, K., Furuya, M., Matsuhashi, M., Mima, T., Fukuyama, H., & Mitani, A. (2022). People with high empathy show increased cortical activity around the left medial parieto-occipital sulcus after watching social interaction of on-screen characters. *Cerebral Cortex*, 32(17), 3581–3601. <https://doi.org/10.1093/cercor/bhab435>.
- Jakobson, L. S., McQuarrie, A. M., Van Landeghem, C., & Smith, S. D. (2024). Traits linked to sensory processing sensitivity mediate the relationship between externally oriented

thinking and fantasizing. *Frontiers in Psychology*, 15(1354120).

<https://doi.org/10.3389/fpsyg.2024.1354120>.

Jauniaux, J., Khatibi, A., Rainville, P., & Jackson, P. L. (2019). A meta-analysis of neuroimaging studies on pain empathy: Investigating the role of visual information and observers' perspective. *Social Cognitive and Affective Neuroscience*, 14(8), 789–813. <https://doi.org/10.1093/scan/nsz055>.

Jordan, M. R., Amir, D., & Bloom, P. (2016). Are empathy and concern psychologically distinct? *Emotion*, 16(8), 1107–1116. <https://doi.org/10.1037/emo0000228>.

Kawakami, S., Okada, N., Satomura, Y., Shoji, E., Mori, S., Kiyota, M., Omileke, F., Hamamoto, Y., Morita, S., Koshiyama, D., Yamagishi, M., Sakakibara, E., Koike, S., & Kasai, K. (2024). Frontal pole–precuneus connectivity is associated with a discrepancy between self-rated and observer-rated depression severity in mood disorders: a resting-state functional magnetic resonance imaging study. *Cerebral Cortex*, 34(7). <https://doi.org/10.1093/cercor/bhae284>.

Kim, S. J., Kim, S. E., Kim, H. E., Han, K., Jeong, B., Kim, J. J., Namkoong, K., & Kim, J. W. (2017). Altered functional connectivity of the default mode network in low-empathy subjects. *Yonsei Medical Journal*, 58(5), 1061–1065. <https://doi.org/10.3349/ymj.2017.58.5.1061>.

Kogler, L., Müller, V. I., Werninghausen, E., Eickhoff, S. B., & Derntl, B. (2020). Do I feel or do I know? Neuroimaging meta-analyses on the multiple facets of empathy. *Cortex*, 129, 341–355. <https://doi.org/10.1016/j.cortex.2020.04.031>.

- Kuniecki, M., Wołoszyn, K., Domagalik, A., & Pilarczyk, J. (2018). Disentangling brain activity related to the processing of emotional visual information and emotional arousal. *Brain Structure and Function*, 223(4), 1589–1597. <https://doi.org/10.1007/s00429-017-1576-y>.
- Lacey, S., Tal, N., Amedi, A., & Sathian, K. (2009). A putative model of multisensory object representation. *Brain Topography*, 21(3–4), 269–274. <https://doi.org/10.1007/s10548-009-0087-4>.
- Lee, M. H., Smyser, C. D., & Shimony, J. S. (2013). Resting-state fMRI: A review of methods and clinical applications. *American Journal of Neuroradiology*, 34(10), 1866–1872. <https://doi.org/10.3174/ajnr.A3263>.
- Li, W., Mai, X., & Liu, C. (2014). The default mode network and social understanding of others: What do brain connectivity studies tell us. *Frontiers in Human Neuroscience*, 8(74), 1–15. <https://doi.org/10.3389/fnhum.2014.00074>.
- Lieberman, M. D., Straccia, M. A., Meyer, M. L., Du, M., & Tan, K. M. (2019). Social, self, (situational), and affective processes in medial prefrontal cortex (MPFC): Causal, multivariate, and reverse inference evidence. *Neuroscience and Biobehavioral Reviews*, 99, 311–328. <https://doi.org/10.1016/j.neubiorev.2018.12.021>.
- Lionetti, F., Aron, A., Aron, E. N., Burns, G. L., Jagiellowicz, J., & Pluess, M. (2018). Dandelions, tulips and orchids: Evidence for the existence of low-sensitive, medium-sensitive and high-sensitive individuals. *Translational Psychiatry*, 8(1). <https://doi.org/10.1038/s41398-017-0090-6>.
- Liu, J., Spagna, A., & Bartolomeo, P. (2022). Hemispheric asymmetries in visual mental imagery. *Brain Structure and Function*, 227(2), 697–708. <https://doi.org/10.1007/s00429-021-02277-w>.

- MacLean, M. W., Hadid, V., Spreng, R. N., & Lepore, F. (2023). Revealing robust neural correlates of conscious and unconscious visual processing: Activation likelihood estimation meta-analyses. *NeuroImage*, 273. <https://doi.org/10.1016/j.neuroimage.2023.120088>.
- McQuarrie, A. M., Smith, S. D., & Jakobson, L. S. (2023). Alexithymia and sensory processing sensitivity account for unique variance in the prediction of emotional contagion and empathy. *Frontiers in Psychology*, 14(1072783). <https://doi.org/10.3389/fpsyg.2023.1072783>.
- McQuarrie, A. M., Smith, S. D., & Jakobson, L. S. (2025). Exploring the links between childhood emotional abuse and empathy: The mediating roles of alexithymia and sensory processing sensitivity. *Acta Psychologica*, 255(104903). <https://doi.org/10.1016/j.actpsy.2025.104903>.
- Morawetz, C., Bode, S., Baudewig, J., Jacobs, A. M., & Heekeren, H. R. (2016). Neural representation of emotion regulation goals. *Human Brain Mapping*, 37(2), 600–620. <https://doi.org/10.1002/hbm.23053>.
- Pearson, J., Naselaris, T., Holmes, E. A., & Kosslyn, S. M. (2015). Mental imagery: Functional mechanisms and clinical applications. *Trends in Cognitive Sciences*, 19(10), 590–602. <https://doi.org/10.1016/j.tics.2015.08.003>.
- Poldrack, R. A. (2006). Can cognitive processes be inferred from neuroimaging data? *Trends in Cognitive Sciences*, 10(2), 59–63. <https://doi.org/10.1016/j.tics.2005.12.004>.
- Simon, J., Rudebeck, P. H., & Rich, E. L. (2021). From affective to cognitive processing: Functional organization of the medial frontal cortex. In *International Review of*

- Neurobiology* (Vol. 158, pp. 1–28). Academic Press Inc.
<https://doi.org/10.1016/bs.irn.2020.11.011>.
- Singer, T., Critchley, H. D., & Preuschoff, K. (2009). A common role of insula in feelings, empathy and uncertainty. *Trends in Cognitive Sciences*, 13(8), 334–340.
<https://doi.org/10.1016/j.tics.2009.05.001>.
- Sklerov, M., Dayan, E., & Browner, N. (2019). Functional neuroimaging of the central autonomic network: Recent developments and clinical implications. *Clinical Autonomic Research*, 29(6), 555–566. <https://doi.org/10.1007/s10286-018-0577-0>.
- Stokes, M., Thompson, R., Cusack, R., & Duncan, J. (2009). Top-down activation of shape-specific population codes in visual cortex during mental imagery. *The Journal of Neuroscience*, 29(5), 1565–1572. <https://doi.org/10.1523/JNEUROSCI.4657-08.2009>.
- Stoodley, C. J., & Schmahmann, J. D. (2009). Functional topography in the human cerebellum: A meta-analysis of neuroimaging studies. *NeuroImage*, 44(2), 489–501.
<https://doi.org/10.1016/j.neuroimage.2008.08.039>.
- Stoodley, C. J., & Schmahmann, J. D. (2010). Evidence for topographic organization in the cerebellum of motor control versus cognitive and affective processing. *Cortex*, 46(7), 831–844. <https://doi.org/10.1016/j.cortex.2009.11.008>.
- Straube, T., & Miltner, W. H. R. (2011). Attention to aversive emotion and specific activation of the right insula and right somatosensory cortex. *NeuroImage*, 54(3), 2534–2538.
<https://doi.org/10.1016/j.neuroimage.2010.10.010>.
- Takeuchi, H., Taki, Y., Nouchi, R., Sekiguchi, A., Hashizume, H., Sassa, Y., Kotozaki, Y., Miyauchi, C. M., Yokoyama, R., Iizuka, K., Nakagawa, S., Nagase, T., Kunitoki, K., & Kawashima, R. (2014). Association between resting-state functional connectivity and

- empathizing/systemizing. *NeuroImage*, 99, 312–322.
<https://doi.org/10.1016/j.neuroimage.2014.05.031>.
- 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>.
- Timmers, I., Park, A. L., Fischer, M. D., Kronman, C. A., Heathcote, L. C., Hernandez, J. M., & Simons, L. E. (2018). Is empathy for pain unique in its neural correlates? A meta-analysis of neuroimaging studies of empathy. *Frontiers in Behavioral Neuroscience*, 12. <https://doi.org/10.3389/fnbeh.2018.00289>.
- Tremblay, M.-P. B., Deschamps, I., Tousignant, B., & Jackson, P. L. (2022). Functional connectivity patterns of trait empathy are associated with age. *Brain and Cognition*, 159. <https://doi.org/10.1016/j.bandc.2022.105859>.
- Uddin, L. Q., Nomi, J. S., Hébert-Seropian, B., Ghaziri, J., & Boucher, O. (2017). Structure and function of the human insula. *Journal of Clinical Neurophysiology*, 34(4), 300–306. <https://doi.org/10.1097/WNP.0000000000000377>.
- Van Overwalle, F., Manto, M., Cattaneo, Z., Clausi, S., Ferrari, C., Gabrieli, J. D. E., Guell, X., Heleven, E., Lupo, M., Ma, Q., Michelutti, M., Olivito, G., Pu, M., Rice, L. C., Schmahmann, J. D., Siciliano, L., Sokolov, A. A., Stoodley, C. J., van Dun, K., ... Leggio, M. (2020). Consensus paper: Cerebellum and social cognition. *Cerebellum*, 19(6), 833–868. <https://doi.org/10.1007/s12311-020-01155-1>.
- Whitfield-Gabrieli, S., & Nieto-Castanon, A. (2012). Conn: A functional connectivity toolbox for correlated and anticorrelated brain networks. *Brain Connectivity*, 2(3), 125–141. <https://doi.org/10.1089/brain.2012.0073>.

Zhou, L., Xu, T., & Feng, T. (2025). The hippocampus–IPL connectivity links to ADHD traits through sensory processing sensitivity. *Cerebral Cortex*, 35.

<https://doi.org/10.1093/cercor/bhaf063>.

Chapter 4: Associations between Sensory Processing Sensitivity and Neural Activity**During an Emotional Contagion Task**

The following study has been formatted for submission to *Neuropsychologia* in accordance with their guidelines for authors. Minor adjustments have been made to the text to allow for consistent formatting within this manuscript.

Abstract

Sensory processing sensitivity (SPS) is a trait associated with strong emotional contagion and empathy. It has positive (SPS+) and negative (SPS-) features. We used functional magnetic resonance imaging to investigate how these features relate to neural activity during emotional contagion. Scans were performed as 27 participants ($M_{age} = 21.07$ years, 18 women) viewed amusing, frightening, mixed-valence, and neutral films. During viewing of amusing (vs. mixed-valence) films both features were linked to increased activity in visual processing areas and in the mirror neuron system, and SPS+ was linked to increased activity in the precuneus. In contrast, when viewing frightening (vs. neutral) films there was less activation in the middle temporal gyrus and left cerebellar lobule VI, which are involved in theory of mind and emotion processing, respectively. As SPS- traits are linked to experiencing strong feelings of personal distress when seeing others in disturbing situations, this finding may reflect a shift to self-focused rather than other-focused processing. In contrast, as scoring high on SPS+ traits offers protection from personal distress, the fact that SPS+ traits were related to lower activity in the precuneus when watching frightening (vs. neutral) films may reflect the operation of a protective mechanism that tamps down on self-reflection in order to support acting with compassion. SPS+ traits were also related to reduced activity in language-related areas when viewing mixed-valence (vs. neutral) films. This may suggest that those scoring high (vs. low) on SPS+ rely less on language-based processes to help them interpret others' mixed emotions.

Keywords: sensory processing sensitivity, empathy, emotional contagion, functional magnetic resonance imaging

Highlights

- Neural activity varies across different types of emotional contagion.
- Sensory processing sensitivity is related to stronger contagion.
- Contagion-related activity was linked to positive and negative SPS trait clusters.
- Both traits were linked to activation in visual areas and the mirror neuron system.
- Activity in other areas may vary with susceptibility to feelings of distress.

Introduction

Empathy is the process of identifying and sharing the emotion of another person, while still recognizing that the emotion belongs to the other person (Cuff et al., 2016). One element of empathy that is critical to the current study is emotional contagion. Emotional contagion forms a building block for empathy and is defined as “catching” the same affective and physiological state as the other person (Hatfield et al., 1993; Prochazkova & Kret, 2017). There are large variations in levels of empathy and emotional contagion in the general population related to personality differences, environmental factors, and affective states. The focus of the current study is on the personality trait of sensory processing sensitivity (SPS), which is characterized by heightened sensitivity to environmental stimuli, emotional reactivity, and deeper processing of information (Aron & Aron, 1997; Aron et al., 2012).

Positive associations have been observed between SPS and both empathy and emotional contagion (McQuarrie et al., 2023). For example, in a behavioural task involving the viewing of affective films, individuals scoring higher on SPS felt the main emotion elicited by the film content more strongly, experienced a wider range of emotions, and were more confident that the emotions they were feeling matched those of the empathizing target compared to those scoring low on SPS. Additionally, SPS positively predicted empathy scores as measured through self-report (McQuarrie et al., 2023).

A recent development in the field of SPS research is the identification of two specific trait clusters within the overarching concept of SPS (Attary & Ghazizadeh, 2021; De Gucht et al., 2022). The positive trait cluster (SPS+) reflects the aspects of SPS related to sensitivity to the aesthetic environment and to subtle internal and external stimuli, and the propensity to engage in spontaneous cognitive processes like imagery. The negative trait cluster (SPS-) includes strong

emotional and physiological reactivity as well as sensitivity to stimuli or situations perceived to be unpleasant (De Gucht et al., 2022; Jakobson et al., 2024). These two trait clusters have distinct relationships to other personality traits and psychological constructs. For example, SPS+ traits are associated with the Big Five personality traits of openness and conscientiousness, whereas SPS- traits are associated with neuroticism, anxiety, depression, and alexithymia (Attary & Ghazizadeh, 2021).

Although both trait clusters are positively associated with a number of empathy-related variables (e.g., perspective-taking, feelings of concern towards another), they differ in their relationships to emotional contagion and the self-oriented emotional reactions experienced by the empathizer (McQuarrie et al., 2025). More specifically, strong SPS- traits predict experiencing stronger contagion when processing negatively valenced films and reporting more personal distress while empathizing, whereas SPS+ traits predict experiencing stronger contagion when processing positively valenced films and offer some protection against feelings of personal distress (McQuarrie et al., 2025). This suggests that the link that Laros-van Gorkom et al. (2025) observed between the overarching trait of SPS and the experience of general distress (not specific to empathic situations) may have been largely attributable to SPS- traits. The authors proposed that distress may arise in individuals with SPS if they are less likely to use emotional disconnection to protect themselves against becoming overwhelmed by others' emotions. Based on the findings of McQuarrie et al. (2025), those most likely to fall in this category are individuals reporting strong SPS- traits, who experience stronger emotional contagion when seeing others in distress and may, as a result, find it more difficult to self-regulate.

The purpose of the current study was to explore the neural correlates of the relationships between SPS and emotional contagion. According to the Neurocognitive Model of Emotional Contagion (Prochazkova and Kret, 2017), emotional contagion is the product of autonomic mimicry and motor mimicry. Autonomic mimicry involves the limbic system and hypothalamic-pituitary-adrenal axis, whereas motor mimicry involves the mirror neuron system, which includes the inferior frontal gyrus (IFG), inferior parietal lobule (IPL), and superior temporal sulcus (Iacoboni, 2009). Prochazkova and Kret (2017) proposed that the anterior insula connects activity within emotion regions and the mirror neuron system to produce this shared experience. Indeed, emotional contagion experienced during the viewing of emotional facial expressions has been associated with increased activity in the IFG (Harada et al., 2016; Hsu et al., 2022), supramarginal gyrus, supplementary motor area, precentral gyrus, IPL, hippocampus and amygdala (Hsu et al., 2022). In addition to the regions involved in emotional contagion, the anterior insula, mid- and anterior cingulate cortex, and medial prefrontal cortex are involved in the overarching process of empathy (Fallon et al., 2020; Fan et al., 2011; Kogler et al., 2020; Timmers et al., 2018).

The neural regions associated with empathy and emotional contagion partially overlap with those associated with SPS. For example, previous neuroimaging studies of SPS have identified stronger neural activity in the IFG and anterior insula (Acevedo et al., 2014, 2018). The viewing of emotional facial expressions (happy and sad) was found to produce activity positively associated with SPS in regions involved in emotion recognition (middle temporal gyrus), decision making (dorsolateral prefrontal cortex), attention (cingulate cortex), and action planning (premotor area; Acevedo et al., 2014). SPS has also been associated with increased brain activity in visual attention areas, potentially indicating that highly sensitive individuals are

attending to visual information more carefully and processing the information more deeply than less sensitive individuals (Jagiellowicz et al., 2011). One limitation of this earlier work, however, was that it treated SPS as a single construct rather than examining SPS+ and SPS- separately.

In the current study, we used functional magnetic resonance imaging (fMRI) to explore individual differences in neural activity evoked during an emotional contagion behavioural task that was related to SPS. The experiment had two specific objectives: 1) to contrast neural activity during the emotional contagion task across various film types; and 2) to determine whether neural activity across different film contrasts was associated with how strongly SPS+ and/or SPS- traits are expressed. We hypothesized that both SPS trait clusters would be associated with greater activity in visual and attention processing regions. As SPS is associated with stronger self-reported empathy and emotional contagion, we also expected to see a positive relationship between both of the SPS trait clusters and neural activity in regions associated with empathy and emotional contagion (e.g., IFG, IPL, medial prefrontal cortex, anterior insula, and cingulate cortex). However, SPS+ and SPS- trait clusters were expected to show different relationships to patterns of neural activity in regions implicated in emotion processing and regulation, due to their contrasting relationships with experiences of personal distress.

Methods

Participants

Participants were recruited from a university undergraduate psychology class. A total of 186 individuals (113 men, 73 women) completed self-report measures online. From this initial sample, 30 eligible individuals (11 men, 19 women) were recruited to complete the fMRI scanning session. Inclusion criteria included passing an MRI screening questionnaire and having

normal or corrected-to-normal vision. Exclusion criteria included self-reported history of neurological disorder or significant head injury, non-Canadian citizenship (due to the potential cultural differences in the emotional contagion experience), and inability to understand English (as all instructions were provided in English). Participants received course credit for a research participation option, monetary compensation to cover the cost of transportation and parking at the scanning location, and the option to receive a copy of their structural brain scan.

Measures

Two self-report measures were administered to collect data on SPS, as recommended by Aron et al. (2012): the Highly Sensitive Person Scale (HSPS; Aron & Aron, 1997) and the Orienting Sensitivity subscale of the Adult Temperament Questionnaire (OS; Evans & Rothbart, 2007). The HSPS has 27 items divided into three subscales: low sensory threshold (6 items), measuring one's discomfort from sensory stimulation; ease of excitation (12 items), measuring the extent to which one becomes overwhelmed by external stimuli; and aesthetic sensitivity (7 items), measuring sensitivity to subtle and aesthetic stimuli. Each item of the HSPS is measured on a seven-option Likert scale from 1 (*not at all*) to 7 (*extremely*). Each subscale is computed by calculating the mean. The OS contains three 5-item subscales that overall measure sensitivity to subtle/low intensity neutral stimuli, subtle/low intensity affective stimuli, and spontaneous cognitive processes (e.g., imagery, dreaming). Each item is measured on a seven-option Likert scale from 1 (*extremely untrue*) to 7 (*extremely true*) with a X (*not applicable*) option. Subscale scores for the HSPS and the OS are computed by calculating the mean.

As described above, recent evidence points to the benefit of dividing the overarching construct of SPS into two components. In the current study, an SPS+ composite score was calculated by finding the mean of the aesthetic sensitivity subscale of the HSPS and the three OS

subscales. An SPS- composite score was calculated by finding the mean of the low sensory threshold and ease of excitation subscales of the HSPS. Each composite score possessed good internal consistency, with Cronbach's alpha values of 0.83 for the SPS+ score and 0.89 for the SPS- score.

Scanning Parameters

MRI scans were completed using a 3 Tesla Siemens Verio MRI scanner (Siemens Healthineers, Erlangen, Germany). Participants first completed a 5-minute structural scan and an 11-minute resting-state functional scan (not included in the current study). Three-dimensional high-resolution T1-weighted gradient-echo anatomical MRI structural scans were collected with a magnetization-prepared rapid gradient-echo (MP-RAGE) sequence. Structural scans used the following parameters: slices of 1-mm thickness, 0 gap, TR/TE = 2400/2.26 ms, flip angle = 8°, 1 x 1 mm in-plane resolution 1 x 1 mm, 256 x 256 matrix, bandwidth = 200 Hz/pixel, and with a field of view of 24 cm.

The task-based fMRI scanning consisted of three fMRI runs, each lasting 8 minutes and 50 seconds. For these scans, a whole-brain echo-planar imaging sequence was used with the following parameters: slice thickness of 3-mm, 0 gap, TR/TE = 3000/30msec, flip angle 90°, 64 x 64 matrix, also with a field of view of 24 cm.

General Procedure

Ethical approval was received by our institutional research ethics board. Participants first provided informed consent and then completed self-report measures of SPS and an MRI screening questionnaire online, as well as additional self-report measures not included in the present study. A subset of participants who were eligible to complete the scanning session (based on the MRI screening questionnaire) were then contacted via phone to book a scan.

During the task, participants watched affective film clips chosen from collections by Samson et al. (2016) and the E-MOVIES database (Maffei & Angrilli, 2019). The clips had been used in a previous study that included a separate sample of 190 university students (McQuarrie et al., 2025). Ratings obtained from that sample supported classification of the films into four subtypes: Amusing, Frightening, Mixed-valence, and Neutral. An example of an Amusing clip included a baby dancing; an example of a Frightening clip showed a bull attacking a person. The Mixed-valence clips depicted situations where an individual was involved in a silly misunderstanding or made a mistake that would not cause serious physical, emotional or social harm (e.g., someone walking into a closed glass door) and were reported by participants to elicit both amusement and embarrassment. The Neutral films were reported to be uninteresting (e.g., watching someone knit).

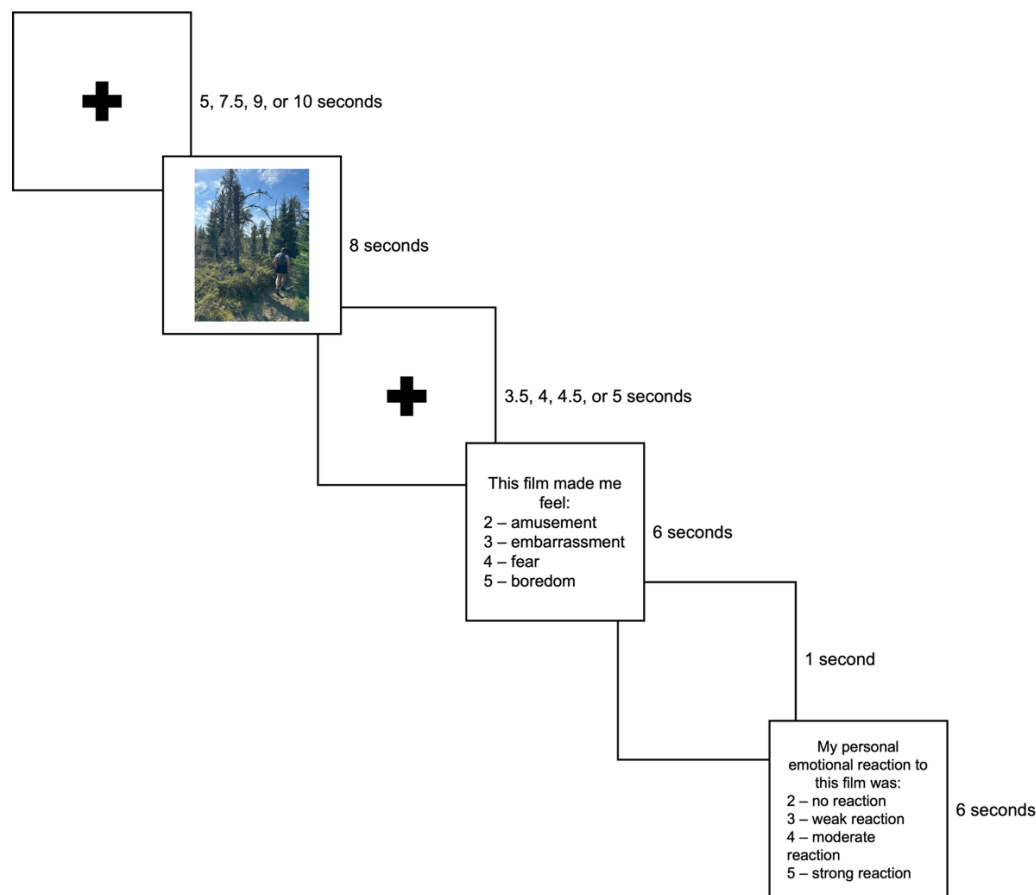
In the current study, participants watched 12 film clips from each of the Amusing, Frightening, Mixed-valence and Neutral categories. Each clip was approximately eight seconds in length and presented without sound. Films were presented in a pseudorandom order that alternated film types and did not allow for films of the same type to be shown back-to-back. The task-based functional scan was broken into three runs, with four film clips of each type shown in each run.

The procedure for this task-based scanning session is presented in Figure 1. Participants first viewed a fixation cross presented for 5, 7.5, 9, or 10 seconds, then watched an affective film clip. Another fixation cross was then presented for 3.5, 4, 4.5, or 5 seconds to allow time for scanning to occur without new stimuli appearing. Participants then answered two questions: “the film made me feel” (amusement, embarrassment, fear or boredom); and “my personal emotional reaction to this film was” (no reaction, weak reaction, moderate reaction, or strong reaction).

These questions addressed the valence and arousal associated with emotional contagion that was experienced. Responses were collected using a four-option button-press device attached to each participants' right hand. Each question was presented for six seconds, with a one second blank screen shown between questions. This procedure was then repeated.

Figure 1

Design of the Emotional Contagion Paradigm



Note. Example of the emotional contagion task. Participants viewed an affective film clip then answered two questions about their reaction to the film clip. This paradigm was repeated for 48 film clips divided into three runs.

Analyses

Data from the SPS self-report measures were cleaned by checking for duplicates (with the first entry retained for duplicate entries), outliers, and abnormal participant response patterns. Missing data were checked to determine if missing at random using the Little's Missing Completely at Random test. An expectation-maximization algorithm was used to estimate missing values. Descriptive statistics were calculated for the two SPS composite scores.

Structural and functional neuroimaging files were analysed using SPM version 12 (<http://www.fil.ion.ucl.ac.uk/spm>). Structural and functional MRI data were centred to (0,0,0) coordinates, segmented into white and grey matter and cerebrospinal fluid, and normalized to a standard brain atlas with Montreal Neurological Institute coordinates. Head motion artifacts were regressed out (three translation and three rotation parameters). Preprocessing was completed with the functional data including slice time correction and spatial smoothing using an 8mm Gaussian filter. Structural and functional images were co-registered.

Second-level analyses of the functional data involved comparing neural activity for each film type (i.e., Amusing, Frightening, Mixed-valence, or Neutral) using *t* tests. The following contrasts were defined: Amusing versus Neutral; Frightening versus Neutral; Mixed-valence versus Neutral; Amusing versus Frightening; Amusing versus Mixed-valence; and Frightening versus Mixed-valence. Differences in neural activity for each contrast were calculated with a voxel threshold of $p < .001$ (uncorrected) and a cluster threshold of $p < .05$ (FWE-corrected).

The two SPS composite scores were then introduced as covariates for each contrast using a regression design. Positive and negative associations between neural activity and each composite score were identified with a voxel threshold of $p < .005$ (uncorrected) and a cluster threshold of minimum of 100 voxels. This more arbitrary cluster threshold was chosen with

caution but to allow effects to be identified in this exploratory study. Neural regions representing significant clusters were identified using the automated anatomical labelling atlas 3 (Rolls et al., 2020).

Results

Self-Report and Behavioural Data

Three participants were excluded due to excessive head movement, leaving a final sample of 27 (18 women, 9 men). The mean age and the SPS+ and SPS- composite scores for these individuals are presented in Table 1. These values were comparable to those seen in the full sample who had completed the screening measures ($N = 172$ after exclusions) and showed similar distribution. These observations suggest that the 27 individuals whose imaging data were analyzed were representative of sample from which they were recruited.

Table 1

Demographic Information of Participants and Descriptive Statistics for Sensory Processing

Sensitivity Trait Components

	Mean	<i>SD</i>	Range
Age (years)	21.07	3.76	18-34
SPS+	4.95	0.62	3.49-6.03
SPS-	3.96	1.00	2.08-5.96

Note. SPS+, positive trait component of sensory processing sensitivity; SPS-, negative trait component of sensory processing sensitivity; *SD*, standard deviation. $N = 27$.

The button-press response device malfunctioned during testing for some participants, and there were also a number of missing responses. Therefore, subjective ratings of the emotional contagion elicited by each film clip were only available for 17 individuals. Examination of

response patterns confirmed that, as expected, these participants were most likely to report feeling amusement, fear, embarrassment, and boredom when watching Amusing, Frightening, Mixed-valence, and Neutral clips, respectively.

A repeated-measures analysis of variance comparing ratings made by the 17 individuals with complete data of the arousal associated with contagion experienced across film types was significant, $F_{(3, 48)} = 21.18$, $p < .001$, $\eta_p^2 = .57$. Planned comparisons confirmed that the mean arousal ratings for the Amusing ($M = 3.35$, $SD = 0.09$), Frightening ($M = 3.37$, $SD = 0.12$), and Mixed-valence films ($M = 3.53$, $SD = 0.10$) did not differ from each other but were significantly higher than arousal ratings for the Neutral films ($M = 2.73$, $SD = 0.14$), $p < .005$ in all cases.

The results reported above closely match those obtained from a separate, large sample who had been tested with the same stimuli (McQuarrie et al., 2025) and support the view that, rather than simply experiencing *non-specific* increases in arousal when watching the valenced films employed here, participants experienced emotional contagion that was consistent with specific cues produced by the characters depicted. We did not analyze relationships between the arousal or valence ratings and the fMRI data due to low power. However, based on the findings reported here, we feel confident that the planned contrasts described below, which utilized data from the full sample of 27 participants, accurately reflect activations associated with specific types of emotional contagion experienced when viewing our stimuli.

Neuroimaging Data

Whole brain analyses of neural activity across the different contrasts are shown in Table 2. Contrasting neural activity for the Amusing, Frightening, and Mixed-Valence films with that seen with Neutral films identified increased activity in the left middle occipital gyrus, right paracentral lobule, and left putamen, respectively. Contrasting Amusing versus Frightening films

identified increased activity in the right fusiform gyrus and decreased activity in the left dorsolateral superior frontal gyrus. Finally, contrasting Amusing versus Mixed-valence films identified increased activity in the left fusiform gyrus, right precuneus (two separate clusters), and right lingual gyrus, and decreased activity in left dorsolateral superior frontal gyrus.

Table 2

Main Effects Comparing Neural Activity for Each Film Type

Brain region (hemisphere)	Peak T	Peak coordinates			Cluster size	Cluster <i>p</i> -value
		<i>x</i>	<i>y</i>	<i>z</i>		
Amusing vs. Neutral Films						
Middle occipital gyrus (L)	5.22	-16	-98	4	274	.019
Frightening vs. Neutral Films						
Paracentral lobule (R)	4.69	2	-22	76	365	.003
Mixed-valence vs. Neutral Films						
Putamen (L)	5.39	-28	-4	4	592	.000
Amusing vs. Frightening Films						
Fusiform gyrus (R)	4.15	28	-62	-12	309	.018
Superior frontal gyrus, dorsolateral (L)	-5.43	-14	18	56	752	.000
Amusing vs. Mixed-valence Films						
Fusiform gyrus (L)	5.61	-38	-60	-18	335	.004
Precuneus (R)	4.91	20	-72	42	1200	.000
Precuneus (R)	4.84	8	-50	62	366	.002
Lingual gyrus (R)	4.83	14	-56	6	439	.001
Superior frontal gyrus, dorsolateral (L)	-5.13	-12	18	58	703	.000

Note. Voxel threshold set at $p < .001$ (uncorrected). Cluster-level *p*-value is FWE-corrected.

Table 3 and Figure 2 present significant clusters of neural activity with SPS+ entered as covariate. When contrasting Amusing versus Neutral films, activity in the left cerebellar lobule VI was negatively associated with SPS+ traits. SPS+ was also negatively associated with activity in the right precuneus and left cuneus for the Frightening versus Neutral films, and with the left thalamus, rolandic operculum, supramarginal gyrus, and superior temporal gyrus for the Mixed-valence versus Neutral films. Finally, when contrasting neural activity for the Amusing versus

Mixed-valence films, SPS+ traits were positively associated with activity in the right inferior temporal gyrus, right IFG (pars opercularis), right supramarginal gyrus, left precuneus, left inferior parietal gyrus, and left precentral gyrus. The Amusing versus Frightening and Frightening versus Mixed-valence contrasts did not produce significant clusters of activity associated with SPS+ traits.

Table 3

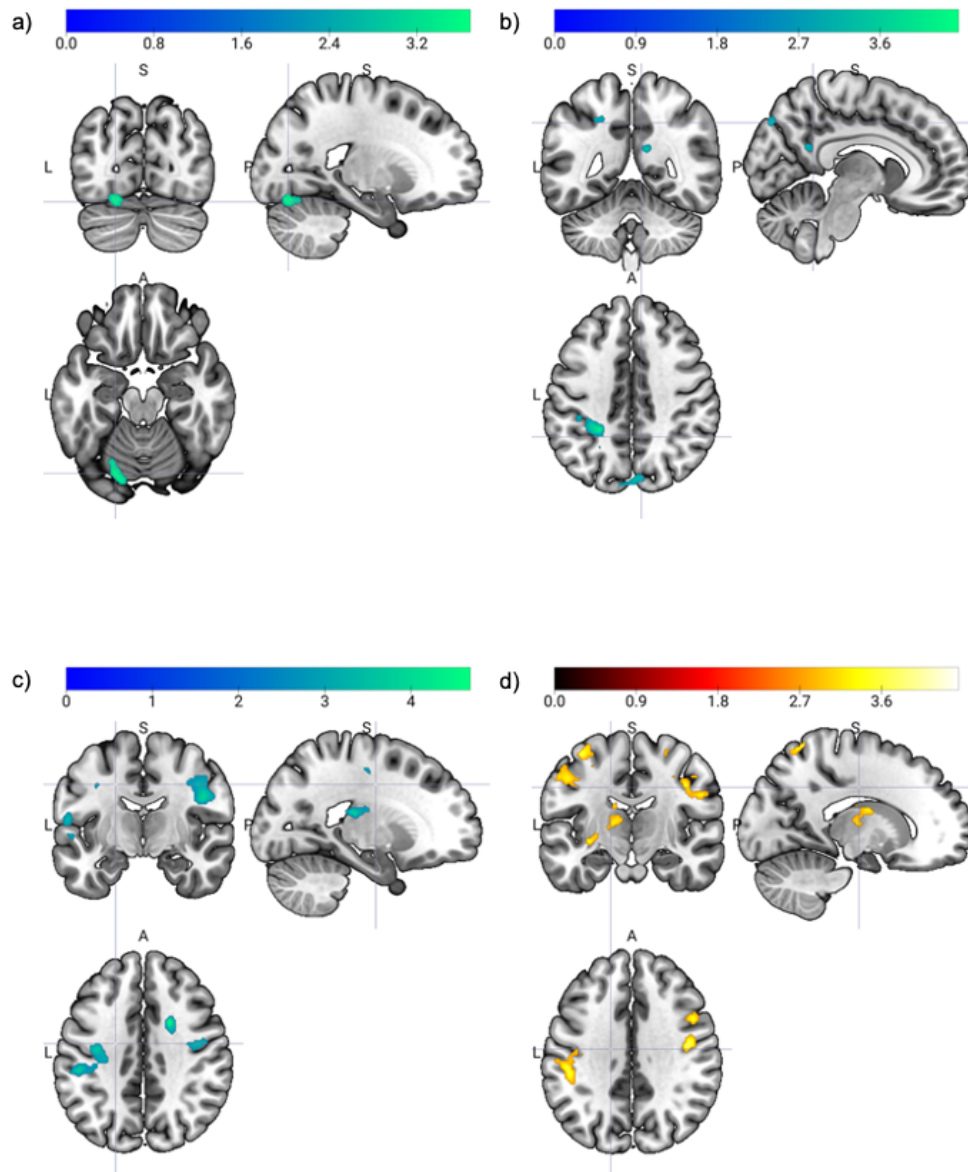
Neural Activity Associated with Sensory Processing Sensitivity Positive Traits

Brain region (hemisphere)	Peak T	Peak coordinates			Cluster size	Cluster <i>p</i> -value
		<i>x</i>	<i>y</i>	<i>z</i>		
Amusing vs. Neutral Films						
Cerebellar lobule VI (L)	-3.71	-20	-78	-18	133	.089
Frightening vs. Neutral Films						
Precuneus (R)	-3.79	12	-48	20	140	.067
Cuneus (L)	-3.74	-10	-86	38	137	.069
Mixed-valence vs. Neutral Films						
Thalamus (L)	-4.40	-18	-26	14	131	.093
Rolandic operculum (L)	-4.22	-52	-2	10	258	.024
Supramarginal gyrus (L)	-4.18	-50	-30	36	397	.007
Superior temporal gyrus (L)	-3.61	-48	-32	10	103	.133
Amusing vs. Mixed-valence Films						
Inferior temporal gyrus (R)	4.59	52	-56	-16	144	.053
Inferior frontal gyrus pars opercularis (R)	4.54	48	6	26	1537	.000
Precuneus (L)	4.40	-16	-58	68	154	.046
Inferior parietal lobule (L)	4.13	-54	-24	50	408	.003
Precentral gyrus (L)	4.07	-40	-10	60	246	.015
Supramarginal gyrus (R)	3.80	46	-38	44	249	.014

Note. Cluster-level *p*-values are uncorrected. Voxel threshold set at $p < .005$ (uncorrected).

Figure 2

Clusters of Neural Activation Associated with Sensory Processing Sensitivity Positive Traits



Note. Clusters of neural activity significantly associated with sensory processing sensitivity positive traits for a) Amusing versus Neutral contrast, b) Frightening versus Neutral contrast, c) Mixed-valence versus Neutral contrast, and c) Amusing versus Mixed-valence contrast.

Abbreviations: L, left; R, right; A, anterior; P, posterior; S; superior.

Table 4 and Figure 3 present significant clusters of neural activity with SPS- traits entered as a covariate. When contrasting Frightening versus Neutral films, activity within the left cerebellar lobule VI and bilateral middle temporal gyrus were negatively associated with SPS-. Activity within the left cerebellar lobules IV and V, right precentral gyrus, and right middle frontal gyrus were positively associated with SPS- in the Amusing versus Mixed-valence contrast. No significant clusters emerged for the other contrasts (i.e., Amusing versus Neutral, Mixed-valence versus Neutral, Amusing versus Frightening, and Frightening versus Mixed-valence).

Table 4

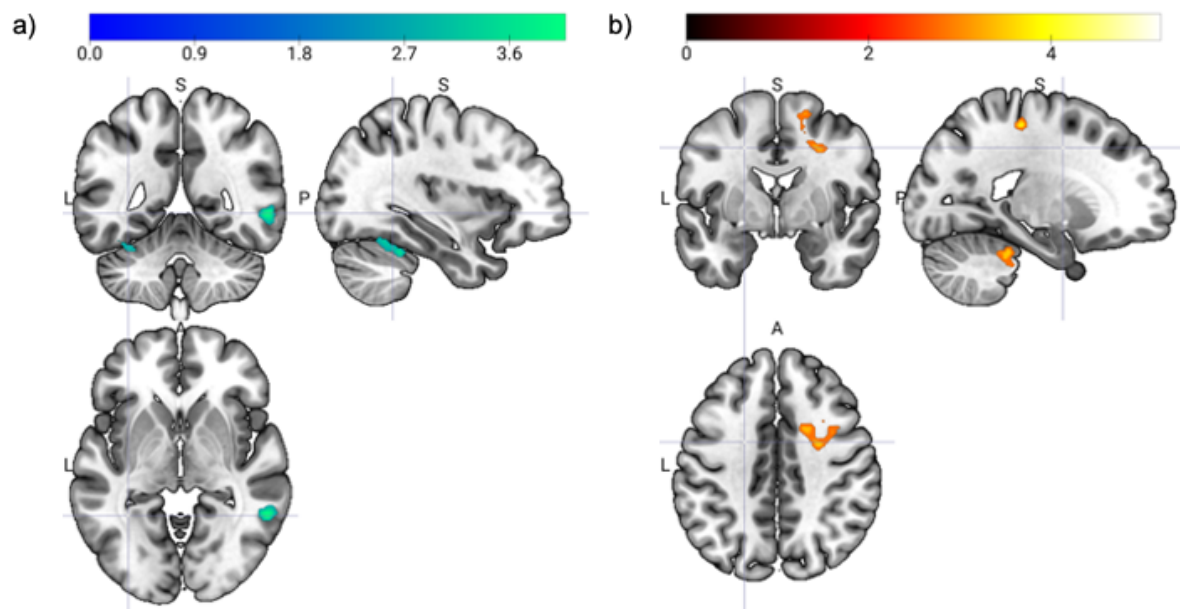
Neural Activity Associated with Sensory Processing Sensitivity Negative Traits

Brain region (hemisphere)	Peak T	Peak coordinates			Cluster size	Cluster <i>p</i> -value
		<i>x</i>	<i>y</i>	<i>z</i>		
Frightening vs. Neutral Films						
Cerebellar lobule VI (L)	-4.28	-32	-44	-28	222	.026
Middle temporal gyrus (R)	-4.14	56	-48	-2	118	.090
Middle temporal gyrus (L)	-3.92	-50	-68	10	126	.081
Amusing vs. Mixed-valence Films						
Cerebellar lobules IV and V (L)	5.33	-16	-38	-24	218	.021
Precentral gyrus (R)	4.08	32	-14	62	232	.018
Middle frontal gyrus (R)	3.54	22	14	52	103	.096

Note. Cluster-level *p*-values are uncorrected. Voxel threshold set at $p < .005$ (uncorrected).

Figure 3

Clusters of Neural Activation Associated with Sensory Processing Sensitivity Negative Traits



Note. Clusters of neural activity significantly associated with sensory processing sensitivity negative traits for a) Frightening versus Neutral contrast, and b) Amusing versus Mixed-valence contrast. Abbreviations: L, left; R, right; A, anterior; P, posterior; S, superior.

Discussion

The following sections provide possible explanations for the patterns of results identified in this study. While informed by prior research, these explanations are considered speculative and require further study (Poldrack, 2006).

Patterns of Brain Activity During Different Types of Emotional Contagion

The first objective of the present study was to compare neural activity presumed to be related to emotional contagion triggered by viewing different film types. Watching amusing

films produced greater activity compared to all other film types in regions involved in visual processing. More specifically, greater activity was identified in the left middle occipital gyrus, bilateral fusiform gyrus, and right lingual gyrus, all of which are involved in higher-level visual processing of faces and the location of objects in space (Palejwala et al., 2021; Saj et al., 2014; Uono et al., 2017). Greater activity during the viewing of Amusing (versus Mixed-valence) films was also identified in the precuneus, which is involved in self-referential processing as part of the default mode network (DMN), and is often activated during empathy tasks (Dadario & Sughrue, 2023; Kogler et al., 2020). Viewing Amusing films also produced lower levels of activity in the left dorsolateral superior frontal gyrus than that seen during viewing of Frightening or Mixed-valence films. The superior frontal gyrus is part of the dorsolateral prefrontal cortex, which is involved in a number of executive functions (Jung et al., 2022). In summary, these findings are consistent with the idea that, when experiencing positive emotional contagion (e.g., feelings of amusement), individuals generally engage in enhanced processing of the people and setting (context), as well as self-reflection. Additionally, there appears to be less top-down executive control over emotions than when experiencing negative forms of emotional contagion.

In contrast to the above, viewing Frightening and Mixed-valence films were associated with greater activity than that seen when viewing Neutral films in regions involved in motor imagery, specifically the left putamen and right paracentral lobule (Lorey et al., 2011; Sacheli et al., 2017). Interestingly, Shafir et al. (2013) found that engaging in motor imagery of sad movements enhanced subjective feelings of sadness, similar to when participants executed or observed sad motor movements. Imagery of happy movements did not enhance positive feelings (Shafir et al., 2013). This might suggest that, when experiencing negative forms of emotional

contagion (e.g., feelings of fear or embarrassment), motor imagery enhances the sharing of the same affective state as the main character in the films.

Exploring Individual Differences in Emotional Contagion Neural Activity

The second objective of this study was to distinguish individual differences in patterns of brain activation seen during our emotion contagion task that were related to the positive and negative facets of SPS. We originally hypothesized that both SPS trait components would be associated with increased activity in neural regions involved in empathy and emotional contagion. While this hypothesis was corroborated by certain findings (e.g., associations between SPS+ and increased activity in the IFG, IPL, and supramarginal gyrus, and greater activity in the precentral gyrus associated with both trait clusters), SPS was also associated with altered neural activity outside of these areas during our emotional contagion task. Possible interpretations of these results will now be explored in more detail.

Links Between SPS and Activity Specific to Contagious Amusement

Our findings provide new insights into individual differences in visual processing seen when experiencing positive emotional contagion, such as feelings of amusement. We observed that strong expression of SPS+ traits (which include heightened sensitivity to pleasant stimuli; De Gucht et al., 2022) was associated with increased activity in the right inferior temporal gyrus during the viewing of Amusing versus Mixed-valence films. This area is part of the ventral visual pathway, involved in higher-level visual processing, such as recognition of objects and faces (Lin et al., 2020). Additionally, SPS- traits were associated with greater activity in the right middle frontal gyrus and left cerebellar lobules IV and V during viewing of Amusing versus Mixed-valence films. Both cerebellar lobule V and the middle frontal gyrus have been proposed to be involved in attention, specifically as part of the ventral attention network (Corbetta et al.,

2008; Yeo et al., 2011; Van Overwalle et al., 2020). As the ventral attention network identifies salient stimuli in the environment (Fox et al., 2006), the positive relationship with SPS- traits we observed may reflect strong sensitivity to highly salient cues.

Several findings suggested that individual differences in SPS might also be associated with increased motor mimicry triggered by viewing Amusing films. First, SPS+ traits were associated with increased activity in the left IPL and right IFG during the viewing of Amusing versus Mixed-valence films. These are core regions included in the mirror neuron system, which is involved in movement imitation (Hsu et al., 2022; Iacoboni, 2009; Prochazkova & Kret, 2017; Rymarczyk et al., 2018). Second, this same contrast revealed greater activity in the right middle frontal gyrus linked to SPS- traits, and greater activity in the precentral gyrus associated with both SPS- (in the right hemisphere) and SPS+ (in the left hemisphere) traits. The middle frontal and precentral gyri have previously been implicated in emotional mimicry (Fu et al., 2025; Kircher et al., 2013). Third, the Amusing versus Mixed-valence contrast also revealed greater activity associated with SPS+ in the supramarginal gyrus. This region is considered to be an extension of the mirror neuron system (Molenberghs et al., 2010). Together, these findings complement those of Acevedo et al. (2014), who identified positive associations between the overarching trait of SPS and activity seen in the bilateral IFG and precentral gyrus while participants viewed happy images. We propose that participants possessing higher levels of SPS (particularly SPS+ traits) experienced greater activity within both the core and extended mirror neuron system while viewing amusing films, and that this automatic motor mimicry contributed to their heightened experience of positive emotional contagion (Prochazkova & Kret, 2017).

In addition to the above, increased activity in the left precuneus during the viewing of Amusing versus Mixed-valence films was also associated with SPS+ traits. This may relate to

the fact that these traits are associated with heightened perspective-taking (McQuarrie et al., 2025) and increased interoceptive accuracy and awareness (Jakobson et al., 2026). As noted earlier, the precuneus has been found to be activated during empathy tasks (Kogler et al., 2020; Timmers et al., 2018) and it is a part of the DMN, which is involved in theory of mind and self-referential processing (Dadario & Sughrue, 2023). It is also part of the paracingulate network, which is a sub-network within the central executive network (Dadario & Sughrue, 2023) and involved in a number of functions including interoception. Interoception is thought to play an important role in emotion contagion and empathy, as individuals who are better able to understand their body sensations can better identify their own emotions and by extension, the emotions of another (Bird & Viding, 2014; Mul et al., 2018). Therefore, increased activity in the precuneus may represent a neural mechanism that supports the ability of individuals scoring higher on SPS+ traits to not only reflect on the pleasurable experience of feeling amused, but also to understand how others feel (a core feature of empathy).

Links Between SPS and Activity Specific to Contagious Fear

In this section, we focus on the fact that, whereas SPS- traits are linked to experiencing strong feelings of personal distress when seeing others in difficult situations, SPS+ appears to have a buffering effect (McQuarrie et al., 2025). This may explain the differing patterns of brain activity associated with SPS- and SPS+ traits that were seen during viewing of Frightening (vs. Neutral) films.

Acevedo et al. (2014) reported reduced activity in the middle temporal gyri (MTG) in individuals scoring higher in the overall trait of SPS during the viewing of sad images. In the present study, we linked bilateral reduction in MTG activity during the viewing of Frightening (versus Neutral) films to stronger expression of SPS- traits, specifically. We hypothesize that this

relationship reflects how experiencing personal distress while empathizing might interfere with theory of mind. Theory of mind, or the process of identifying the mental state of another, most commonly activates the temporoparietal junction, medial prefrontal cortex, superior temporal sulcus, and precuneus (Bernhardt & Singer, 2012; Bird & Viding, 2014; Lamm et al., 2011); however, clusters of activity within the MTG also frequently appear during theory of mind tasks (Boccadoro et al., 2019; Schurz et al., 2014). Experiencing strong personal distress has been linked to poor theory of mind/perspective-taking abilities (Israelashvili et al., 2020). It may be that participants with high levels of SPS- were less engaged in these forms of mentalizing because processing their own feelings of fear and personal distress took precedence. This would explain the reduced MTG activity they displayed when viewing these films.

The relationship between SPS- and increased personal distress may also explain the reduced activity in the left cerebellar lobule VI that was associated with viewing Frightening films. An investigation into the functional networks of the cerebellum found that lobule VI is implicated in a cerebellar limbic network involved in emotional processing—in particular, in reading the faces of others (Stoodley & Schmahmann, 2009; Van Overwalle et al., 2024). Lobule VI is also postulated to play an important role in social perception (specifically, the processing of biological motion; Van Overwalle et al., 2020). If the experience of fear and personal distress leads individuals scoring high in SPS- traits to become more self-focused, this may help explain the reduced activity associated with this trait that was evident in an area involved in processing others' nonverbal cues.

Finally, the fact that SPS+ traits are negatively related to the experience of personal distress may explain why SPS+ traits were linked to reduced activity in the right precuneus during the viewing of Frightening (versus Neutral) films. As previously described, the precuneus

has been named as a major node in the DMN, which has functions in self-reflective processing, mind-wandering, and memory recall (Dadario & Sughrue, 2023; Raichle, 2015; Raichle et al., 2001). The DMN is more active when someone is engaged in these internally-oriented activities, but during externally-oriented tasks connectivity of regions involved in the DMN is reduced (Menon, 2023). It is possible that, when viewing disturbing films, individuals with strong SPS+ traits tamp down on self-reflection as a protective mechanism, via deactivation of the DMN. This may help them to manage feelings of personal distress, potentially making them better able to act with compassion (Jordan et al., 2016).

Links Between SPS and Activity Specific to Mixed-Valence Contagion

The contrast of Mixed-valence versus Neutral films identified negative associations between SPS+ traits and activity in multiple regions of the left hemisphere including the supramarginal gyrus, superior temporal gyrus, rolandic operculum, and thalamus. One possible explanation for these findings relates to the fact that these regions are all involved in various aspects of language, and language participates in other-oriented emotion perception by providing a context to assist with identifying the emotion being experienced by the other person (Betz et al., 2019). A meta-analysis investigating changes in brain activity associated with emotion concept words found that these words activated the left superior temporal gyrus, MTG, and IFG across a variety of emotion perception paradigms (Brooks et al., 2017). Due to the role of these neural regions in semantic processing, the authors concluded that this activation may have reflected retrieval of emotion concepts during emotional perception (Brooks et al., 2017). Increased activation in the left supramarginal gyrus, rolandic operculum, and thalamus has also been linked to semantic processing. For example, more activity is seen in the left supramarginal gyrus during processing of real words than non-words, suggesting a role for this area in

representing phonological or semantic information at the lexical level (Xiao et al., 2005). In addition, expertise in cognitive domains involving language has been associated with increased activation of the left rolandic operculum (Neumann et al., 2016), and increased activation in the thalamus has been linked to its role in modulating a range of language functions, including those involving semantic operations (Bulut & Hagoort, 2024). The fact that participants who strongly express SPS+ traits showed reduced activity in these four regions during the viewing of Mixed-valence films may suggest that they rely less on language-based processes (relative to visual and/or interoceptive cues, for example) to help them interpret others' mixed emotions, which are often conveyed by nuanced or ambiguous nonverbal cues. Further research is needed to explore this possibility.

Limitations

This study investigated associations between neural activity during an emotional contagion task and levels of the positive and negative clusters of SPS. As this study involved correlational analyses, causal conclusions cannot be made. In addition, our sample size was fairly small, particularly given our interest in examining individual differences. For this reason, efforts should be made to replicate the findings reported here in a larger sample.

Unfortunately, we experienced technical difficulties with the button-press response device which limited our ability to collect subjective data regarding film valence and arousal. Having said that, for reasons outlined earlier, we are quite confident that the film clips used in the present study did elicit the expected forms of emotional contagion.

Conclusions and Future Directions

This study complements and extends the work of Acevedo et al. (2014, 2018) and Jagiellowicz et al. (2011), which represented the first efforts to explore links between SPS and

task-based changes in neural activity. Our work is unique in its focus on emotional contagion. It also provides important insights into individual differences in how the brain responds to emotional changes elicited by viewing affective films. The first general finding was that viewing amusing films produced greater activity compared to all other film types in regions involved in high-level visual processing, and more activity than frightening or mixed-valence films in areas involved in empathy. Subsequent analyses provided novel insights into neural mechanisms that may underpin key features of SPS+ and SPS- traits that relate to high-level visual and attentional processes as well as motor mimicry (a key contributor to emotional contagion). Our findings may also provide insight into the heightened sensitivity to pleasurable forms of stimulation characteristic of those with strong SPS+ traits. We propose that increased activity in a core area in the DMN during viewing of Amusing (versus Mixed-valence) films may have reflected a neural mechanism that amplifies positive affect in those scoring high in SPS+ through engagement in self-reflection.

A second general finding from our initial analysis was that viewing frightening or mixed-valence films produced more activation than amusing films in areas involved in motor imagery—possibly enhancing the sharing of negative affective states. Subsequent analyses provide new insights into processes underlying the differing relationships that SPS- and SPS+ traits have to the experience of personal distress. Specifically, we suggested that individuals scoring high in SPS- traits dampen activity related to processing others' cues, whereas those scoring high on SPS+ traits tamp down on activity in regions involved in self-reflection. The former response might limit one's ability to act with compassion, while the latter might enhance it.

Clearly, more work is needed to assess the appropriateness of the conclusions we have drawn. In addition, as someone can score high (or low) on one or both SPS trait clusters, future work involving a larger sample should examine how individual differences in the relative strength of these traits relates to patterns of neural activity. Isolating variance related to SPS from that related to partially overlapping traits such as alexithymia (McQuarrie et al., 2025) should also be a goal of future research in this area.

It would be beneficial in this work to include both behavioural and physiological data. Emotional contagion is often measured using electromyography of facial muscles to capture the motor mimicry component of the construct, which Prochazkova and Kret (2017) proposed involves the mirror neuron system. As we identified neural activity in regions involved in the mirror neuron system associated with SPS, it would be useful to incorporate electromyographic recording in a future study, but recording changes in physiology associated with autonomic arousal could also be informative.

Data Statement

The data files will be uploaded to a repository at <https://openneuro.org/>.

Acknowledgements

We would like to thank Dr. Jennifer Kornelsen and Lydia Chu for their assistance. AMM was supported by a doctoral scholarship from the Natural Sciences and Engineering Council of Canada.

Author Contributions

Amanda M. McQuarrie: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Visualization, Writing – original draft, and Writing – review and editing. **Lorna S. Jakobson:** Conceptualization, Funding

acquisition, Methodology, Supervision, Writing – review and editing. **Stephen D. Smith:**

Conceptualization, Formal analysis, Funding acquisition, Methodology, Supervision, Writing – review and editing.

Informed Consent

Ethical approval was received from the university research ethics boards (protocol number HE2021-0192, approval granted February 2022, and Multisite HE2021-0192, approval granted July 2023) and the health authority research approval committee (protocol number: SH2021:201, approval granted November 2023). Participants provided informed consent prior to participation.

Funding Sources

This work was supported by grants from the Natural Sciences and Engineering Council (NSERC) of Canada [grant numbers: RGPIN-2019-05485 and RGPIN-2023-03443].

References

- Acevedo, B. P., Aron, E. N., Aron, A., Sangster, M. D., Collins, N., & Brown, L. L. (2014). The highly sensitive brain: An fMRI study of sensory processing sensitivity and response to others' emotions. *Brain and Behavior*, 4(4), 580–594. <https://doi.org/10.1002/brb3.242>.
- Acevedo, B. P., Aron, E., Pospos, S., & Jessen, D. (2018). The functional highly sensitive brain: A review of the brain circuits underlying sensory processing sensitivity and seemingly related disorders. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 373(20170161). <https://doi.org/10.1098/rstb.2017.0161>.
- Aron, E. N., & Aron, A. (1997). Sensory-processing sensitivity and its relation to introversion and emotionality. *Journal of Personality and Social Psychology*, 73(2), 345–368. <https://doi.org/10.1037/0022-3514.73.2.345>.
- Aron, E. N., Aron, A., & Jagiellowicz, J. (2012). Sensory processing sensitivity: A review in the light of the evolution of biological responsivity. *Personality and Social Psychology Review*, 16(3), 262–282. <https://doi.org/10.1177/1088868311434213>.
- Attary, T., & Ghazizadeh, A. (2021). Localizing sensory processing sensitivity and its subdomains within its relevant trait space: A data-driven approach. *Scientific Reports*, 11(1). <https://doi.org/10.1038/s41598-021-99686-y>.
- Bernhardt, B. C., & Singer, T. (2012). The neural basis of empathy. *Annual Review of Neuroscience*, 35, 1–23. <https://doi.org/10.1146/annurev-neuro-062111-150536>.
- Betz, N., Hoemann, K., & Barrett, L. F. (2019). Words are a context for mental inference. *Emotion*, 19(8), 1463–1477. <https://doi.org/10.1037/emo0000510>.
- Bird, G., & Viding, E. (2014). The self to other model of empathy: Providing a new framework for understanding empathy impairments in psychopathy, autism, and alexithymia.

- Neuroscience and Biobehavioral Reviews*, 47, 520–532.
<https://doi.org/10.1016/j.neubiorev.2014.09.021>.
- Boccadoro, S., Cracco, E., Hudson, A. R., Bardi, L., Nijhof, A. D., Wiersema, J. R., Brass, M., & Mueller, S. C. (2019). Defining the neural correlates of spontaneous theory of mind (ToM): An fMRI multi-study investigation. *NeuroImage*, 203.
<https://doi.org/10.1016/j.neuroimage.2019.116193>.
- Brooks, J. A., Shablack, H., Gendron, M., Satpute, A. B., Parrish, M. H., & Lindquist, K. A. (2017). The role of language in the experience and perception of emotion: A neuroimaging meta-analysis. *Social Cognitive and Affective Neuroscience*, 12(2), 169–183. <https://doi.org/10.1093/scan/nsw121>.
- Bulut, T., & Hagoort, P. (2024). Contributions of the left and right thalami to language: A meta-analytic approach. *Brain Structure and Function*, 229(9), 2149–2166.
<https://doi.org/10.1007/s00429-024-02795-3>.
- Corbetta, M., Patel, G., & Shulman, G. L. (2008). The reorienting system of the human brain: From environment to theory of mind. *Neuron*, 58(3), 306–324.
<https://doi.org/10.1016/j.neuron.2008.04.017>.
- Cuff, B. M. P., Brown, S. J., Taylor, L., & Howat, D. J. (2016). Empathy: A review of the concept. *Emotion Review*, 8(2), 144–153. <https://doi.org/10.1177/1754073914558466>.
- Dadario, N. B., & Sughrue, M. E. (2023). The functional role of the precuneus. *Brain*, 146(9), 3598–3607. <https://doi.org/10.1093/brain/awad181>.
- De Gucht, V., Woestenburg, D. H. A., & Wilderjans, T. F. (2022). The different faces of (high) sensitivity, toward a more comprehensive measurement instrument. Development and validation of the Sensory Processing Sensitivity Questionnaire (SPSQ). *Journal of*

- Personality Assessment*, 104(6), 784–799.
<https://doi.org/10.1080/00223891.2022.2032101>.
- Evans, D. E., & Rothbart, M. K. (2007). Developing a model for adult temperament. *Journal of Research in Personality*, 41(4), 868–888. <https://doi.org/10.1016/j.jrp.2006.11.002>.
- Fallon, N., Roberts, C., & Stancak, A. (2020). Shared and distinct functional networks for empathy and pain processing: A systematic review and meta-analysis of fMRI studies. *Social Cognitive and Affective Neuroscience*, 15(7), 709–723.
<https://doi.org/10.1093/scan/nsaa090>.
- Fan, Y., Duncan, N. W., de Greck, M., & Northoff, G. (2011). Is there a core neural network in empathy? An fMRI based quantitative meta-analysis. *Neuroscience and Biobehavioral Reviews*, 35(3), 903–911. <https://doi.org/10.1016/j.neubiorev.2010.10.009>.
- Fox, M. D., Corbetta, M., Snyder, A. Z., Vincent, J. L., & Raichle, M. E. (2006). Spontaneous neuronal activity distinguishes human dorsal and ventral attention systems. *Proceedings of the National Academy of Sciences*, 103(26), 10046–10051.
<https://doi.org/10.1073/pnas.0604187103>.
- Fu, Y., Wang, D., Liu, J., Wang, H., Wen, F., Chen, W., & Liu, Z. (2025). The shared neural substrates of emotional mimicry and emotional contagion: An activation likelihood estimation meta-analysis and meta-analytic connectivity modeling analysis. *Social Cognitive and Affective Neuroscience*, 20(1). <https://doi.org/10.1093/scan/nsaf091>.
- Harada, T., Hayashi, A., Sadato, N., & Iidaka, T. (2016). Neural correlates of emotional contagion induced by happy and sad expressions. *Journal of Psychophysiology*, 30(3), 114–123. <https://doi.org/10.1027/0269-8803/a000160>.

- Hatfield, E., Cacioppo, J. T., & Rapson, R. L. (1993). Emotional Contagion. *Psychological Science*, 2(3), 96–99. <https://doi.org/10.1111/1467-8721.ep10770953>.
- Hsu, C. T., Sato, W., Kochiyama, T., Nakai, R., Asano, K., Abe, N., & Yoshikawa, S. (2022). Enhanced mirror neuron network activity and effective connectivity during live interaction among female subjects. *NeuroImage*, 263. <https://doi.org/10.1016/j.neuroimage.2022.119655>.
- Iacoboni, M. (2009). Imitation, empathy, and mirror neurons. *Annual Review of Psychology*, 60(1), 653–670. <https://doi.org/10.1146/annurev.psych.60.110707.163604>.
- Israelashvili, J., Sauter, D., & Fischer, A. (2020). Two facets of affective empathy: Concern and distress have opposite relationships to emotion recognition. *Cognition and Emotion*, 34(6), 1112–1122. <https://doi.org/10.1080/02699931.2020.1724893>.
- Jagiellowicz, J., Xu, X., Aron, A., Aron, E., Cao, G., Feng, T., & Weng, X. (2011). The trait of sensory processing sensitivity and neural responses to changes in visual scenes. *Social Cognitive and Affective Neuroscience*, 6(1), 38–47. <https://doi.org/10.1093/scan/nsq001>.
- Jakobson, L. S., McQuarrie, A. M., Van Landeghem, C., & Smith, S. D. (2024). Traits linked to sensory processing sensitivity mediate the relationship between externally oriented thinking and fantasizing. *Frontiers in Psychology*, 15(1354120). <https://doi.org/10.3389/fpsyg.2024.1354120>.
- Jakobson, L. S., Pearson, P. M., & Rigby, S. N. (2026). Links between facets of alexithymia, self-rated interoception, and social perception. *Frontiers in Psychology*, 16(1669056). <https://doi.org/10.3389/fpsyg.2025.1669056>.
- Jordan, M. R., Amir, D., & Bloom, P. (2016). Are empathy and concern psychologically distinct? *Emotion*, 16(8), 1107–1116. <https://doi.org/10.1037/emo0000228>.

- Jung, J., Lambon Ralph, M. A., & Jackson, R. L. (2022). Subregions of DLPFC display graded yet distinct structural and functional connectivity. *The Journal of Neuroscience*, 42(15), 3241–3252. <https://doi.org/10.1523/JNEUROSCI.1216-21.2022>.
- Kircher, T., Pohl, A., Krach, S., Thimm, M., Schulte-Rüther, M., Anders, S., & Mathiak, K. (2013). Affect-specific activation of shared networks for perception and execution of facial expressions. *Social Cognitive and Affective Neuroscience*, 8(4), 370–377. <https://doi.org/10.1093/scan/nss008>.
- Kogler, L., Müller, V. I., Werminghausen, E., Eickhoff, S. B., & Derntl, B. (2020). Do I feel or do I know? Neuroimaging meta-analyses on the multiple facets of empathy. *Cortex*, 129, 341–355. <https://doi.org/10.1016/j.cortex.2020.04.031>.
- Lamm, C., Decety, J., & Singer, T. (2011). Meta-analytic evidence for common and distinct neural networks associated with directly experienced pain and empathy for pain. *NeuroImage*, 54(3), 2492–2502. <https://doi.org/10.1016/j.neuroimage.2010.10.014>.
- Laros-van Gorkom, B. A. P., Damatac, C. G., Stevelmans, I., & Greven, C. U. (2025). Relationships of sensory processing sensitivity with creativity and empathy in an adult sample. *Frontiers in Psychology*, 15(1465407). <https://doi.org/10.3389/fpsyg.2024.1465407>.
- Lin, Y.-H., Young, I. M., Conner, A. K., Glenn, C. A., Chakraborty, A. R., Nix, C. E., Bai, M. Y., Dhanaraj, V., Fonseka, R. D., Hormovas, J., Tanglay, O., Briggs, R. G., & Sughrue, M. E. (2020). Anatomy and white matter connections of the inferior temporal gyrus. *World Neurosurgery*, 143, e656–e666. <https://doi.org/10.1016/j.wneu.2020.08.058>.
- Lorey, B., Pilgramm, S., Bischoff, M., Stark, R., Vaitl, D., Kindermann, S., Munzert, J., & Zentgraf, K. (2011). Activation of the parieto-premotor network is associated with vivid

- motor imagery—A parametric fMRI study. *PLoS ONE*, 6(5).
<https://doi.org/10.1371/journal.pone.0020368>.
- Maffei, A., & Angrilli, A. (2019). E-MOVIE - Experimental MOVies for Induction of Emotions in neuroscience: An innovative film database with normative data and sex differences. *PLoS ONE*, 14(10), e0223124. <https://doi.org/10.1371/journal.pone.0223124>.
- McQuarrie, A. M., Smith, S. D., & Jakobson, L. S. (2023). Alexithymia and sensory processing sensitivity account for unique variance in the prediction of emotional contagion and empathy. *Frontiers in Psychology*, 14(1072783).
<https://doi.org/10.3389/fpsyg.2023.1072783>.
- McQuarrie, A. M., Smith, S. D., & Jakobson, L. S. (2025). Exploring the links between childhood emotional abuse and empathy: The mediating roles of alexithymia and sensory processing sensitivity. *Acta Psychologica*, 255(104903).
<https://doi.org/10.1016/j.actpsy.2025.104903>.
- Menon, V. (2023). 20 years of the default mode network: A review and synthesis. *Neuron*, 111(16), 2469–2487. <https://doi.org/10.1016/j.neuron.2023.04.023>.
- Molenberghs, P., Brander, C., Mattingley, J. B., & Cunnington, R. (2010). The role of the superior temporal sulcus and the mirror neuron system in imitation. *Human Brain Mapping*, 31(9), 1316–1326. <https://doi.org/10.1002/hbm.20938>.
- Mul, C., Stagg, S. D., Herbelin, B., & Aspell, J. E. (2018). The feeling of me feeling for you: Interoception, alexithymia and empathy in autism. *Journal of Autism and Developmental Disorders*, 48(9), 2953–2967. <https://doi.org/10.1007/s10803-018-3564-3>.
- Neumann, N., Lotze, M., & Eickhoff, S. B. (2016). Cognitive expertise: An ALE meta-analysis. *Human Brain Mapping*, 37(1), 262–272. <https://doi.org/10.1002/hbm.23028>.

- Palejwala, A. H., Dadario, N. B., Young, I. M., O'Connor, K., Briggs, R. G., Conner, A. K., O'Donoghue, D. L., & Sughrue, M. E. (2021). Anatomy and white matter connections of the lingual gyrus and cuneus. *World Neurosurgery*, *151*, e426–e437. <https://doi.org/10.1016/j.wneu.2021.04.050>.
- Prochazkova, E., & Kret, M. E. (2017). Connecting minds and sharing emotions through mimicry: A neurocognitive model of emotional contagion. *Neuroscience and Biobehavioral Reviews*, *80*, 99–114. <https://doi.org/10.1016/j.neubiorev.2017.05.013>.
- Poldrack, R. A. (2006). Can cognitive processes be inferred from neuroimaging data? *Trends in Cognitive Sciences*, *10*(2), 59–63. <https://doi.org/10.1016/j.tics.2005.12.004>.
- Raichle, M. E. (2015). The brain's default mode network. *Annual Review of Neuroscience*, *38*, 433–447. <https://doi.org/10.1146/annurev-neuro-071013-014030>.
- Raichle, M. E., MacLeod, A. M., Snyder, A. Z., Powers, W. J., Gusnard, D. A., & Shulman, G. L. (2001). A default mode of brain function. *Proceedings of the National Academy of Science*, *98*(2), 676–682.
- Rolls, E. T., Huang, C.-C., Lin, C.-P., Feng, J., & Joliot, M. (2020). Automated anatomical labelling atlas 3. *NeuroImage*, *206*, 116189. <https://doi.org/10.1016/j.neuroimage.2019.116189>.
- Rymarczyk, K., Zurawski, L., Jankowiak-Siuda, K., & Szatkowska, I. (2018). Neural correlates of facial mimicry: Simultaneous measurements of EMG and BOLD responses during perception of dynamic compared to static facial expressions. *Frontiers in Psychology*, *9*(52). <https://doi.org/10.3389/fpsyg.2018.00052>.
- Sacheli, L. M., Zapparoli, L., De Santis, C., Preti, M., Pelosi, C., Ursino, N., Zerbi, A., Banfi, G., & Paulesu, E. (2017). Mental steps: Differential activation of internal pacemakers in

- motor imagery and in mental imitation of gait. *Human Brain Mapping*, 38(10), 5195–5216. <https://doi.org/10.1002/hbm.23725>.
- Saj, A., Cojan, Y., Musel, B., Honoré, J., Borel, L., & Vuilleumier, P. (2014). Functional neuro-anatomy of egocentric versus allocentric space representation. *Neurophysiologie Clinique/Clinical Neurophysiology*, 44(1), 33–40. <https://doi.org/10.1016/j.neucli.2013.10.135>.
- Samson, A. C., Kreibig, S. D., Soderstrom, B., Wade, A. A., & Gross, J. J. (2016). Eliciting positive, negative and mixed emotional states: A film library for affective scientists. *Cognition and Emotion*, 30(5), 827–856. <https://doi.org/10.1080/02699931.2015.1031089>.
- Schurz, M., Radua, J., Aichhorn, M., Richlan, F., & Perner, J. (2014). Fractionating theory of mind: A meta-analysis of functional brain imaging studies. *Neuroscience and Biobehavioral Reviews*, 42, 9–34. <https://doi.org/10.1016/j.neubiorev.2014.01.009>.
- Shafir, T., Taylor, S. F., Atkinson, A. P., Langenecker, S. A., & Zubieta, J.-K. (2013). Emotion regulation through execution, observation, and imagery of emotional movements. *Brain and Cognition*, 82(2), 219–227. <https://doi.org/10.1016/j.bandc.2013.03.001>.
- Stoodley, C. J., & Schmahmann, J. D. (2009). Functional topography in the human cerebellum: A meta-analysis of neuroimaging studies. *NeuroImage*, 44(2), 489–501. <https://doi.org/10.1016/j.neuroimage.2008.08.039>.
- Timmers, I., Park, A. L., Fischer, M. D., Kronman, C. A., Heathcote, L. C., Hernandez, J. M., & Simons, L. E. (2018). Is empathy for pain unique in its neural correlates? A meta-analysis of neuroimaging studies of empathy. *Frontiers in Behavioral Neuroscience*, 12. <https://doi.org/10.3389/fnbeh.2018.00289>.

- Uono, S., Sato, W., Kochiyama, T., Kubota, Y., Sawada, R., Yoshimura, S., & Toichi, M. (2017). Time course of gamma-band oscillation associated with face processing in the inferior occipital gyrus and fusiform gyrus: A combined fMRI and MEG study. *Human Brain Mapping, 38*(4), 2067–2079. <https://doi.org/10.1002/hbm.23505>.
- Van Overwalle, F., Ma, Q., Haihambo, N., Bylemans, T., Catoira, B., Firouzi, M., Li, M., Pu, M., Heleven, E., Baeken, C., Baetens, K., & Deroost, N. (2024). A functional atlas of the cerebellum based on NeuroSynth task coordinates. *Cerebellum, 23*, 993–1012. <https://doi.org/10.1007/s12311-023-01596-4>.
- Van Overwalle, F., Manto, M., Cattaneo, Z., Clausi, S., Ferrari, C., Gabrieli, J. D. E., Guell, X., Heleven, E., Lupo, M., Ma, Q., Michelutti, M., Olivito, G., Pu, M., Rice, L. C., Schmahmann, J. D., Siciliano, L., Sokolov, A. A., Stoodley, C. J., van Dun, K., ... Leggio, M. (2020). Consensus Paper: Cerebellum and Social Cognition. *Cerebellum, 19*(6), 833–868. <https://doi.org/10.1007/s12311-020-01155-1>.
- Xiao, Z., Zhang, J. X., Wang, X., Wu, R., Hu, X., Weng, X., & Tan, L. H. (2005). Differential activity in left inferior frontal gyrus for pseudowords and real words: An event-related fMRI study on auditory lexical decision. *Human Brain Mapping, 25*(2), 212–221. <https://doi.org/10.1002/hbm.20105>.
- Yeo, B. T. T., Krienen, F. M., Sepulcre, J., Sabuncu, M. R., Lashkari, D., Hollinshead, M., Roffman, J. L., Smoller, J. W., Zöllei, L., Polimeni, J. R., Fischl, B., Liu, H., & Buckner, R. L. (2011). The organization of the human cerebral cortex estimated by intrinsic functional connectivity. *Journal of Neurophysiology, 106*(3), 1125–1165. <https://doi.org/10.1152/jn.00338.2011>.

Chapter 5: General Conclusion

The previous chapters presented three studies investigating the relationship between SPS and empathy/emotional contagion, focusing on links to environmental factors and the neural correlates of this relationship. A novel aspect of this work was the distinction between SPS+ and SPS- traits. Dividing the overall concept of SPS into positive and negative components is a relatively new approach; however, previous research has indicated that these clusters are distinctly different (De Gucht et al., 2022; Jakobson et al., 2024) and that they differ in their relationships to other personality traits and, by extension, resulting behaviour (Attary & Ghazizadeh, 2021). Each study included in this manuscript measured SPS through its positive and negative components, identifying differences between how these trait components relate to a range of empathy-related constructs. The neural correlates of each component in the brain at rest and during emotional contagion were also explored. The findings support the view that, overall, individuals with higher levels of SPS are more empathetic; however, for those scoring higher in SPS- traits, this may potentially come at a risk to their own well-being.

SPS is equally predicted by both genetic and environmental factors (Assary et al., 2021). Additionally, high-SPS individuals are disproportionately influenced by their environment, with those raised in adverse circumstances being more strongly and negatively impacted, and those raised in a supportive environment being more strongly and positively impacted, compared to less-sensitive individuals (Aron et al., 2012; Lionetti & Pluess, 2024). The study presented in Chapter 2 concluded that SPS mediates the pathway between the experience of emotional abuse in childhood and generally heightened levels of self-reported empathy as adults. Additionally, high-SPS individuals felt positive and negative emotions more strongly (depending on whether

the participants scored higher on SPS+ or SPS- traits, respectively). This emphasizes the role of childhood environment in the development of SPS and empathic abilities.

The study presented in Chapter 2 also included the personality trait alexithymia. Although not the focus of subsequent studies, including alexithymia as a covariate in SPS studies is important as these traits frequently co-occur and interact (Jakobson & Rigby, 2021). Alexithymia was also positively predicted by the experience of emotional abuse in childhood, implicating an environmental influence on the expression of this trait. As there was a significant relationship between alexithymia and empathy and emotional contagion even after accounting for the influence of SPS, future research would benefit from continuing to measure both traits.

The studies presented in Chapters 3 and 4 included data collected through functional magnetic resonance imaging. There is limited existing research exploring the neural correlates of SPS; the current studies provided novel findings specifically looking at the relationship between SPS and empathy/emotional contagion in the brain. Across both studies, there emerged a pattern consistent with deeper overall processing, particularly within emotional and visual regions. This depth of processing was present both when participants were not completing a task (i.e., at rest) and while completing an emotional contagion task. More specifically, individuals scoring higher on SPS+ traits experienced enhanced FC and neural activity in regions involved in visual processing (i.e., LOC, intracalcarine cortex, and inferior temporal gyrus). This trait cluster was also associated with increased FC in regions involved in mental imagery (i.e., superior parietal lobule and LOC), and greater activity during the emotional contagion task in regions associated with empathy (i.e., precuneus), and the mirror neuron system and emotional mimicry (i.e., IPL, IFG, and precentral gyrus). Participants scoring higher on SPS- traits also experienced enhanced FC in areas of visual processing (i.e., LOC), interoceptive processing (i.e., insula, primary

somatosensory cortex), and rumination (i.e., precuneus and frontal pole) while at rest. During the emotional contagion task, high SPS- traits were associated with increased activity in regions involved in attentional processing (e.g., cerebellar lobules IV and V, and middle frontal gyrus). Acevedo et al. (2021) initially proposed a deeper level of processing reflected in the high-SPS brain. The current studies provide additional evidence of this, particularly as it may relate to empathy and related constructs.

The Experience of Personal Distress

Distinguishing between SPS+ and SPS- traits should be an important objective of researchers interested in mental health and well-being. As presented in the model of SPS and emotions by Lionetti and Pluess (2024), SPS may influence well-being through its impact on the perception and processing of emotions and emotional reactivity. However, one's ability to regulate their emotions may vary as a function of the relative strength of SPS trait components. Based on this model, an individual who expresses stronger SPS+ traits should be more sensitive to positive stimuli, be better able to regulate their emotions, and have better well-being than someone who expresses stronger SPS- traits, whose hypersensitivity to negative stimuli interferes with emotion regulation (Lionetti & Pluess, 2024).

This model is highly relevant to one result reported in each study comprising this thesis, namely that the experience of personal distress while empathizing differed depending on whether the participant reported high levels of SPS+ or SPS- traits. More specifically, whereas SPS+ traits acted as a protective factor against the experience of personal distress, SPS- traits heightened distress. As described above, while empathy generally promotes prosocial behaviour, the experience of personal distress can act as a deterrent against behaving in a prosocial manner (Jordan et al., 2016). Therefore, individuals who possess high levels of SPS- traits may have

high levels of empathy (compared to individuals without SPS) but be less likely to help others in difficult situations due to the personal distress they are feeling.

The differing relationships between the SPS trait clusters and personal distress was highlighted as explanations for a number of results presented in Chapters 3 and 4. Differences in emotion regulation strategies may underlie these differences. As presented in the model by Lionetti and Pluess (2024), SPS+ individuals may have more effective emotion regulation abilities than individuals with SPS- traits. This could contribute to enhanced distress tolerance and overall well-being (Brindle et al., 2015; Lionetti & Pluess, 2024).

Clinical Implications and Treatment

There is minimal research investigating the clinical implications and treatment of heightened empathy. Most of the research has investigated the alternative, that is, possessing lower levels of empathy. The following section will: explore the implications and treatment for empathy deficits; describe clinical implications of experiencing too much empathy; and present the status of investigations into treatment for SPS and how this could relate specifically to the enhanced personal distress found in high SPS- individuals.

Implications and Treatment of Empathy Deficits

Empathic deficits can be present for the cognitive component, affective component, or for empathy as a whole. Different personality traits or psychopathologies can be defined in part by deficits across empathy components. For example, psychopathy or antisocial personality disorder often includes intact cognitive empathy but difficulties with affective empathy (Lamm et al., 2016). Alternatively, individuals with autism spectrum disorder may possess difficulties with cognitive empathy but intact affective empathy (Lamm et al., 2016). In contrast, narcissistic

personality disorder has been implicated with deficits across both empathy components (Decety & Moriguchi, 2007).

Correctly identifying the type of empathy deficit (i.e., whether it involves incorrectly identifying what the other person is feeling versus a deficit in feeling that same emotion) has important implications for treatment. For example, interventions focusing on cognitive empathy have been effective at improving perspective-taking and social understanding in individuals with autism spectrum disorder (Lecheler et al., 2021; Southall & Campbell, 2015). A recent meta-analysis investigating empathy interventions found that cognitive empathy training methods were effective at improving cognitive empathy up to three months post-intervention (but not longer; Wu et al., 2024). Interventions that were “subject-oriented” (e.g., involving emotion recognition), “object-oriented” (e.g., using virtual reality to simulate life as the empathy target), and “socially-oriented” (e.g., social and communication skills training) were all effective at enhancing cognitive empathy. Wu et al. (2024) note that affective empathy interventions have not been as successful, only showing positive effects at one-week post-intervention. Additionally, as improvements were noted only with socially-oriented interventions, there is a need for future research to focus on improving interventions for affective empathy.

Implications of Heightened Empathy

Possessing higher levels of empathy is, for the most part, considered to be beneficial for prosocial behaviour and moral decision-making, as well as interpersonal interactions and relationships. However, there appears to be a fine line between the benefits of possessing high levels of empathy and potential negative outcomes for the empathizer. High levels of affective empathy, specifically, are related to the development of feelings such as sadness, guilt, distress, and anxiety, which may develop into internalizing disorders (Huang et al., 2025). Another

negative outcome frequently associated with experiencing high levels of empathy, particularly affective empathy and personal distress, is the experience of burnout or poor professional quality of life (Huang et al., 2025).

SPS has been found to be associated with a greater risk of internalizing symptoms (Attary & Ghazizadeh, 2021) and burnout across a number of professions (Bordarie & Mourtialon, 2023; Chacón et al., 2023; Meyerson et al., 2020; Pérez-Chacón et al., 2021; Redfearn et al., 2020). The SPS- component emerges as the primary driver of these relationships (Golonka & Gulla, 2021). A study by McQuarrie and Jakobson (2025) found that levels of self-compassion negatively mediated the relationship between SPS- traits and burnout, general stress, anxiety, and depression in clinical and counselling psychologists. Thus, possessing high levels of SPS- traits predicted lower levels of self-compassion, which then predicted greater risk of burnout and internalizing symptoms (McQuarrie & Jakobson, 2025). The experience of personal distress and poor emotion regulation while working in helping professions may help explain these relationships.

Potential Treatment for Heightened Empathy Associated with SPS- Traits

There are few investigations into psychological treatment with high-SPS individuals; however, there is a theme across results that individuals with high levels of SPS have a greater response to treatment compared to a low-SPS population. Two separate studies utilizing similar treatment programs designed to develop resilience and self-efficacy in children and adolescents found that youth who were highly sensitive had significantly lower levels of depression (Kibe et al., 2020; Pluess & Boniwell, 2015) and higher levels of self-esteem (Kibe et al., 2020) post-treatment compared to pre-treatment. Depression and self-esteem scores for participants who were not highly sensitive did not differ over the treatment program (Kibe et al., 2020; Pluess &

Boniwell, 2015). This indicates that psychological interventions can be effective in the treatment of distress associated with SPS. The results from these studies also lend additional support to the conceptualization of SPS in that individuals with high levels of SPS are uniquely influenced by their environment, whether negative or supportive, compared to their low-sensitive counterparts (Aron et al., 2012; Lionetti & Pluess, 2024).

Based on the model by Lionetti and Pluess (2024), developing more effective emotion regulation strategies and increased distress tolerance may be potential areas of treatment focus for individuals with high levels of SPS- traits, to improve well-being and reduce personal distress in empathic situations. Psychological interventions such as cognitive behavioural therapy, dialectical behaviour therapy, and acceptance and commitment therapy may all be effective forms of treatment targeting emotion regulation and distress tolerance.

One technique incorporated in each of these psychological interventions is mindfulness. A study by Bakker and Moulding (2012) found that the relationship between SPS and anxiety was moderated by levels of mindfulness and acceptance of the emotional experience. They found a strong positive relationship between SPS and anxiety when participants also had low levels of mindfulness or were avoidant of emotions. The relationship between SPS and anxiety was not significant when participants had high levels of mindfulness or were able to accept their emotional experience (Bakker & Moulding, 2012). This indicates that mindfulness and acceptance are two psychological strategies that may be effective at reducing distress in those with high levels of SPS.

Self-compassion may be an additional, related area of intervention to reduce the negative implications from possessing high levels of empathy. High self-compassion has been identified as a protective factor for burnout and job satisfaction in the general population (Szoke et al.,

2023; Vaillancourt & Wasyliw, 2020) whereas low self-compassion (seen in those with strong SPS- traits) is a risk factor (McQuarrie & Jakobson, 2025). As mindfulness is a key component of self-compassion (Neff, 2023) and can be low in individuals with heightened SPS (Takahashi et al., 2020), including mindfulness techniques should be a priority when treating these individuals, to reduce their risk of burnout and internalizing symptoms.

The potential for improving mindfulness and self-compassion in order to reduce personal distress and the risk of burnout and internalizing symptoms was explored in a study by Birnie et al. (2010). The authors found that involvement in a mindfulness-based stress reduction program did lead to positive gains in self-compassion and mindfulness, while also reducing internalizing symptoms and levels of personal distress. Strengthening mindfulness abilities allowed for the participants to observe others' suffering without becoming overwhelmed by it (Birnie et al., 2010). Although the sample included in this study were not specifically high-SPS participants, the results suggest that applying this approach to a SPS sample might produce an even stronger response to treatment (Aron et al., 2012; Lionetti & Pluess, 2024). Efforts to fine-tune individualized psychological intervention protocols that emphasize the use of mindfulness and self-compassion training to reduce levels of personal distress in both the general population and in those with high levels of SPS- traits should be an important area of future research.

Concluding Remarks

The three studies presented here provide a detailed investigation into the relationship between SPS and empathy. The findings contribute to our understanding of how early adversity may shape the expression of different facets of SPS, and to how each of these facets relates to a range of empathy-related constructs, including emotional contagion and personal distress. They also provide novel insights into the neural correlates of the high-SPS brain. This is significant as

these are relatively new areas of SPS research that are less well understood. The experience of personal distress while empathizing emerged as a significant component of the relationship between empathy and SPS, as the two SPS trait clusters possessed opposing links with this empathy-related construct. The heightened personal distress associated with SPS- traits, specifically, provided potential explanations for some of the neuroimaging results.

Interventions aimed at reducing distress experienced by individuals scoring high on SPS- traits should be an important focus of future research. This chapter explored potential avenues for interventions, specifically involving mindfulness, self-compassion, and emotion regulation strategies to reduce distress. Continuing to refine how we assess and tailor interventions for individuals with SPS is important. Whereas clinical implications for empathy deficits are well-researched, there are fewer investigations into the implications of possessing too much empathy. Yet high-SPS individuals are at an increased risk of experiencing a range of complications that may be related, in part, to heightened empathy, such as anxiety, depression, and occupational burnout. It is therefore important to continue this line of enquiry into the potential clinical effects and psychological treatments for individuals with high levels of positive and negative SPS traits.

References

- Acevedo, B., Santander, T., Marhenke, R., Aron, A., & Aron, E. (2021). Sensory processing sensitivity predicts individual differences in resting-state functional connectivity associated with depth of processing. *Neuropsychobiology*, 80, 185-199. <https://doi.org/10.1159/000513527>.
- Aron, E. N., Aron, A., & Jagiellowicz, J. (2012). Sensory processing sensitivity: A review in the light of the evolution of biological responsivity. *Personality and Social Psychology Review*, 16(3), 262–282. <https://doi.org/10.1177/1088868311434213>.
- Assary, E., Zavos, H. M. S., Krapohl, E., Keers, R., & Pluess, M. (2021). Genetic architecture of Environmental Sensitivity reflects multiple heritable components: A twin study with adolescents. *Molecular Psychiatry*, 26(9), 4896–4904. <https://doi.org/10.1038/s41380-020-0783-8>.
- Attary, T., & Ghazizadeh, A. (2021). Localizing sensory processing sensitivity and its subdomains within its relevant trait space: A data-driven approach. *Scientific Reports*, 11(20343). <https://doi.org/10.1038/s41598-021-99686-y>.
- Bakker, K., & Moulding, R. (2012). Sensory-processing sensitivity, dispositional mindfulness and negative psychological symptoms. *Personality and Individual Differences*, 53(3), 341-346. <https://doi.org/10.1016/j.paid.2012.04.006>.
- Birnie, K., Speca, M., & Carlson, L. E. (2010). Exploring self-compassion and empathy in the context of mindfulness-based stress reduction (MBSR). *Stress & Health*, 26(5), 359-371. <https://doi-org.uml.idm.oclc.org/10.1002/smi.1305>.
- Bordarie, J., & Mourtialon, C. (2023). Study of the relationship between sensory processing sensitivity and burnout syndrome among speech and language therapists. *International*

- Journal of Environmental Research and Public Health*, 20(23).
<https://doi.org/10.3390/ijerph20237132>.
- Brindle, K., Moulding, R., Bakker, K., & Nedeljkovic, M. (2015). Is the relationship between sensory-processing sensitivity and negative affect mediated by emotional regulation? *Australian Journal of Psychology*, 67(4), 214-221. <https://doi.org/10.1111/ajpy.12084>.
- Chacón, A., Avargues-Navarro, M., Pérez-Chacón, M., & Borda-Mas, M. (2023). Occupational psychosocial risks and quality of professional life in service sector workers with sensory processing sensitivity. *Behavioral Sciences*, 13(6), 496-517.
<https://doi.org/10.3390/bs13060496>.
- De Gucht, V., Woestenburg, D. H. A., & Wilderjans, T. F. (2022). The different faces of (high) sensitivity, toward a more comprehensive measurement instrument. Development and validation of the Sensory Processing Sensitivity Questionnaire (SPSQ). *Journal of Personality Assessment*, 104(6), 784–799.
<https://doi.org/10.1080/00223891.2022.2032101>.
- Decety, J., & Moriguchi, Y. (2007). The empathic brain and its dysfunction in psychiatric populations: Implications for intervention across different clinical conditions. *BioPsychoSocial Medicine*, 1, 1-21. <https://doi.org/10.1186/1751-0759-1-22>.
- Golonka, K., & Gulla, B. (2021). Individual differences and susceptibility to burnout syndrome: Sensory processing sensitivity and its relation to exhaustion and disengagement. *Frontiers in Psychology*, 12(751350). <https://doi.org/10.3389/fpsyg.2021.751350>.
- Huang, C., Wu, Z., Sha, S., Liu, C., Yang, L., Jiang, P., Zhang, H., & Yang, C. (2025). The dark side of empathy: The role of excessive affective empathy in mental health disorders. *Biological Psychiatry*, 98, 404-415. <https://doi.org/10.1016/j.biopsych.2024.12.020>.

Jakobson, L. S., McQuarrie, A. M. M., Van Landeghem, C. V., & Smith, S. D. (2024). Traits

linked to sensory processing sensitivity mediate the relationship between externally oriented thinking and fantasizing. *Frontiers in Psychology, 15*(1354120).

<https://doi.org/10.3389/fpsyg.2024.1354120>.

Jakobson, L. S., & Rigby, S. (2021). Alexithymia and sensory processing sensitivity: Areas of

overlap and links to sensory processing styles. *Frontiers in Psychology, 12*(583786).

<https://doi.org/10.3389/fpsyg.2021.583786>.

Jordan, M., Amir, D., & Bloom, P. (2016). Are empathy and concern psychologically distinct?

Emotion, 16(8), 1107-1116. <https://doi.org/10.1037/emo0000228>.

Kibe, C., Suzuki, M., Hirano, M. & Boniwell, I. (2020). Sensory processing sensitivity and

culturally modified resilience education: Differential susceptibility in Japanese

adolescents. *PLoS One, 15*(9). <https://doi.org/10.1371/journal.pone.0239002>.

Lamm, C., Bukowski, H., & Silani, G. (2016). From shared to distinct self-other representations

in empathy: Evidence from neurotypical function and socio-cognitive disorders.

Philosophical Transactions B, 371(1686). <https://doi.org/10.1098/rstb.2015.0083>.

Lecheler, M., Lasser, J., Vaughan, P. W., Leal, J., Ordetx, K., & Bischofberger, M. (2021). A

matter of perspective: An exploratory study of a theory of mind autism intervention for

adolescents. *Psychological Reports, 124*(1), 39-53.

<https://doi.org/10.1177/0033294119898120>.

Lionetti, F., & Pluess, M. (2024). The role of environmental sensitivity in the experience and

processing of emotions: Implications for well-being. *Philosophical Transactions B,*

379(20230244). <https://doi.org/10.1098/rstb.2023.0244>.

- McQuarrie, A. M. M., & Jakobson, L. S. (2025). Exploring links between sensory processing sensitivity, professional quality of life, and negative affectivity in clinical and counselling psychologists. *PLoS Mental Health*, 2(7). <https://doi.org/10.1371/journal.pmen.0000362>.
- Meyerson, J., Gelkopf, M., Eli, I., & Uziel, N. (2020). Burnout and professional quality of life among Israeli dentists: The role of sensory processing sensitivity. *International Dental Journal*, 70, 29-37. <https://doi.org/10.1111/idj.12523>.
- Neff, K. (2023). Self-compassion: Theory, method, research, and intervention. *Annual Reviews of Psychology*, 74, 193-218. <https://doi.org/10.1146/annurev-psych-032420>.
- Pérez-Chacón, M., Chacón, A., Borda-Mas, M., & Avargues-Navarro, M. (2021). Sensory processing sensitivity and compassion satisfaction as risk/protective factors from burnout and compassion fatigue in healthcare and education professionals. *International Journal of Environmental Research and Public Health*, 18(2), 611-626. <https://doi.org/10.3390/ijerph18020611>.
- Pluess, M., & Boniwell, I. (2015). Sensory-Processing Sensitivity predicts treatment response to a school-based depression prevention program: Evidence of Vantage Sensitivity. *Personality and Individual Differences*, 82, 40-45. <https://doi.org/10.1016/j.paid.2015.03.011>.
- Redfearn, R., van Ittersum, K., & Stenmark, C. (2020). The impact of sensory processing sensitivity on stress and burnout in nurses. *International Journal of Stress Management*, 27(4), 370-379. <https://doi.org/10.1037/str0000158>.
- Southall, C., & Campbell, J. M. (2015). What does research say about social perspective-taking interventions for students with HFASD? *Exceptional Children*, 81(2), 194-208. <https://doi.org/10.1177/0014402914551740>.

- Szoke, D., Lancaster, C., & Hazlett-Stevens, H. (2023). Relationships between burnout, secondary traumatic stress, mindfulness, and self-compassion in victim advocates. *Violence Against Women*, 29(12-13), 2551-2568. <https://doi.org/10.1177/10778012231185535>.
- Takahashi, T., Kawashima, I., Nitta, Y., & Kumano, H. (2020). Dispositional mindfulness mediates the relationship between sensory-processing sensitivity and trait anxiety, well-being, and psychosomatic symptoms. *Psychological Reports*, 123(4), 1083-1098. <https://doi.org/10.1177/0033294119841848>.
- Vaillancourt, E., & Wasyliw, L. (2020). The intermediary role of burnout in the relationship between self-compassion and job satisfaction among nurses. *Canadian Journal of Nursing Research*, 52(4), 246-254. <https://doi.org/10.1177/0844562119846274>.
- Wu, X., Su-Chen, Y., Xue-Jing, L., Yu-Qing, Z., Ya-Zhuo, K., & Hu, L. (2024). Categories of training to improve empathy: A systematic review and meta-analysis. *Psychological Bulletin*, 150(10), 1237-1260. <https://doi.org/10.1037/bul0000453>.

Appendix: Consent Forms

Research Project Title: Responses to Emotional Film Clips

Principal Investigator: Amanda McQuarrie, M.A., Ph.D. Student
Department of Psychology, University of Manitoba
[email address]

Research Supervisors: Dr. Lorna Jakobson, Ph.D., Professor
Department of Psychology, University of Manitoba
[email address]
Dr. Stephen Smith, Ph.D., Professor
Department of Psychology, University of Winnipeg
[email address]

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

This study is funded in part by the Natural Sciences and Engineering Research Council of Canada.

Thank you for your interest in participating in this research study. We will be looking at how different personality traits and experiences during childhood affect one's emotional responses. People differ in how they react to situations, and we are attempting to figure out why this may be.

Please note, to participate in this study, you must:

- Be a student registered in PSYC 1200 (Introduction to Psychology) at the University of Manitoba;
- Be a Canadian citizen;
- Speak English as your first language;
- Have no history of diagnosed neurological disorders or significant head injuries;
- Have normal or correct-to-normal vision;
- And be 18 years or older.

What will you be doing?

If you take part in this study, you will first complete demographic questions regarding age, sex, and gender. You will then complete a behavioural task. During this task, you will watch short film clips that have been chosen to potentially cause you to feel certain emotions. After watching each clip, you will answer questions about how much you felt each of several emotions. There are no right or wrong answers, we simply want to know how the film clips make you feel.

After completing this behavioural task, you will answer questionnaires about certain personality traits and life experiences that you have had. Again, there are no right or wrong answers, these questions will tell us more about what makes you... you. Overall, your participation in this study will take approximately 60 minutes.

At the end of the study, we will provide you with more detailed information about the purpose of the study and invite you to email the Principal Investigator if you have any questions.

Risks to Participating

We do not foresee there to be any major risks to your participation in this study. You will be watching film clips that may be disturbing or cause you to feel strong emotions, but the scenes depicted are similar to ones you might encounter in everyday life (e.g., when watching TV). You will also be answering some personal questions about yourself and your experiences growing up, but you are free to omit items you do not wish to answer. We will also provide a list of community mental health resources at the end of the study, for those who may want to access them.

Benefits to Participating

By participating in this study, you will gain a deeper understanding of how research in psychology is conducted.

Compensation

Participants will receive two credits towards the Research Participation component of your overall grade in PSYC 1200. These credits will be applied to your SONA account after participation.

Confidentiality

All information collected in this study will be confidential and private; however, please note that your responses are being collected through Qualtrics Online Survey Software, a third-party survey software. Qualtrics is required to follow privacy laws, so the risk of privacy breach is similar to that seen with the use of email or social media platforms. UofM email addresses entered during data collection will be stripped from the database when it is downloaded from the Qualtrics server and stored in a file that is separate from the file containing the database. Both files will be password-protected, and accessible only to authorized members of the research team.

Some of the people who complete the current study may qualify for additional studies in our lab that we hope to run throughout 2023. If you express an interest in learning more about these upcoming opportunities to participate in research, and you qualify for the studies, we will send you an invitation via your UofM email. Agreeing to receive this information would, in no way, oblige you to take part in our future research, it would simply allow us to issue the invitation. Additionally, you will receive a separate consent form for any future studies in which you agree to take part. If you agree to take part in another study, we will use your UofM email address to link the data collected from you in that study to the data collected from you today. Once any necessary data linkage is complete and a summary of the results from the current study has been distributed, the file containing the UofM email addresses will be destroyed. At this point, it will be impossible for anyone, including the researchers, to link data collected for the present purpose, or a future study, with specific participants. The anonymized database will be kept indefinitely and be uploaded to an electronic data repository.

Voluntary Participation

Your participation in this study is completely voluntary. If you agree to take part, you can withdraw from the study without any consequences or penalties by closing your browser. You can also withdraw after the study by emailing the PI, but this will not be possible if the data have already been analyzed or anonymized (approximately April 2023). You will still receive the research credits even if you withdraw from participation.

A summary of the findings will be emailed to you by April 2023; it will include only group results. Results from this study will appear in student theses and may be published in peer-reviewed journals and presented in research talks or at academic and professional conferences. Again, only group data will be disclosed.

Thank you for considering participating in this study. If you have any questions, please feel free to email the Principal Investigator or Research Supervisors. If you have any questions or concerns about your rights as a research participant, you may contact the University of Manitoba Fort Garry Research Ethics Board at humanethics@umanitoba.ca or (204) 474-7122.

Clicking “I agree” at the bottom of this page indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

This research has been approved by the Research Ethics Board at the University of Manitoba, Fort Garry campus. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Officer at 204-474-7122 or humanethics@umanitoba.ca. We encourage you to save or print a copy of this consent form now for your records, as it will not be available later.

If you do not wish to participate in this study now, please close your web browser or click “I DISAGREE” below.

If you have read the information presented in this form and do not have any questions about this study, please click “I AGREE” when you are ready to begin. You should only click “I AGREE” if you agree to participate with full knowledge of the study presented to you in this information and consent form, and of your own free will. **NOTE: If you decide to complete the study, we suggest that you do so in a quiet place where you will not be interrupted. We would appreciate it if you could turn off your phone and all instant messaging programs or other programs currently running on your computer before continuing. Thank you for your consideration.**

I AGREE I DISAGREE



Research Project Title: Personality and Brain Functioning

Principal Investigator: Amanda McQuarrie, Department of Psychology, University of Manitoba,
[email address]

Research Supervisors: Dr. Lorna Jakobson, Department of Psychology, University of Manitoba,
[email address]
Dr. Stephen Smith, Department of Psychology, University of Winnipeg,
[email address]

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

This study is funded in part by the Natural Sciences and Engineering Research Council of Canada.

Thank you for your interest in participating in this research study. We will be looking at how different personality traits affect one's emotional responses and how these emotional responses are reflected in how the brain functions. People differ in how they react to situations, and we are attempting to figure out why this may be and how this relates to brain function. We will address the latter question by obtaining **functional magnetic resonance imaging (fMRI) brain scans** from study participants.

Please note, to participate in this study, you must:

- Be a student registered in PSYC 1200 (Introduction to Psychology) at the University of Manitoba;
- Be at least 18 years old;
- Be a Canadian citizen;
- Speak English as your first language;
- Have no history of diagnosed neurological disorders or significant head injuries;
- Have normal or corrected-to-normal vision (e.g., contact lenses);
- Be willing to abide by any COVID-19 protocols required by Shared Health and the Winnipeg Regional Health Authority;
- Have completed an fMRI screening questionnaire, which confirmed that you:
 - Are not currently pregnant;
 - Do not have any metal in your body;
 - And are not claustrophobic.

What will you be doing?

If you decide to take part in this study, you will first complete an online survey including questions about certain personality traits. There are no right or wrong answers to any of the questions asked. Finally, you will be asked to complete an MRI screening form. *It is very important that you answer these screening questions truthfully as your responses will be used to determine if it is safe for you to undergo an MRI scan.* The entire survey is expected to take you around 45 minutes to complete.

If you are eligible to undergo an MRI scan, the PI will contact you via phone to book the scanning session. If you decide to take part in the MRI scan, you will need to go to the scanning facility. When you arrive for your brain scan, the technician will go through the MRI screening questionnaire with you one more time. If you are cleared to undergo the scan you will be asked to lie still with your eyes closed for approximately 15 minutes. Then, you will watch short film clips and answer questions about how each clip made you feel. Your brain activity will be measured while you complete these tasks. The total time in the MRI scanner will be approximately 45-60 minutes. With set-up and other safety protocols, you will be at the MRI facility for approximately 90 minutes. For completing this phase of the study, you will receive 3 credits toward your PSYC 1200 research participation requirement.

At the end of the study, we will provide you with more detailed information about the purpose of the study and invite you to email the Principal Investigator if you have any questions. More information will also be provided on how to access a summary of the findings. We expect this summary to be available by approximately January 2025.

Although the MRI scan is being performed for research rather than clinical purposes, it is possible that we may detect a medical condition that you did not know about. In this event, your scan will be sent to a radiologist and become part of your medical health record. If the radiologist determines that additional scans are necessary, they may contact your family physician. For this reason, we will ask you to supply your family physician's contact information below, if you are interested in taking part.

Risks to Participating

We do not foresee there to be any major risks to your participation in this study. The MRI scan itself may cause discomfort, particularly due to the loud noise made by the scanner. To reduce any negative effects from the scanner's noise, participants are provided with earplugs before scanning begins. Some participants may experience mild claustrophobia in the scanner. If you become uncomfortable while in the MRI scanner, you can press the emergency response button in order to stop the scan. Additionally, there could be a risk of injury if you improperly answer the screening form. For example, the presence of metal in your body can cause severe injury in the scanner.

The film clips you will be shown in this study have been chosen from popular movies or YouTube clips, and may elicit a positive, negative, or mixed emotional response (or no response). They are similar in emotional intensity to things you might encounter in everyday life

(e.g., when watching TV). However, if you feel uncomfortable watching these videos, you can press the emergency response button to stop the scan.

In the unlikely event that you experience distress resulting from your participation (or if you have a pre-existing mental health concern), we encourage you to reach out for support. A contact list for support services appears at the end of this consent form and will be presented again later.

Benefits to Participating

By participating in this study, you will gain a deeper understanding of how research in psychology — particularly brain scanning-related research — is conducted. Additionally, you will assist us to better understand individual differences in how people's brains function.

Compensation

Participants will receive up to five credits towards the Research Participation component of your overall grade in PSYC 1200. The number of research credits provided will depend on the amount of time you devote to the study. If you only complete the online portion of the study, you will receive two credits. If you go on to travel to the MRI scanning location you will receive an additional three credits, and be given \$20 to offset transportation or other costs, whether or not you undergo the brain scan. Participants who complete the MRI scan will also be given the option to receive an image of their brain, which will be sent to them at a later date.

Confidentiality

All research information collected in this study will be confidential and private; however, please note that, as mentioned above, your personal information and brain scans may be shared with a radiologist and your Family Doctor and become part of your medical health record if incidental clinical findings are found.

Additionally, your responses to the survey are being collected through Qualtrics Online Survey Software, a third-party survey software. Qualtrics is required to follow privacy laws, so the risk of privacy breach is similar to that seen with the use of email or social media platforms.

All participants will receive a unique code and all collected research data will refer to you only by this code. Your name will not be used when scoring your results nor will it be linked to any of your results as part of the research study. The document linking the codes to your name, email address, and phone number will be password-protected and stored on a shared drive only accessible by the PI and Research Supervisors. This document will be deleted as soon as the summary of the results is sent to participants (approximately January 2025).

The anonymized data will be kept indefinitely and will be accessible to the Principal Investigator and her supervisors. A copy of it may also be uploaded to an electronic data repository if requested by academic journals. You will be provided with the opportunity to receive a summary of the results (by approximately January 2025), but this summary will only include group results (no individual findings will be shared).

Voluntary Participation

Your participation in this study is completely voluntary and you are free to withdraw at any point throughout the study. You can withdraw from the online portion of the study at any point without any consequences or penalties by closing your browser. If you would like to withdraw at any point after the online portion of the study, simply do so by letting the Principal Investigator know either in person or via email. You will still receive the research credits even if you withdraw from participation. If you finish participating in the study and then wish to withdraw your consent, email requests must be received before the data are analyzed (approximately January 2025).

Results from this study may be presented at academic and professional conferences and may be published in peer-reviewed journals. De-identified data (e.g., listing participants as Participant 1 rather than by name) may be stored in public data repositories as part of open-science initiatives.

Thank you for considering participating in this study. If you have any questions, please feel free to email the Principal Investigator or Research Supervisors. If you have any questions or concerns about your rights as a research participant, you may contact the University of Manitoba Fort Garry Research Ethics Board at humanethics@umanitoba.ca or (204) 474-7122.

List of Support Services

- **Psychological Service Centre:** 204-474-9222
- **University of Manitoba Student Counselling Centre:** 204-474-8592
- **Klinic Crisis Line (24/7):** 204-786-8686
- **Klinic Community Health:** 204-784-4090
- **Mobile Crisis Service:** 204-940-1781
- **Crisis Stabilization Unit (24/7):** 204-940-3633,
- **Adult Mental Health Crisis Response Centre (24/7 Services),** 204-940-1781
- **Manitoba Addictions Helpline:** 1-855-662-6605

*IF YOU ARE IN CRISIS, CALL THE KLINIC CRISIS LINE: 204-786-8686

Notice Regarding Collection, Use, and Disclosure of Personal Health Information by the University

Your personal health information is being collected under the authority of *The University of Manitoba Act*. The information you provide will be used by the University for the purpose of communication. Your personal health information may be disclosed to Shared Health. Your personal health information will not be used or disclosed for other purposes, unless permitted by *The Personal Health Information Act* (PHIA). If you have any questions about the collection of your personal health information, contact the Access and Privacy Office (tel. 204-474-9462), 233 Elizabeth Defoe Library, University of Manitoba, Winnipeg, MB, R3T 2N2.

Clicking “I agree” at the bottom of this page indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and/or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

This research has been approved by the Research Ethics Board at the University of Manitoba, Fort Garry campus. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Officer at 204-474-7122 or humanethics@umanitoba.ca. We encourage you to save or print a copy of this consent form now for your records, as it will not be available later.

If you do not wish to participate in this study now, please click “I DISAGREE” below.

If you are interested in participating, please complete the following items:

- ☐ I understand that, if unexpected clinical findings are found in my MRI scan, my personal information and images will be shared with a radiologist and possibly my Family Doctor.

Your Family Physician’s name: _____

Your Family Physician’s Clinic name: _____

Your Family Physician’s phone number: _____

If you have read the information presented in this form and do not have any questions about this study, please click “I AGREE”. You should only click “I AGREE” if you agree to participate with full knowledge of the study presented to you in this information and consent form, and of your own free will. By clicking “I AGREE”, you also consent to the PI contacting you via phone to book the fMRI scan.

I AGREE I DISAGREE

Name (please print): _____

Signature: _____

Date: _____

Phone number: _____

COVID-19 Consent Appendix

This document contains important information about in-person research during the COVID-19 public health crisis. COVID-19 (also called SARS-CoV2) is an illness caused by the coronavirus.

Coronaviruses are most commonly spread from an infected person through: a) respiratory droplets when you cough or sneeze; b) close personal contact, such as touching or shaking hands; or c) touching something with the virus on it, then touching your eyes, nose or mouth before washing your hands.

The University of Manitoba is committed to taking measures to protect the health and safety of their campuses and the wider community. Your safety is important to us. The university has suspended most research that cannot be conducted remotely or virtually. This project requires in-person visits. Therefore, it is important to understand that your participation in this study may increase your exposure to COVID-19.

Our project has been approved to proceed by the Research Ethics Board, our Faculty, the COVID Recovery Response Team, the COVID Recovery Steering Committee, and the University Provost. In order to gain approval, we created policies to ensure the safety of the research team and participants. These plans were reviewed and approved by the parties above. These precautions include:

- All study research teams are wearing 3-ply reusable or disposable masks. You are also required to wear a mask.
- We also require all of our employees to screen themselves for symptoms daily before they come into work, and we'll screen you for symptoms the day of your visit.
- You should not attend any visits if you are not feeling well or exhibiting any symptoms of COVID-19, if you have been a close contact with someone with COVID-19 (or awaiting tests results), or have been told by a health official to self-isolate.
- We are following meticulous infection control practices, including disinfection, wearing gloves, and hand washing.
- We are limiting the number of visitors accompanying people for their study visits, and have rearranged and/or removed furniture in our waiting areas to enforce strict physical distancing practices.
- We ask that you attend the study alone. Accommodations can be made if necessary. Please let us know ahead of time if you require someone to attend with you.

COVID-19 is a serious health threat and the situation is evolving rapidly. If you feel that you are from a group that is more vulnerable to COVID-19 effects (e.g., senior (over the age of 60 years), immuno-compromised), please discuss your participation with the research team before providing your consent. You are under no obligation to participate and can change your mind about participating in the research at any time and without consequence.

The University of Manitoba is closely watching the situation in Manitoba and may restrict in-person research at any time. We will continue to keep you informed as to changes that may occur to this study.

There is a possibility that during your participation in the study you could come into contact with someone with COVID-19. We are required to collect your personal contact information that we must retain in order to follow up with you and/or conduct contact tracing if you may have been exposed to COVID-19 in coming to the research site. We cannot guarantee anonymity as the personal contact information identifies you as a participant and we may be required to disclose this information in the event of a possible exposure. Your contact information will be kept separately from data collected through the research study to allow for de-identification of the research data. You maintain your right to withdraw from the study at any time, including your research data. If you do withdraw from the study, we will still need to continue to maintain your contact information and will only give it to the University's Environmental Health and Safety (EHS) Office, Manitoba Health, and/or Shared Health if required for contact tracing. Please note, Manitoba Health, Shared Health or the University's EHS office will not have access to your research data.

If you have questions regarding this study, measures we are taking to keep all parties safe, or have any concerns, please do not hesitate to ask. You can contact any of the researchers or the Human Ethics office at humanethics@umanitoba.ca.

Clicking "I AGREE" indicates that you have understood to your satisfaction the information regarding participation and the COVID-19 risk and agree to participate. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

I AGREE I DISAGREE

Name (please print): _____

Signature: _____

Date: _____