

**ALEXITHYMIA AND INDIVIDUAL DIFFERENCES IN EMOTION
VALUATION AND SENSORY PROCESSING**

by

Sarah Nugent Rigby

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Department of Psychology
University of Manitoba
Winnipeg, Manitoba, Canada

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Abstract

Alexithymia is a dimensional personality trait characterized by difficulties identifying and describing feelings (DIF, DDF) and an externally-oriented thinking (EOT) style; it is also associated with impairments in emotion perception. The overarching goal of my dissertation was to investigate the ways in which alexithymic traits predict natural variation in our evaluation of emotional scenes, and in sensory processing more generally. In an initial experimental study, 106 adults completed measures of alexithymia and sensory processing sensitivity (SPS) and then made speeded judgments regarding the pleasantness of emotional scenes. Participants with stronger EOT and those who reported being easily overwhelmed by sensory environments evaluated the valence of positive scenes less accurately than those reporting low levels of these traits. Strong EOT also predicted less accurate evaluation of scenes depicting implied motion. I next used a survey-based approach to explore links between alexithymia and the processing of and responsiveness to environmental and body-based sensory cues in a non-clinical sample of 201 adults. My initial findings supported the view that EOT and problems with emotional appraisal (DIF/DDF) are distinct in a general sample, with each subscale showing unique relationships to certain aspects of sensory processing. Importantly, a mediation analysis suggested that links between interoceptive impairment and alexithymic traits could be accounted for by an individual's general sensory processing style. I next applied latent profile analysis to determine whether interrelationships between my study variables varied across distinct subgroups of individuals. This analysis revealed five classes of individuals that could be meaningfully distinguished by their relative strength of different alexithymic traits, and by differences in their interoceptive accuracy and sensory profiles. The classes identified included two alexithymic, one typical, and two alexithymic groups, showing different susceptibilities to

SPS. My dissertation provides support for the view that alexithymia is a multifaceted trait characterized by atypicalities in sensory processing that could impact embodiment, and perceptual and cognitive processes. As alexithymia is a transdiagnostic risk factor for psychopathology and a range of physical health problems, this basic research may have important implications for clinical science and intervention.

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Abbreviations

ABIC	Adjusted Bayesian Information Criterion
ACC	Anterior Cingulate Cortex
AES	Aesthetic Sensitivity
ANOVA	Analysis of Variance
APS	Affective Perceptual Sensitivity
ASD	Autism Spectrum Disorder
AS	Associative Sensitivity
BLRT	Bootstrapped Likelihood Ratio Test
CFI	Comparative Fit Index
CNS	Central Nervous System
DDF	Difficulties Describing Feelings
DIF	Difficulties Identifying Feelings
EOE	Ease of Excitation
EOT	Externally-Oriented Thinking
HA	High Alexithymia
IM	Implied Motion
IA	Interoceptive Accuracy
LA	Low Alexithymia
LO	Lateral Occipital Region
LH	Left Cerebral Hemisphere
LMR-LRT	Lo-Mendell-Rubin Adjusted Likelihood Ratio Test
LPA	Latent Profile Analysis
LR	Low Registration
LST	Low Sensory Threshold
MA	Moderate Alexithymia
MEPs	Motor Evoked Potentials
NPS	Neutral Perceptual Sensitivity
OPA	Occipital Place Area
PPA	Parahippocampal Place Area
RH	Right Cerebral Hemisphere
RMSEA	Root Mean Square Error of Approximation
RT	Response Time
SA	Sensory Avoidance
Seek	Sensation Seeking
Sen	Sensory Sensitivity
SPS	Sensory Processing Sensitivity
SRMR	Standardized Root Mean Square Residual
TBI	Traumatic Brain Injury

ToM	Theory of Mind
TOS	Transverse Occipital Sulcus
TMS	Transcranial Magnetic Stimulation

CHAPTER 1: GENERAL INTRODUCTION

The ways in which we process emotion cues are complex and achieving a better understanding of factors that underlie atypicalities in emotion processing is important. A key variable explored in this thesis is alexithymia—a personality trait characterized by difficulties identifying and describing one’s emotions, an externally-oriented thinking style, limited fantasizing abilities, and problems distinguishing emotions from non-affective body sensations (Nemiah, Freyberger, & Sifneos, 1976). High levels of alexithymia are associated with impairments in emotion perception. The overarching goal of my dissertation was to evaluate the ways in which specific alexithymic traits predict natural variation in our overall perception and experience of emotional stimuli, and in sensory processing more generally, using a combination of experimental and survey-based approaches.

My dissertation provides novel insights into the alexithymia construct and suggests directions for future research in the basic and clinical sciences. Before presenting my research, I will provide a brief review of the vast literatures examining emotion processing and emotional brain networks. I will also provide background information about alexithymia. I will conclude this introductory chapter with a brief overview of the studies that comprise this dissertation.

Emotions and Emotional Brain Networks

Almost fifty years ago, Ekman and Friesen (1971) conjectured that humans universally share six basic emotions (i.e., fear, anger, happiness, sadness, disgust, surprise), and that these distinct states have developed through evolutionary processes. Emotions are thought to serve adaptive functions that promote survival (LeDoux, 2012). As reviewed by Shackman and Wager (2019), however, the conceptualization of emotions has been equivocal in the recent literature. Whereas some research points to emotions as discrete states (Nummenmaa & Saarimäki, 2019),

others have commented that this view is limited based on the overlap observed across emotions with respect to the physiological and behavioural responses they evoke (Barrett & Satpute, 2019). Not surprisingly, emotions are strongly tied to both our internal states and our external environments. Complex dynamics between one's inner state and environment alter the ways in which emotions are understood, experienced, and expressed (Shackman & Wager, 2019). Understanding and adapting to one's emotional experience requires integrating bottom-up (e.g., physiological resonance) and top-down (e.g., regulation) processes, and atypicalities in either area can contribute to emotional pathology, such as anxiety disorders (Kim et al., 2011). Top-down processes include factors such as our previous beliefs, feelings, and attitudes, all of which can impact our perception of others and strongly influence our behaviour (Brooks & Freeman, 2019).

Neural regions frequently implicated in emotion processing in the literature include the amygdala, hypothalamus, periaqueductal grey, ventral striatum, insula, orbitofrontal cortex, and medial prefrontal cortex (Pessoa, 2017). Functions within these regions contribute to various cognitive and emotional systems. The amygdala is a structure that is typically underscored as the centre point of emotion and may be considered an important hub for integrated systems (Pessoa, 2017). This structure exhibits afferent and efferent connections to many neural regions, such as the hypothalamus, medial prefrontal cortex, orbitofrontal cortex, and brainstem (Kim et al., 2011; Pessoa, 2014, 2017), as well as sensory and somatosensory systems (Pessoa et al., 2017). When an environmental threat is perceived, the amygdala is thought to receive quick but imprecise signals through the thalamic pathway, and more complex but slower information transmitted through its cortical pathways (Dèbiec, 2014). Amygdala function is regulated in part through the medial and dorsal lateral prefrontal cortices (Kim et al., 2011). While the

amygdala's role in emotion processing is frequently highlighted, it is important to note that more recent understandings also emphasize its importance in information processing systems, salience marking, novelty detection, and the maintenance of vigilance and arousal (Pessoa, 2014).

Although isolated structures are often underscored in studies of the emotional brain, emotions themselves should be viewed as arising within "broadly distributed neural circuits" (Shackman & Wager, 2019, p. 693). Pessoa et al. (2017) contend that a better understanding of human emotion comes from conceptualizing the emotional brain as comprising of combinations of functionally integrated systems involving cortical and subcortical connections; and from recognizing the importance of *interactions* between large-scale networks, rather than focusing on the independent functions of structures within these networks. These authors argue for a broader view of emotions that also considers their relationships with cognitive functions. Indeed, it is well known that emotions affect brain responses related to memory, attention, and decision-making, and it has been suggested that signals arising from emotion and cognition might be integrated within the lateral prefrontal cortex (Pessoa et al., 2014).

Hemispheric Specialization for Emotion Processing

The idea that there are hemispheric asymmetries in emotion processing has been discussed in the literature for decades. Some of the most prominent theories relating to this are described briefly below. In discussing these theories, and at later points in this dissertation, I will emphasize work that investigates asymmetries in the processing of visual stimuli. Here, it is important to note that researchers have often taken advantage of the fact that each hemisphere initially processes visual input presented in the contralateral hemifield. In divided visual field studies, for example, stimuli are briefly flashed to one visual field or the other; a right hemisphere (RH) advantage is shown when stimuli initially presented to the left visual field are

processed more efficiently and/or accurately than those initially presented to the right visual field, and a left hemisphere (LH) advantage reflects the reverse.

According to the *Right Hemisphere Hypothesis* (Borod et al., 1998), the RH is specialized for emotion processing irrespective of stimulus valence. This hypothesis is supported by work using images of emotional stimuli in which initial processing by the RH (compared to LH) results in faster and more accurate behavioural responses (Calvo & Beltrán, 2014; Kayser et al., 2016; Simon-Thomas, Role, & Knight, 2005) and increased visual attention capture (Alpers, 2008). The *Valence Hypothesis* (Ahern & Schwartz, 1979) contends that the LH and RH preferentially process positively and negatively valenced information, respectively (e.g., Jansari, Rodway, & Goncalves, 2011). Support for this theory is mixed (Rodway, Wright, & Hardie, 2003). Thus, although the RH consistently shows advantages when processing negative facial expressions, findings regarding the LH advantage for positive expressions are more variable (Najt, Bayer, & Hausmann, 2013). The *Approach Withdrawal Hypothesis* (Rutherford & Lindell, 2011), also referred to as the *Approach Avoidance Hypothesis* (Harmon-Jones, 2004), emphasizes that we are either directed toward (approach system) or away from (avoidance system) emotional stimuli. According to this theory, processing emotion information that prompts approach is LH lateralized, whereas processing information that prompts avoidance is RH lateralized (Balconi, Vanutelli, & Grippa, 2017; Carver & Harmon-Jones, 2009; Harmon-Jones, Schmeichel, Mennitt, & Harmon-Jones, 2011; Robinson, Boyd, & Persich, 2016). An important conclusion to draw from the extant literature is that whether one sees support for the RH, valence, and/or the approach withdrawal hypotheses depends on the paradigm used (see Prete et al., 2015), the task demands (Coronel & Federmeier, 2014), the integrity of the corpus callosum (Prete et al., 2014), and the particular brain structures being studied (Costanzo et al.,

2015).

A recent model proposed by Shobe (2014) captures aspects of all three of the theories referred to above. Shobe contends that communication between the hemispheres is integral to processing emotional information. In her view, the two hemispheres play qualitatively different roles in our understanding and experience of emotions. The RH is responsible for automatically processing and coding emotional stimuli for valence, and for generating affect (i.e., a “genuine” or “gut” response). The LH provides additional interpretation of the emotion information, maintaining a positive bias important for emotion regulation, problem solving, and social interactions. Accurate processing of negatively valenced information in the LH is dependent upon the successful transfer of this information from the RH. When this transfer is disrupted, the LH’s ability to interpret negatively valenced stimuli and label emotions is compromised, and its positive bias becomes particularly evident. Shobe argues that interhemispheric communication and bilateral processing become increasingly important as task complexity increases. Support for her model comes from work evaluating temporal responses to emotional images (Mattavelli, Rosanova, Casali, Papagno, & Romero Lauro, 2016; O’Hare, Atchley, & Young, 2016), and from studies including people with agenesis of the corpus callosum (Paul et al., 2006), for example.

Alexithymia and Emotion Processing

Alexithymia is a stable and dimensional personality trait (Bagby, Parker, & Taylor, 2020) that is seen in approximately 10% of the general population (Mattila et al., 2010). In addition to being characterized by problems understanding and describing their own emotions, individuals displaying high levels of alexithymia show impairments in facial expression recognition (Jongen et al., 2014; Parker, Prkachin, & Prkachin, 2005), emotional body language processing (Borhani,

Borgomaneri, Làdavas, & Bertini, 2016), empathy (Bird & Viding, 2014; Valdespino, Antezana, Ghane, & Richey, 2017), and emotion regulation (Luminet & Zamariola, 2018; Panayiotou & Constantinou, 2017; Walker, O'Connor, & Schaefer, 2011). They also report having more interpersonal deficits (Jordan & Smith, 2017) and lower quality dyadic relationships (Kafetsios & Hess, 2019) than alexithymic individuals. Alexithymia is also associated with increased suicide risk (De Berardis et al., 2017), and is considered a risk factor for a wide range of conditions, including but not limited to: eating disorders (Fujiwara, Kube, Rochman, Macrae-Korobkov, & Peynenburg, 2017), major depressive disorder (Suslow et al., 2016; Zhang 2017), posttraumatic stress disorder (Frewen, Dozois, Neufeld, & Lanius, 2008), problems with alcohol use (Thorberg, Young, Sullivan, & Lyvers, 2009), and psychosomatic conditions (Larsen, Brand, Bermond, & Hijman, 2003). Alexithymia is highly prevalent in individuals with neurological disorders (Fusaroli, Bjørndahl, Roepstorff, & Tylén, 2015) such as traumatic brain injury (TBI), stroke, and epilepsy (Ricciardi, Demartini, Fotopoulou, & Edwards, 2015), although it is unclear whether alexithymia itself is distinct from the preponderance of affective disorders that are also frequently seen in these populations. Alexithymia is also seen in more than 50% of adolescents (Milosavljevic et al., 2016) and adults (Berthoz, Lalanne, Crane, & Hill, 2013) with autism spectrum disorder (ASD). It is widely held that the study of this transdiagnostic marker might provide important insights into factors underlying conditions involving social impairment (e.g., Grynberg et al., 2012), and into the functioning of the social brain more generally.

Factors that May Predispose Individuals to Alexithymia. There are various theories regarding the etiology of alexithymia. Genetic factors appear to play a role. Indeed, particular genes that are associated with alexithymia have been identified (Mezzavilla et al., 2015), and up to 42% of the variance in alexithymia can be accounted for by genetic contributions (Picardi et

al., 2011). However, disruptions in emotional and cognitive development have also been postulated to increase risk of alexithymia, as have atypicalities in sensory processing. In addition, alexithymia has been linked to atypicalities in parts of the emotional brain and acquired forms of alexithymia have been described in several neurological conditions. An overview of some of the research in these different areas is provided below.

Emotional and Cognitive Development. In his Multiple Code Theory, Bucci (1997) argued that emotions are first experienced as non-verbal representations early in life. Verbal representations are thought to develop later, alongside language development. In this view, alexithymia may reflect problems connecting these non-verbal and verbal representations. People with alexithymia might also lack the symbols to best represent their physiological states, resulting in a disconnect between their ability to experience physiological responses to emotionally charged events and their ability to understand them at a conscious level (see Taylor, 2000). Disruptions in early stages of the development of emotional awareness, and underdevelopment of emotional schemas, have been proposed as avenues through which alexithymia develops (Lane & Schwartz, 1987). Alexithymia has also been associated with disruptions in general language abilities (the alexithymia-language hypothesis; Hobson et al., 2018), and with alterations in various stages of emotion regulation (Preece, Becerra, Allan, Robinson, & Dandy, 2017).

Darrow and Follette (2014) conceptualize alexithymia from a behaviour analytic perspective as a deficit in one's repertoire of verbal behaviours about emotional concepts. They conjecture that a range of factors that limit opportunities for children to learn how to label and distinguish between their emotional states might contribute to alexithymia. These factors include things such as: failure of early caregivers to model emotional experiences or to notice or attend

to a child's emotion experiences (affecting subsequent learning/labeling of emotion language); very over- or under-sensitive learning environments; and disrupted development of relational framing (i.e., the establishment of relationships between emotions and emotional verbal behaviour). Darrow and Follette also suggest that children in whom emotional expression was extinguished or punished, and those who were not positively reinforced for expressing their emotions after trauma, might also be at increased risk for developing alexithymia.

Although early development may be very important, alexithymia can also be acquired in adulthood and reflect an avoidant coping response to traumatic experiences (Berenbaum, 1996; Krystal, 1982). Psychoanalytic theories highlight the roles that primitive ego defenses, experience of childhood trauma, and insecure attachment to caregivers might play in increasing one's risk for developing alexithymia later in life (Taylor & Bagby, 2013). Emotional neglect by caregivers early in childhood is also associated with later development of alexithymia; indeed, neglect accounts for 13% of the variance in this trait (Aust & Bajbouj, 2014). Aust and Bajbouj (2014) found that, in individuals with high levels of alexithymia, early neglect was associated with reduced acceptance of emotional experiences, increased problems regulating emotions, and experiencing elevated physiological sensations that accompany emotions.

Sensory Processing. Numerous observations have led to the suggestion that alexithymia may be associated with atypicalities in interoceptive processing (see Brewer, Cook, & Bird, 2016). Problems with interoception could make it challenging for one to distinguish between one's own physical and emotional states, but it could also disrupt other aspects of emotional processing (Bird & Viding, 2014).

Although impairments in interoception have been described by some as markers of alexithymia (Brewer et al., 2016), there are conflicting theories regarding the nature of this

relationship (Scarpazza & di Pellegrino, 2018) and interoceptive deficits are not always observed in people with strong alexithymic traits (Nicholson et al., 2018). These mixed findings may relate to an important point raised earlier—namely, that emotions are strongly tied to our processing of both internal states *and* cues from the external environment. A key idea tested in the present work is that alexithymia is associated with particular ways of processing sensory information in general. In particular, I explored its relationship to a genetically predetermined trait called sensory processing sensitivity (SPS; Aron & Aron, 1997). People displaying SPS have rich inner lives and engage in deep/complex processing; of particular relevance to the current research is the fact that they are also highly sensitive to both positive and negative environmental stimuli, and tend to approach novel situations cautiously (Aron, Aron, & Jagiellowicz, 2012). As will be discussed in more detail in Chapters 2 and 3, past research has suggested relationships between specific alexithymic traits and these latter aspects of SPS (Liss, Mailloux, & Erchull, 2008).

Neural Alterations in Alexithymia. As noted earlier, alexithymia is a common feature in neurological disorders (Ricciardi et al., 2015). It can arise secondary to TBI; indeed, Wood and Williams (2007) found that 57.9% of participants in their study who had experienced a TBI exhibited high levels of alexithymia. Increased problems identifying and describing emotions, in particular, is characteristic of this population (Koponen et al., 2005). Based on Shobe's (2014) model of emotion processing, one might speculate that disruptions in interhemispheric transfer (which are often observed in TBI; Mathias et al., 2004) contribute to these difficulties. Hobson et al. (2018) found that, in individuals who had experienced a TBI, language impairment and damage to regions within the inferior frontal gyrus were both associated with alexithymia.

Structural and functional alterations in various neural regions involved within the emotion networks described earlier are often seen in people with alexithymia. For example, Ho, Wong, and Lee (2016) observed alterations in the integrity of the right superior longitudinal fasciculus in non-depressed individuals with alexithymia; they also reported that those with concomitant major depressive disorder showed disruptions in the morphology of the corpus callosum. Atypicalities in cerebellar (see Petrosini, Cutuli, Picerni, & Laricchiuta, 2017) and amygdala (Goerlich-Dobre, Lamm, Pripfl, Habel, & Votinov, 2015) volumes have also been observed in people with alexithymia; the former might contribute to deficits in emotional embodiment, and the latter to problems with empathy.

Alexithymia has been associated with functional alterations during emotion processing in the anterior cingulate cortex (ACC), insula, amygdala, corpus callosum, fusiform gyrus, parahippocampal gyrus, and orbitofrontal prefrontal cortex (Bermond, Vorst, & Moormann, 2006; Kano & Fukudo, 2013; Petrosini et al., 2017; Van der Velde et al., 2013; Xu, Opmeer, van Tol, Goerlich, & Aleman, 2018). Donges and Suslow (2017) concluded that alterations in activity within the amygdala, fusiform gyrus, and insula are more often observed in alexithymia when task demands are challenging, and when emotion information is negatively valenced. Jongen et al. (2014) observed that *hypoactivity* in the ACC, amygdala, insula, striatum, inferior frontal gyrus, middle temporal gyrus, thalamus, parahippocampal gyrus, and middle frontal gyrus was associated with reduced performance on a facial emotion labeling task in people with high, compared to the low, levels of alexithymia. Conversely, Heinz et al. (2010) observed *increased* activity in the ACC in people with high (vs. low) levels of alexithymia during an emotional perception task, which they argued might reflect efforts to down-regulate or suppress high arousal emotion information. These authors also found that insular activity was influenced

by both valence and arousal in alexithymic individuals, but only by arousal in those with alexithymia. In line with this, Hadjikhani et al. (2017) found that alexithymic traits were positively related to increased insula activity when viewers were forced to look at the eyes of static faces displaying different expressions during passive viewing—an act that might increase arousal. Importantly, Deng, Ma, and Tang (2013) suggested that whether they observed reduced or enhanced functional activation of the ACC, mediofrontal cortex, and insula in individuals with alexithymia depended on both stimulus valence and intensity. Together, these findings suggest that it is important to consider both task demands and the content of emotional stimuli when studying the neural correlates of alexithymia.

Alterations in hemispheric contributions to emotion processing are sometimes observed in behavioural and neuroimaging studies when people with high levels of alexithymia process emotional information. Thus, alexithymia has been associated with increased RH malfunctioning, inhibition, responsivity, or impairment (Aftanas & Varlamov, 2004; Bermond et al., 2006; Kano et al., 2003; Ricciardi et al., 2015); with LH hyperactivation (Bermond et al., 2006; Karlsson, Näätänen, & Stenman, 2008); and/or with deficits in interhemispheric transfer of emotion information (Parker, Keightley, Smith, & Taylor, 1999; Shobe, 2014; Ho 2016). Some suggest that disconnection between right and left cerebral hemispheres could account for problems associating non-verbal and verbal representations of emotions (Taylor, 2000).

Measurement and Conceptualization of Alexithymia. A variety of measures have been developed to assess alexithymia. One of the most widely-used self-report instruments is the 20 item Toronto Alexithymia Scale (TAS-20; Bagby, Parker, & Taylor, 1994). This measure is comprised of three subscales: Difficulty Identifying Feelings (DIF), Difficulty Describing Feelings (DDF), and Externally-Oriented Thinking (EOT). Subscale scores are summed to

generate a total score, with higher values indicating stronger expression of alexithymia. This conceptualization of alexithymia is referred to in later chapters as the “Toronto model.”

Researchers have also argued that alexithymia includes both a cognitive component (that can be measured by the TAS-20) and an affective component (that is not captured by this instrument) which includes both flattened affect and deficits fantasizing (e.g., Bermond et al., 2006; Goerlich-Dobre, Bruce, Martens, Aleman, & Hooker, 2014). This way of conceptualizing alexithymia is referred to in Chapter 3 as the “Amsterdam model.” Both the cognitive and affective components of alexithymia can be measured using the Bermond Vorst Alexithymia Questionnaire (BVAQ; Bermond & Vorst, 2001). Considering these two dimensions separately has allowed for the conceptualization of different *subtypes* of alexithymia, distinguished on the basis of how people score on each dimension (e.g., Berthoz & Hill, 2005; Goerlich-Dobre et al., 2014; Larsen et al., 2003; Vorst & Bermond, 2001). This may be important, as these subtypes are argued to differentially predict specific emotion regulation difficulties (Moormann et al., 2008). However, it should be noted that there may be overlap between particular cognitive and affective subscales (de Vroege, Emons, Sijtsma, & van der Feltz-Cornelis, 2018), and some researchers have argued that the construct of alexithymia is best captured by the DIF, DDF, and EOT dimensions (Preece et al., 2017).

Although *distinguishing between* the TAS-20 subscales in neurobiological research is relatively nascent, the available research suggests that doing so is important. DDF appears to be the alexithymia dimension that is most consistently associated with emotional knowledge deficits (Luminet & Zamariola, 2018). However, as summarized by Goerlich et al. (2018), both DIF and DDF seem to be important in implicit and explicit emotion processing and are associated with atypical activity within the amygdala and neural regions associated with somatosensory

processing. EOT, on the other hand, does not seem to be as strongly related to activity within emotion networks in the brain. Interestingly, Aaron, Snodgrass, Blain, and Park (2018) conjecture that EOT may be a stable trait that predicts an individual's aptitude for emotion processing, whereas DIF and DDF may be more state-like and predict one's tendency to engage in emotion processing in real life.

Some researchers have purported that EOT is conceptually distinct from the other subscales of the TAS-20, in that it is more associated with cognition and attention than with one's experience of emotions (Demers & Koven, 2015; Goerlich, 2018; Moriguchi et al., 2009; Preece, Becerra, Robinson, Dandy, & Allan, 2018; Preece et al., 2017). Preece et al. (2017) developed the attention-appraisal model of alexithymia, building upon Gross's (2014) valuation model of emotion regulation. According to Gross's model, when an emotional reaction occurs, we must first attend to it, following which we appraise or make sense of that reaction and then respond to it. According to Preece et al., problems with EOT might reflect disruptions during the attention stage of emotion regulation, arising from reduced focus on internal emotion cues. Conversely, problems with DIF and DDF reflect problems at the appraisal stage. Based on the foregoing discussion, it seems to be important for researchers to examine the TAS-20 subscales individually, rather than relying solely on overall alexithymia scores. This approach was taken in the current work.

Dissertation Overview

The preceding sections provide context for some of the research questions that were undertaken in my dissertation. Specifically, in Chapter 2 I evaluated how performance on an emotional scene perception task varied as a function of both the strength of viewers' alexithymic traits and particular stimulus characteristics, including whether the images were positively or

negatively valenced and whether they did or did not depict implied motion (a feature presumed to increase stimulus complexity; see Chapter 2). I also sought to explore whether alexithymic traits influenced the strength or direction of any observed hemispheric asymmetries in the processing of scenes. In a supplementary analysis, I compared the variance accounted for by alexithymia and SPS in performance in my scene perception task.

There were two main aims for the research described in Chapter 3. First, I investigated relationships between self-reported alexithymic traits and both the processing of and responsiveness to environmental and body-based sensory information in a large sample of young adults. Second, I explored whether I could identify subtypes of participants based on their responses on these measures. I was particularly interested in the question of whether distinct subtypes of alexithymia might emerge.

The over-arching goal of my dissertation was to make several novel contributions to the literature by exploring how alexithymic traits affect our assessments of emotional scenes, and relate to atypicalities in the processing of both internal and environmental sensory cues. From a basic science perspective, this work enhances our understanding of the social brain and of factors that contribute to natural variation in social perceptual and cognitive processes. But this work also has the potential to inform clinical practice; I will return to this topic in my concluding chapter.

CHAPTER 2: ALEXITHYMIC TRAITS AND THE VALUATION OF EMOTIONALLY VALENCED SCENES

High levels of alexithymia are associated with altered emotion perception (Grynberg et al., 2012; Jongen et al., 2014; Parker, Prkachin, & Prkachin, 2005; Vermeulen, Luminet, & Corneille, 2006). These findings are well established in the area of facial expression recognition. In contrast, the ways in which this trait influences emotional scene perception has been relatively underexplored. Extending our knowledge in this area is important, given that integration of various types of cues (e.g., facial expressions, body postures, surrounding objects, context) is an essential step for optimal emotion understanding in everyday life, and individual differences are important to consider (rather than control for) when researching visual scene perception (De Haas, Iakovidis, Schwarzkopf, & Gegenfurtner, 2019). The main goals of Chapter 2 were to investigate the relationship between alexithymic traits and the evaluation of static emotional scenes, and to explore whether the introduction of implied motion cues affected this relationship. Additionally, the work described in this chapter aimed to elucidate whether or not individuals with strong alexithymic traits exhibited atypical hemispheric contributions to emotional scene perception. A final goal of this chapter was to compare variance accounted for by alexithymia and SPS during scene perception.

Scene Perception

When visually processing the scene around us in a natural environment we are constantly inundated with sensory information. According to Malcolm, Groen, and Baker (2016), visual scene understanding is a complex and dynamic task that involves processing environmental information in ways that support various behavioural goals, such as scene recognition, search, or navigation. While the gist or meaning of scenes can be rapidly gleaned (Malcolm et al., 2016),

achieving full scene understanding requires combining information about low-level features (e.g., colour, edge density, spatial frequency, and motion) with high-level characteristics such as context (Wu, Wick, & Pomplun, 2014). Henderson and Hayes (2017) studied observers' eye movements as they passively viewed scenes, and generated "attention maps" (based on fixation density) for regions of high visual saliency and high semantic saliency. They found that semantic saliency accounted for significantly more variance in fixation behaviour than visual saliency. Moreover, whereas semantic saliency continued to account for unique variance in attention after controlling for visual saliency, the reverse relationship was not significant. These findings were replicated when they asked participants to make on-line decisions about these scenes (Henderson, Hayes, Rehrig, & Ferreira, 2018). Together, their results suggest that cognitive relevance is strongly implicated in attentional guidance during scene processing. Individual differences in scan patterns have also been found to account for individual differences in cognitive abilities (more than 40% of variance in viewer intelligence and working memory abilities and more than 33% of processing speed; Hayes & Henderson, 2017), and account for significant variance in the strength of ASD and attention deficit disorder traits, as well as dyslexia scores (Hayes & Henderson, 2018). Together, these findings suggest that scene understanding involves a combination of bottom-up and top-down processes (Malcom et al., 2016) and individual differences in scene processing may have important clinical implications (Hayes & Henderson, 2018).

Our brains have evolved specialized systems to process scene information including, but not limited to, regions within both the ventral and dorsal visual streams (Malcolm et al., 2016). The parahippocampal place area (PPA), occipital place area (OPA; also known as the transverse occipital sulcus [TOS; Ganaden, Mullin, & Steeves, 2013]), and retrosplenial complex are

frequently implicated during natural scene perception, as they show greater activation in response to scenes than to faces or objects (Groen, Silson, & Baker, 2017). These regions show strong functional connectivity with one another and seem to include anterior subnetworks implicated in spatial memory and processing, and posterior subnetworks responsible for scene perception (Epstein & Baker, 2019).

Objects are always found within visual scenes, and the processing of objects and scenes appears to be interactive. For example, the PPA and OPA are sensitive to changes in *object* properties, such as the space around which viewers can interact with an object (i.e., the interaction envelope; Bainbridge & Oliva, 2015). Additionally, during initial stages of repetitive transcranial magnetic stimulation (rTMS) to the left lateral occipital region (LO)—a region preferentially activated by objects—object categorization is impaired but scene categorization and activity within the left PPA is enhanced (Mullin & Steeves, 2013). Interestingly, although applying rTMS to the left LO leads to reduced activity in the left TOS, rTMS to the left TOS does not impact object processing in the left LO (Rafique, Solomon-Harris, & Steeves, 2015). Despite falling outside of the classically defined retinotopic cortex, scene regions show contralateral (vs. ipsilateral), peripheral (vs. foveal), and elevation-related (i.e., upper or lower visual field) biases, supporting the view that the distinction between low- and high-level processing breaks down during scene perception (Epstein & Baker, 2019; Groen et al., 2017).

Processes that support scene understanding involve placing oneself *within* a scene (Groen et al., 2017). If the scene depicts humans or manipulable objects, the observer may also embody or simulate the actions portrayed or implied (Malcolm et al., 2016). Although one may argue that scenes (and the objects within them) are rarely completely emotionally neutral (i.e., that they generally hold some degree of micro-valence), increasing the emotional saliency of scenes also

impacts how scenes are processed and understood. For example, Bradley, Sapigao, and Lang (2017) observed that when viewing highly arousing emotional scenes, viewers' pupils generally showed a dilation response within 500ms of scene presentation, and they remained dilated until stimulus offset, potentially reflecting an overall arousal response to emotional scenes regardless of their valence. Kuniecki, Wołoszyn, Domagalik, and Pilarczyk (2017) found that fixating on emotional elements within valenced (compared to neutral) scenes resulted in greater responsivity in the lateral occipital complex. Introducing emotional content to scenes also affected fixation behaviours and fixation-related neural responses in this study. Frank and Sabatinelli (2014) reported that, compared to viewing neutral scenes, processing emotional scenes (regardless of valence) leads to enhanced activity within the amygdala, ventral visual structures, and particular thalamic nuclei (pulvinar and mediodorsal). Members of this research team also observed increased activity within and bidirectional connectivity between the orbitofrontal cortex, amygdala, and fusiform gyrus while participants passively viewed emotional, compared to neutral, scenes (Frank, Costa, Averbeck, & Sabatinelli, 2019). These authors posit that interactions between parts of this circuit determine stimulus value, update reward contingencies, and modulate attention to emotional stimuli. Interestingly, early posterior negativity and activations within the frontoparietal and lateral occipital regions were stronger in response to pleasant than unpleasant scenes. This enhanced "pleasure bias" may reflect evolved attention processes when viewing pleasant scenes (Frank & Sabatinelli, 2019).

Certain classes of stimuli within scenes, such as faces and bodies, strongly capture attention (Wu, 2014). Viewing an expressive face in a scene contributes to our understanding of the valence or meaning of the scene. Although there is notable overlap between neural structures that are involved in processing emotional scenes and expressive faces, distinguishable responses

in particular regions are often observed. This was demonstrated in the results of a meta-analysis of functional imaging studies measuring emotion enhancement of blood oxygen level dependent signals, performed by Sabatinelli et al. (2011). These authors confirmed that expressive scenes and faces similarly activated the amygdala. Overlapping activation patterns were also evident within the medial prefrontal cortex, inferior frontal cortex, inferior temporal cortex, and extrastriate occipital cortex, although *clusters* within these regions sometimes distinguished scenes from faces. However, they also found that regions within LO and orbitofrontal cortex, dorsal ACC, pulvinar, and the medial dorsal nucleus of the thalamus were more strongly activated during processing of emotional scenes compared to faces. Thus, although there is overlap in the neural substrates of emotional face and scene perception, there are fundamental differences in the underlying neural processes.

Factors that Increase the Complexity of Scene Perception

As noted above, increasing the emotional saliency of scenes broadens the network of neural regions that are involved in scene processing. As outlined in Chapter 1, the valence of emotional cues is also important to consider. Positive valence generally motivates approach, whereas negative valence might motivate a larger range of responses including approach, avoidance, aggression, or “freezing” depending on the situation (Kuhbandner, Spachtholz, & Pastötter, 2016; Roelofs, 2017). As such, the processing of negatively valenced scenes may be more complex than the processing of positively valenced scenes—a fact that may impact the extent to which the right and left cerebral hemispheres are differentially engaged in their processing (e.g., Shobe, 2014).

This idea was tested in a study by Hughes and Rutherford (2013). They developed a paradigm to investigate hemispheric contributions to the processing of emotional stimuli, and

used it to test viewers' evaluations of images obtained from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) and letters (Hughes, Upshaw, Macaulay, & Rutherford, 2016). Unlike in the divided visual field technique, in Hughes and Rutherford's task viewers make judgments regarding stimuli presented centrally for relatively long exposure durations (2.5 s). On some trials, a flashing square is presented in the left or right periphery early during stimulus presentation, to draw attention and thereby "distract" the contralateral hemisphere—ostensibly shifting processing more heavily toward the ipsilateral hemisphere. Hughes and Rutherford contend that comparing participants' performance during left and right distractor trials provides an index of laterality, and that adding a no distractor condition allows one to explore the possible advantages of hemispheric interaction. The results of their study on asymmetry in the processing of emotional scenes were mostly in line with the valence hypothesis (RH advantage for negative and LH advantage for positive scenes). Interestingly, however, they also found that processing negatively valenced scenes benefitted more from hemispheric interaction than processing positive scenes, providing some evidence that negative scenes are more complex.

Other stimulus characteristics also undoubtedly increase scene complexity. In addition to valence, in the current investigation I was interested in the extent to which the presence or absence of implied motion (IM) within static images of scenes influenced how these scenes were evaluated. As noted earlier, motion information within scenes can capture attention (Wu, 2014). Importantly, motion can be real (as in the case of dynamic stimuli such as films) or simply *implied* (in static photographs). Movement can be suggested visually in a static image in a variety of ways, such as through the use of diagonal, gestural, and directional lines. The information that is captured in "frozen action" photos (e.g., of a person diving into water)

conveys a strong sense of movement that is incorporated into our representation of the scene in memory (Freyd & Finke, 1984). IM can be present in images of animate beings or inanimate objects (Shirai & Imura, 2014). The processing of IM in these different types of stimuli may involve different encoding mechanisms (Lu, Li, & Meng, 2016), but nonetheless the idea that images that depict IM are more *complex* than those that do not is supported by the observation that viewing IM images recruits areas of the brain important for processing real motion (Kourtzi & Kanwisher, 2000), and produces larger motor evoked potentials (MEPs; indicating increased motor facilitation), compared to viewing images that do not contain IM (Borgomaneri, Gazzola, & Avenanti, 2012). It is also supported by the finding that increasing IM *coherence* enhances activity within the middle temporal complex, as does real motion coherence (Jia, Xu, Sweeney, Wang, Sung, & Wang, 2019).

There appears to be neural overlap between regions that encode IM and emotion information (Kolesar et al., 2016). Thus, images of body postures that imply action *or* emotion result in similarly increased MEPs compared to non-action and emotionally neutral postures (Borgomaneri et al., 2012). When IM provides emotional cues, the valence of the information conveyed seems to be an important determinant of one's neural response. For example, Schutter, Hofman, and Van Honk (2008) found that participants showed increased MEPs in response to static facial expressions depicting fear compared to happy and neutral expressions. Similarly, Borgomaneri, Gazzola, and Avenanti (2014) found heightened MEPs early in processing when participants viewed negatively valenced scenes, and elevations later in processing for emotionally intense scenes regardless of valence. In a subsequent study, these authors looked at temporal responses to images of emotional/IM body postures (Borgomaneri, Gazzola, & Avenanti, 2015). They found that people oriented to emotional IM early in processing and

showed evidence consistent with engaging in simulation of both emotional and neutral actions later in processing. Thus, overall the work reviewed suggests that IM seems to impact how faces, bodies, and scenes are processed.

Given that IM is a factor that seems to increase scene complexity, images containing IM might benefit from hemispheric interaction in typical adults. In this regard, it has been reported that TMS applied to two components within motion-sensitive visual area V5/MT+ in the LH decreases efficiency of processing low-level motion information in the contralateral visual field, whereas stimulation of these areas in the RH affects processing of such information in both contralateral and ipsilateral visual fields (Strong, Silson, Gouws, Morland, & McKeefry, 2019). These findings suggest that the RH may play a key role in processing motion cues from the environment quickly, given its more rapid access to information across the visual fields.

Alexithymia and Perception of Faces and Scenes

The relationship between alexithymic traits and impairments in processing facial expressions has been widely studied. Results from this work suggest that typical adults with high (compared to low) levels of alexithymia are less accurate when labeling static facial expressions (Jongen et al., 2014), are slower to respond to face-like stimuli depicting angry expressions (Vermeulen et al., 2006), and show increased difficulty recognizing briefly presented facial expressions (Swart, Kortekaas, & Aleman, 2009). People with stronger alexithymic traits require greater emotional intensity to identify images of fearful (but not happy or disgusted) facial expressions (Starita et al., 2018). In addition, fixating on the eye region of static faces is associated with decreased task accuracy during emotion perception tasks in adults with alexithymia (Fujiwara, 2018).

Some work examining the effects of alexithymic traits on facial expression processing has been conducted in clinical populations. For example, in a study of adults with and without ASD, some difficulties in emotional processing were more closely related to the presence of alexithymia than to ASD severity (Cook, Brewer, Shah, & Bird, 2013). Comorbid alexithymia in adolescents with ASD is associated with decreased accuracy in perception of anger (Milosavljevic et al., 2016). In adults with eating disorders, alexithymia accounts for unique variance in recognition thresholds for facial expressions of happiness, disgust, and pain (Brewer, Cook, Cardi, Treasure, & Bird, 2015).

In studies that have evaluated links between specific TAS-20 subscales and facial emotion recognition, stronger DDF has been associated with increased difficulty processing negative facial expressions (Parker et al., 2005), and slower responses to angry and fearful expressions (Ihme et al., 2014). In their review, Donges and Suslow (2017) suggest that stronger DIF might be linked to reduced RH engagement during emotion perception and/or impaired capacity to embody fearful facial expressions. These authors further speculate that EOT might be linked to lower processing efficiency when encountering threatening facial expressions. Overall, the reviewed work suggests that people with higher levels of alexithymia may require stronger emotion cues (e.g., increased expression intensity) and more time to process this information during various facial expression perception tasks (Grynberg et al., 2012).

Scene perception has been less widely studied in alexithymia, and the results of extant work exploring this using IAPS images (the source of images used in the present investigation) have been mixed. In a behavioural study, Koven (2014) found that people with strong (compared to weak) alexithymic traits rated positive and neutral IAPS images more negatively. Interestingly, no group differences were observed with aversive images. The authors suggested

that people with alexithymia show a decreased response to appetitive information or greater physiological decoupling (i.e., disparity between physiological arousal and subjective ratings of arousal). In contrast, in other work group differences in *subjective* ratings regarding IAPS images have not been observed, although differences in neural (e.g., Berthoz et al., 2002; Franz, Schaefer, Schneider, Sitte, & Bachor, 2004; Heinzl et al., 2010) and electrodermal (e.g., Pollatos & Gramann, 2011) responses were evident.

Alexithymia is associated with atypical responses to affective films. In one study, participants with disordered eating were required to label the emotion of the protagonist during viewing of brief films. Higher TAS-20 scores were associated with deficits in emotion recognition, and accounted for 29% of the variance in task performance (Ridout, Thom, & Wallis, 2010). Alexithymic traits also seem to affect emotional and physiological responses to affective films (Karlsson et al., 2008). For example, women with high (vs. low) EOT show dampened physiological reactions in response to (but comparable subjective ratings of) sad films, which suggests that EOT may be the alexithymic dimension that contributes most strongly to physiological decoupling (Davydov, Luminet, & Zech, 2013). Stronger alexithymic traits are also associated with a tendency to report experiencing “no emotions” and providing lower arousal ratings when viewing evocative films, and to exhibiting faster responses to items asking about one’s emotions (Aaron et al., 2018). The regression findings from this work also suggested that EOT was associated with lower awareness of emotional states and of reduced experience of mixed emotional reactions to negatively valenced films, in particular.

Alexithymic traits also seem to affect the ways in which information within scenes is integrated to develop scene understanding. Thus, presenting facial expressions that are congruent (vs. incongruent) with scene context (e.g., viewing a fearful face in a scene where a

gun is pointing toward the person) improves affect recognition in typical groups, but not in some clinical groups (ASD, schizophrenia) that are often marked by heightened alexithymia (Sasson, Pinkham, Weittenhiller, Faso, & Simpson, 2016). These group differences were not observed when evaluating affect recognition for faces presented in isolation. Individuals with ASD in this work also showed reduced attention to faces when viewing scenes with incongruent emotion information. Although alexithymic traits were not measured in this study, others have reported that alexithymia predicts reduced attention to faces in scenes better than an ASD diagnosis (Bird, Press, & Richardson, 2011). Furthermore, Yamashita et al. (2016) found that, in alexithymic adults, judgments of changes in subtle facial expressions were fastest when the expression changes were consistent with changes in the valence of a scene, but that this congruency effect was not evident in alexithymic individuals. This suggests that integration of emotional context with facial cues may be disrupted in alexithymia. Further support for this idea comes from recent work by Jakobson and Pearson (2020). They found that stronger DIF was associated with needing more time to integrate and utilize nonverbal cues (from facial expression, prosody, and body posture) to infer how a speaker's intended a non-literal statement to be understood (i.e., whether the statement was meant to be taken literally, was spoken sarcastically, or was a lie). Others have reported that EOT, in particular, is associated with shorter fixation dwell times on images depicting depressive (but not anxious, neutral, or positive) content (Wiebe, Kersting, & Suslow, 2017). Thus, overall there is evidence that alexithymia is associated with atypical integration of emotional (facial expression and context) cues, and reduced attention to faces during scene perception.

In the natural world we often interpret and react to emotional information conveyed, in part, by movement. There is some evidence that the introduction of movement cues might

increase the processing challenge for people with stronger alexithymic traits. For example, Lorey et al. (2012) reported that participants with high (vs. low) levels of alexithymia were less confident (although not less accurate) in their judgments of the valence of emotions conveyed through whole-body point-light displays. Recently, Wei, Rushby, and De Blasio (2019) suggested that alexithymia is associated with an attentional bias toward perceptual motion cues at the expense of socially relevant gaze cues. The relationship between alexithymia and IM has been explored with stimuli depicting emotional body postures. Here, although alexithymic individuals showed modulation of early visual encoding (N190) of body postures depicting fear, those with alexithymia did not (Borhani et al., 2016). Interestingly, although these authors noted that encoding of IM body motion *itself* might be preserved at the neural level in alexithymia, other work suggests that alexithymia may affect how this information is encoded and/or maintained in working memory. For example, Senior, Hassel, Waheed, and Ridout (2018) asked participants reporting different levels of alexithymic traits whether two images of briefly and consecutively presented faces were identical or not. The second image presented was either the same as the first, or the expression depicted was 25% more or less intense than that shown in the first image. By comparing speed and accuracy on these trial types, they made inferences about the degree to which participants automatically incorporated information about continuing (forward) motion into their memory representations. Participants with stronger DIF scores showed smaller forward memory biases, which the authors argued reflected poorer processing of IM cues. To my knowledge, the relationship between alexithymia and IM has yet to be explored with emotional scenes.

How, or if, hemispheric contributions to emotion perception are altered in those with alexithymia is unclear. As noted in Chapter 1, some work suggests that alexithymia is associated

with increased RH malfunctioning, inhibition, or impairment (Aftanas & Varlamov, 2004; Bermond et al., 2006; Kano et al., 2003; Ricciardi et al., 2015), LH hyperactivation or biases (Bermond et al., 2006; Karlsson et al., 2008), or deficits in interhemispheric transfer of emotion information (Liemburg et al., 2012; Parker, Keightley, Smith, & Taylor, 1999; Shobe, 2014). Any (or all) of these problems could, in theory, lead to deficits in cue integration for processing of (particularly complex) emotional stimuli, such as those depicting IM.

The Current Study

The primary goal of Chapter 2 was to explore how variation in individual difference variables and stimulus complexity impacted emotional scene understanding. A subgoal of Chapter 2 was to use the paradigm developed by Hughes and Rutherford (2013) to measure hemispheric contributions to emotion perception. The current work extends their findings by accounting for alexithymia and for IM within scenes. As suggested above, the introduction of IM in emotional scenes should increase the computational complexity of the images resulting in increased processing difficulty, especially for those with stronger alexithymic traits.

I expected to replicate the findings of Hughes and Rutherford (2013) regarding hemispheric asymmetries in task performance, as described above. In addition, I expected that positive images would be easier to process than negative images, replicating findings of positivity biases in emotion perception (Zhao et al., 2017). Moreover, if negative valence and IM increase scene complexity, I reasoned that participants would generally be slower and less accurate when judging scenes with these attributes, compared to ones that were positively valenced and did not imply motion. Importantly, I also predicted that people reporting high (vs. low) levels of alexithymia would perform worse on the emotional scenes task overall, show atypical laterality effects, and/or be more strongly affected by the introduction of IM due to

problems with cue integration.

For exploratory purposes, I also assessed another individual difference variable, namely SPS. Individuals displaying this trait show sensory sensitivity, have rich inner lives, engage in deep/complex processing, and approach novel situations cautiously (Aron et al., 2012). They also exhibit heightened emotional reactivity to (Lionetti et al., 2018), and are easily overwhelmed by (Aron et al., 2012), positively and negatively valenced stimuli—factors that can interfere with cognitive processing. Including a measure of this trait was of particular interest as past research suggests a link between alexithymia and certain aspects of SPS (e.g., Liss, Mailloux, & Erchull, 2008). Given this, in an exploratory analysis I sought to determine if alexithymia or SPS better predicted task performance.

Method

Participants

I tested a sample of university students recruited through the Introduction to Psychology participant pool at the University of Manitoba; each received credit toward a course requirement. One male participant did not complete the alexithymia measure, and his data were excluded from all analyses. This left a final sample of $N = 106$ (64 women and 42 men, aged 18–31 years; $M = 21.0$, $SD = 2.8$). Participation was restricted to individuals who self-reported being right-handed and having normal or corrected-to-normal vision. Handedness was later confirmed through administration of a questionnaire (see below). All participants reported having normal developmental histories, and no previous diagnosis of a neurological disorder or significant head injury.

Procedure

The Psychology/Sociology Human Research Ethics Board at the University of Manitoba approved the testing protocol. All participants gave informed consent to take part and were tested individually in a quiet, dimly lit room. Participants completed a questionnaire designed to assess current mood (the International Positive and Negative Affect Schedule—Short Form, or PANAS; Thompson, 2007); this is often recommended in alexithymia research to ensure that low mood does not confound the results (e.g., Lane et al., 2015). They then completed the Edinburgh Handedness Inventory (Oldfield, 1971) and the emotional scenes task, in that order. The experimental task was explained verbally to each participant before they began the task and participants could ask questions during this time. Following the emotional scenes task, participants completed a demographics questionnaire, the TAS-20 (Bagby, Parker, & Taylor, 1994) and a measure of SPS, namely the Highly Sensitive Person Scale (HSPS; Aron & Aron, 1997). The order in which the last two questionnaires were completed was counterbalanced across participants. The entire testing protocol took 30 min to complete.

Materials

International Positive and Negative Affect Schedule – Short Form. The PANAS (Thompson, 2007) was administered to measure negative affect prior to the experimental task. This 10-item self-report questionnaire was derived from the original PANAS (Watson, Clark, & Tellegen, 1998). Five items assess positive affect (i.e., alert, inspired, determined, attentive, active) and five items assess negative affect (i.e., upset, hostile, ashamed, nervous, afraid). Participants indicated the extent to which they felt each of the emotions in the present moment on a 5-point Likert scale, ranging from 1 = *Very slightly or not at all* to 5 = *Extremely*. The PANAS shows adequate reliability and validity (Thompson, 2007).

Edinburgh Handedness Inventory. The Edinburgh Handedness Inventory (Oldfield, 1971) is a 12-item questionnaire used to assess participants' hand dominance as they complete daily tasks, such as writing, throwing, and using eating utensils. It was administered to confirm that participants met the inclusion criterion of being right-handed. In completing the inventory, participants indicated whether they preferred to use their right or left hand for a variety of unimanual activities. Participants were also instructed to indicate if they would never use their other hand unless they were absolutely forced to, or whether they were indifferent to which hand was used. A laterality quotient was computed for each participant based on his or her responses, with positive scores indicating right-handedness, and larger absolute scores indicating stronger handedness.

Toronto Alexithymia Scale – 20. The TAS-20 (Bagby et al., 1994) is comprised of 20 items that contribute to three subscales assessing core features of alexithymia: (1) difficulty identifying feelings (DIF; 7 items; e.g., “I am often confused about what emotion I am feeling”); difficulty describing feelings (DDF; 5 items; e.g., “I am able to describe my feelings easily”); and externally-oriented thinking (EOT; 8 items; e.g., “I prefer to just let things happen rather than understand why they turned out that way”). For each item, participants responded using a 5-point Likert scale ranging from 1 = *Strongly disagree* to 5 = *Strongly agree*. Scores can range from 20 to 100. Scores equal to or greater than 61 signify alexithymia, and scores equal to or less than 51 signify alexithymia (Parker, Taylor, & Bagby, 2003). Scores falling between these cut points are classified as borderline.

Highly Sensitive Person Scale. The HSPS (Aron & Aron, 1997) consists of 27 items that provide a measure of SPS. Participants responded to each item using a 7-point Likert scale ranging from 1 = *Not at all* to 7 = *Extremely*. A mean score is computed to obtain a total score

out of seven. Lionetti et al. (2018) recommend using the 30th and 70th percentiles to group individuals according to low, moderate, and high levels of SPS. These groups are referred to as Dandelions, Tulips, and Orchids, respectively. These labels were chosen to reflect differences in resiliencies across the groups. Dandelions can do well under most circumstances, whereas Orchids are more sensitive and need optimal early environments to thrive. Tulips fall somewhere in the middle of these extremes.

Based on confirmatory factor analyses, Smolewska, McCabe, and Woody (2006) proposed that the HSPS measures three specific aspects of SPS: ease of excitation (EOE), low sensory threshold (LST), and aesthetic sensitivity (AES). The EOE subscale (12 items) taps into how strongly one is affected by body-based cues (pain, hunger) and how easily one handles being in busy environments and multi-tasking. The LST subscale (6 items) addresses the extent to which one feels overwhelmed by or uncomfortable with certain kinds of sensory experiences, and how strongly one seeks to avoid them. The AES subscale (7 items) assesses the extent to which one feels “moved” by the arts. Subscale scores are obtained by averaging responses on relevant items.

Emotional Scenes Task. As in Hughes and Rutherford’s (2013) protocol, when completing the emotional scenes task participants made judgments regarding photographs obtained from the IAPS (Lang et al., 2008). Normative arousal and valence ratings have been compiled for this picture set, using scales that range from 0 = *Low arousal/Unpleasant* to 9 = *High arousal/Pleasant*. Images selected for this investigation ($N = 120$) were relatively neutral in arousal (mean rating 4.00–6.00); half were negatively valenced (mean rating 2.00–3.99; e.g., a car crash) and half were positively valenced (mean rating 6.01–8.00; e.g., smiling children). Half of the images of each valence depicted IM (e.g., a tornado) and half did not (e.g., a

mountain). Within positive and negative sets, mean valence was comparable for images with vs. without IM (paired *t*-tests: positive images, $p = .69$; negative images, $p = .71$), and images across all four sets had comparable subjective arousal ratings ($p \geq .11$). See Appendix A for a complete list of the stimuli used. Image sets were balanced with regard to content, with approximately two-thirds of the images of each type depicting humans or non-human animals, and the remainder depicting scenes from nature or inanimate objects. In the majority of cases, the most salient content fell near the centre of the image. In a few cases, the most salient content was displaced towards the left (four negative and three positive images) or the right (four negative and five positive images); one of the positive images in the latter set was mirror-reversed so that four images of each valence had a focal element that was displaced to the left or the right.

The procedures followed were closely modeled on the paradigm outlined by Hughes and Rutherford (2013). The task was created using E-Prime 2.0 (Psychology Software Tools, 2012) and was presented to participants on a PC computer. Each participant rested his/her chin on a chin rest to ensure that head position was aligned with the centre of the screen, at a viewing distance of approximately 57 cm. Each trial began with presentation of a central fixation cross for 500 ms, followed by a central stimulus image for 2.5 s. Stimulus images subtended a visual angle of 2.9° in height and 3.9° in width. A small white square (0.41° in height and width) served as the distractor. On one third of the trials of each type, the distractor appeared 7.4° to the right of center; on one third of the trials it appeared 7.4° to the left of center; and on the remaining trials no distractor was presented (see Figure 1 for an example of the task procedure). When present, the appearance of the distractor coincided with presentation of the stimulus image, and the distractor then blinked on-and-off at 50 ms intervals for 300 ms.

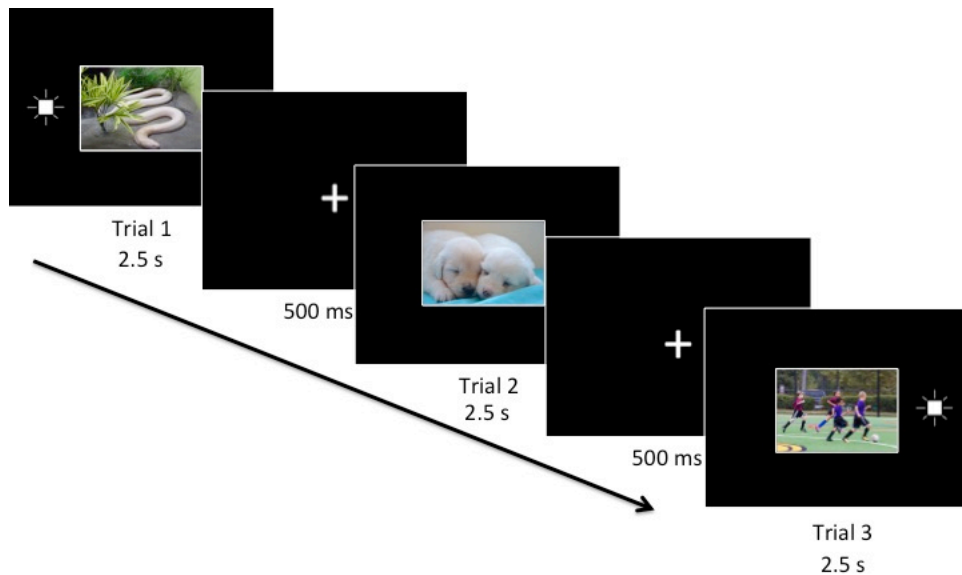


Figure 1. Procedure from the emotional scenes task. Each trial began with a fixation cross for 500 ms followed by the presentation of a stimulus image for 2.5 s. A lateralized distractor accompanied some of the trials. Participants made “pleasant” or “unpleasant” judgments with a bimanual key press.

On each trial, participants were asked to classify the image presented as pleasant or unpleasant as quickly and accurately as possible using the keyboard. *Pleasant* was equated with making the participant feel “happy, pleased, satisfied, contented, or hopeful”, whereas *unpleasant* was equated with making the participant feel “unhappy, annoyed, unsatisfied, melancholic, despaired, or bored” (as per Hughes & Rutherford, 2013, p. 170). Half of the participants pressed the “f” and “j” keys simultaneously with their index fingers for pleasant images and pressed the “d” and “k” keys simultaneously with their middle fingers for unpleasant images; key assignments were reversed for the remaining participants. Trials ended when a response was made or 2.5 s after stimulus onset (whichever came first), and the next trial began after the participant pressed the space bar. Participants completed 18 practice trials (3 positive and 3 negative trials in each distractor condition), featuring scenes not included in the experimental set. They then completed one experimental block consisting of 120 trials.

Stimulus order within the experimental block was randomized for each participant. I collected accuracy and response time (RT) data for each trial.

Results

The analyses were completed using SPSS 25 (Armonk, NY: IBM Corp.), and adopting an alpha level of .05 for tests of significance. Scores on the Edinburgh Handedness Inventory confirmed that all participants were right-handed ($M = 79.5$, $SD = 22.9$, $Range = 12.5 - 100.0$). Strength of handedness was unrelated to task performance and was not considered further.

Alexithymia Grouping

Consistent with past research (Mattila et al., 2010), 63% of the overall sample was lexithymic, 24% scored in the borderline range, and 14% were alexithymic. To create groups of comparable size for the analyses, I classified participants as low, moderate, or high in alexithymic traits using cut scores for tertiles of the distribution of TAS-20 Total scores. The mean Total scores of the Low Alexithymia (LA), Moderate Alexithymia (MA), and High Alexithymia (HA) groups were 37.5 ($SD = 4.5$), 47.6 ($SD = 2.4$) and 59.3 ($SD = 5.3$), respectively. The three groups had comparable sex distributions, $\chi^2(2) = .82$, $p = .66$.

Emotional Scenes Task

Mean RT. Participants did not show anticipatory responses (i.e., $RT < 300$ ms following stimulus onset), but in $< 1.9\%$ of cases mean RT for a given participant in a condition was > 3.25 SD above the group mean. Before analyzing the RT data, distributions were winsorized by replacing these outliers with the next slowest mean RT in the relevant condition that was not an outlier. The resulting distributions had acceptable skewness and kurtosis. Mean RTs were submitted to a 3 (Alexithymia Group: Low, Moderate, High) x 2 (Valence: Positive, Negative) x 3 (Distractor Location: Right, Left, None) x 2 (IM: Present, Absent) analysis of variance

(ANOVA), with repeated measures on the last three factors. As self-reported negative affect was comparable in the three groups, $F(2, 103) = 0.66, p = .52$, PANAS-negative scores were not included in this analysis. Significant main effects were followed up with LSD tests, and significant interactions with tests of simple main effects.

Based on past research (Hughes & Rutherford, 2013), I predicted a significant Distractor Location x Valence interaction but this was not supported. Indeed, there were no significant interactions involving distractor location ($0.17 \leq p \leq 0.87$). There was, however, a significant main effect of distractor location, $F(2, 206) = 64.12, p < .001, \eta_p^2 = .38$, with participants responding more slowly in the no distractor than in the right or left distractor conditions ($p < .001$), which themselves did not differ ($p = .99$ for both contrasts). Possible explanations for these counterintuitive findings are discussed below.

I also found main effects of valence, $F(1, 103) = 5.11, p = .026, \eta_p^2 = .047$, and IM, $F(1, 103) = 6.67, p = .011, \eta_p^2 = .061$. Participants were fastest at classifying positive images and images that did not depict IM; both of these main effects are evident in the (non-significant) interaction between these variables plotted in Figure 2. There were no effects or interactions involving alexithymia group in the analysis of the RT data.

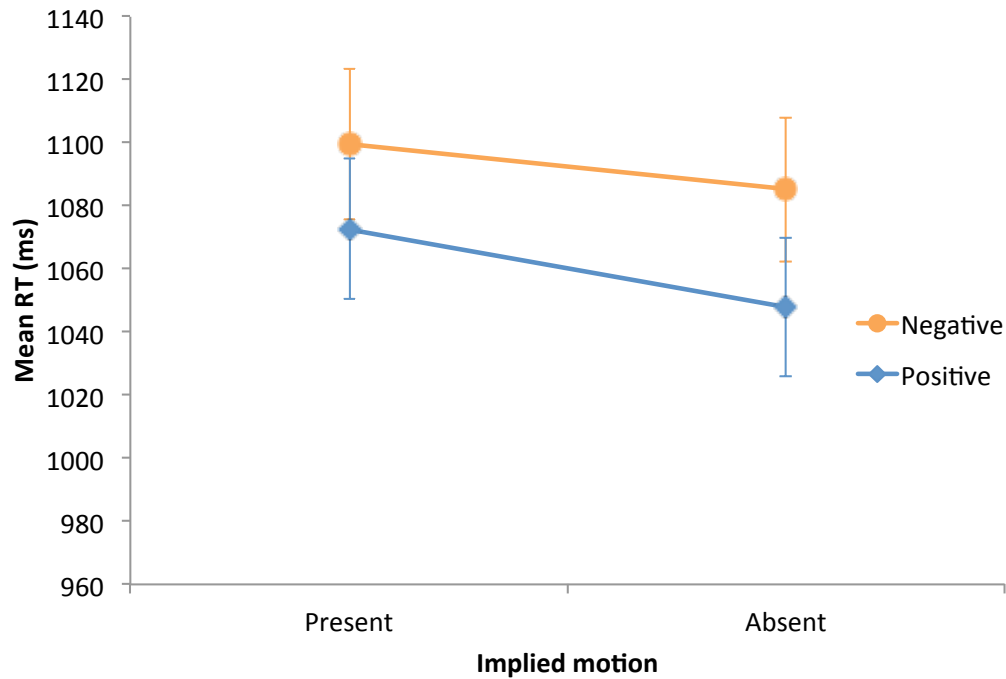


Figure 2. Mean RTs for scene classification (SE indicated). Judgments were fastest for scenes that did not depict implied motion and for those that were positively valenced.

Accuracy. Accuracy was defined as classifying a scene in a way that was consistent with its normative valence ratings (i.e., rating a positive scene as “pleasant” and rating a negative scene as “unpleasant”); in essence, then, it reflected sensitivity to valence. Individual participants’ accuracy across the 10 trials included in each condition was converted to a percentage score. In 1.3% of cases, mean accuracy within a condition was > 3.25 *SD* below the group mean for that condition. Distributions were winsorized by replacing these outliers with the next score that was not an outlier; the resulting distributions exhibited acceptable skewness and kurtosis. Mean scores were submitted to an ANOVA with the same structure as that used in the analysis of the RT data, and the same approach was used for follow-up tests.

There were no main effects or interactions involving distractor location ($0.24 \leq p \leq 0.93$). As with the RT data, I observed main effects of valence, $F(1, 103) = 4.05$, $p = .047$, $\eta_p^2 = .038$,

and IM, $F(1, 103) = 18.54, p < .001, \eta_p^2 = .153$. I also observed a significant Valence x IM interaction, $F(1, 103) = 33.83, p < .001, \eta_p^2 = .247$ (see Figure 3). Overall, viewers were more accurate when judging the valence of positive images without IM than in any other condition ($p < .001$ for all contrasts). Combined with the results of the RT analysis this finding suggests that, overall, positive scenes that did not depict IM were the easiest scenes to classify.

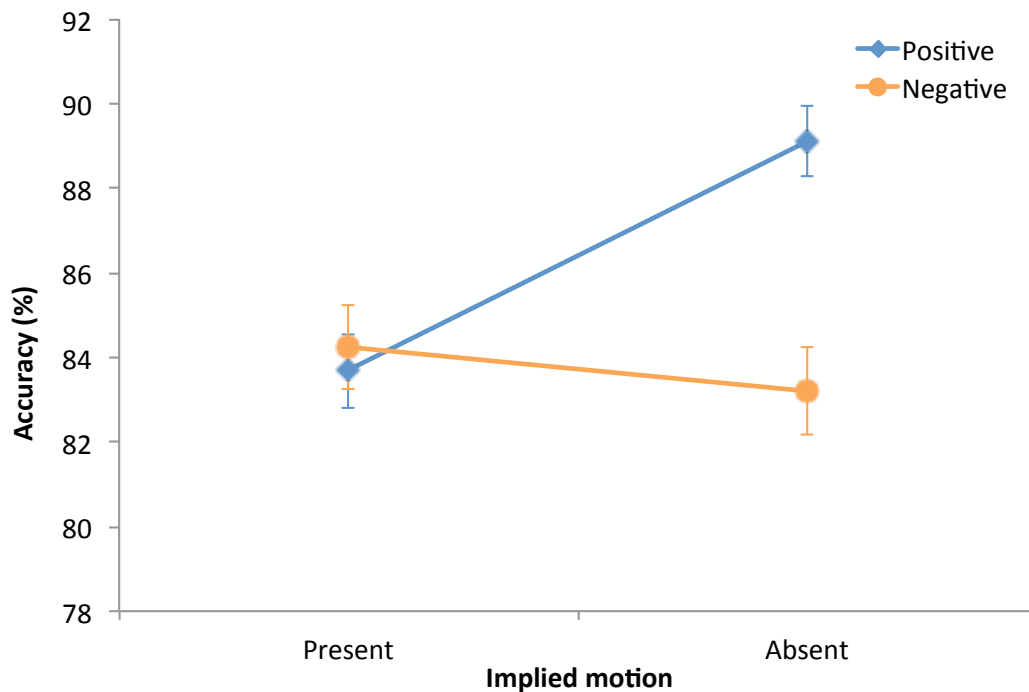


Figure 3. Mean classification accuracy for positively and negatively valenced scenes that did, or did not, depict implied motion (SE indicated). Judgments were most accurate for scenes that did not depict implied motion and were positively valenced.

I also observed a significant Group x Valence interaction, $F(2, 103) = 3.04, p = .05, \eta_p^2 = .056$ (see Figure 4). The LA group was more accurate than the MA and HA groups when rating positive scenes, and their ratings of these scenes were more accurate than their ratings of negative scenes ($p \leq .003$ for all contrasts). This suggests an underlying “positivity bias” in the LA group. Conversely, the MA and HA groups exhibited similar accuracy in their classification of both types of scenes.

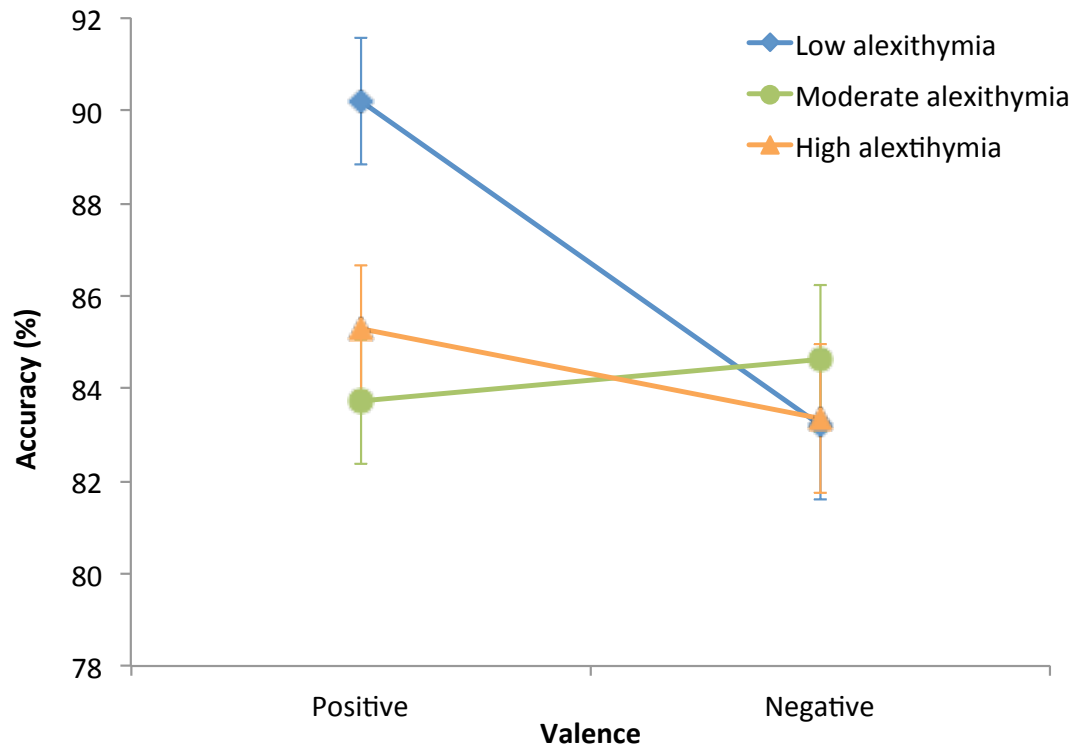


Figure 4. Group differences in mean classification accuracy for positively and negatively valenced scenes (SE indicated). Participants with moderate-to-high alexithymic traits were less accurate at judging the valence of positive scenes than those with low alexithymic traits.

Follow-up tests on the significant Group x IM interaction, $F(2, 103) = 3.89, p = .024, \eta_p^2 = .07$, showed that those reporting stronger alexithymic traits found it particularly hard to evaluate more complex emotional scenes that depicted IM. Thus, the MA and HA groups were less accurate when judging the valence of IM-present vs. IM-absent scenes ($p \leq .048$ for both contrasts; see Figure 5). They also evaluated IM-present scenes less accurately than the LA group ($p \leq .032$ for both contrasts).

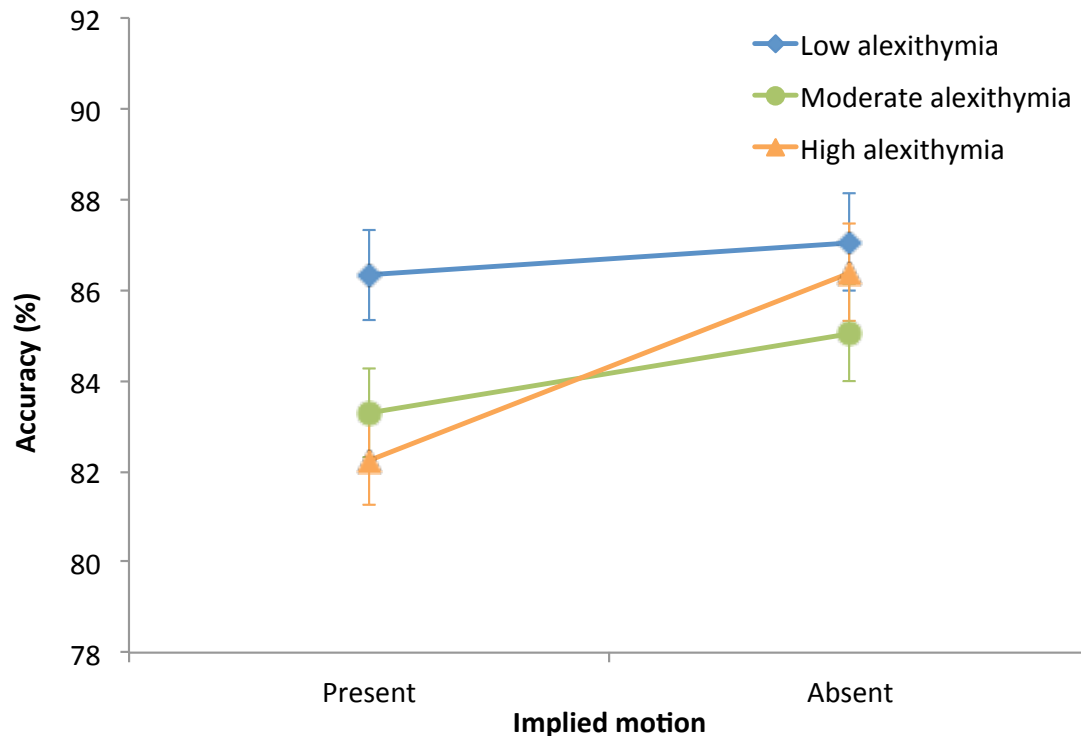


Figure 5. Group differences in mean classification accuracy for scenes with, and without, implied motion (SE indicated). Participants with moderate and high alexithymic traits were less accurate at judging the valence of scenes that depicted implied motion than those with low alexithymic traits.

Regressions. To get a clearer indication of what aspects of alexithymia contributed to group differences in performance, I ran separate multiple regressions predicting accuracy in all four task conditions. Significant relationships between TAS-20 scores and task performance were only observed in the two conditions in which group differences were seen, namely the assessment of positive scenes and scenes depicting IM. In each regression, I used the forced entry method, entering PANAS-negative scores (to account for potential negative affect) and the three TAS-20 subscale scores (EOT, DDF, and DIF) as predictors. The overall models in both analyses were significant ($R^2 \geq .093$, $p \leq .040$; $f^2 \geq .15$). As shown in Table 1, the EOT scale of the TAS-20 accounted for unique variance in both regressions. Individuals reporting stronger

EOT rated positive scenes as less pleasant and were less accurate at judging the valence of IM scenes than individuals scoring low on EOT.

Table 1.
Linear Model Predicting Accuracy in Judgments Regarding Positive and Implied Motion Scenes

		<i>b</i>	<i>SE b</i>	β	<i>p</i>
Positive Scenes	(Constant)	59.32	2.78		0.00
	PANAS Neg	0.08	0.20	0.04	0.68
	DIF	-0.14	0.10	-0.15	0.18
	DDF	-0.09	0.14	-0.07	0.53
	EOT	-0.25	0.11	-0.21	0.03
Implied Motion Scenes	(Constant)	57.31	1.98		0.00
	PANAS Neg	-0.01	0.14	-0.01	0.94
	DIF	-0.04	0.07	-0.06	0.59
	DDF	-0.18	0.10	-0.19	0.07
	EOT	-0.20	0.08	-0.24	0.01

Note. PANAS Neg: PANAS Negative Affect, Difficulty Identifying Feelings (DIF), Difficulty Describing Feelings (DDF), Externally-Oriented Thinking (EOT)

Supplementary Analyses: Alexithymia vs. SPS

TAS-20 Total scores were significantly correlated with HSPS Total scores, and significant correlations were observed between specific subscales of the two measures (see Table 2). Moreover, the distributions of Dandelions, Tulips, and Orchids were different across the three alexithymia groups, $\chi^2(4) = 12.12, p = .016$, with the proportion of Orchids increasing from LA (14.3%), to MA (33.3%), to HA (48.6%) (see Figure 6).

Table 2.

Correlations Between Measures of Alexithymia and Sensory Processing Sensitivity

		TAS-20			
		Total	DIF	DDF	EOT
HSPS	Total	0.26**	0.42**	0.23*	-0.13
	EOE	0.33**	0.46**	0.29**	-0.06
	AES	-0.06	0.12	-0.02	-.267**
	LST	0.17	0.25*	0.11	-0.02

Note. TAS-20: Toronto Alexithymia Scale: Difficulty Identifying Feelings (DIF), Difficulty Describing Feelings (DDF), Externally-Oriented Thinking (EOT), HSPS: Highly Sensitive Person Scale: Ease of Excitation (EOE); Aesthetic Sensitivity (AES); Low Sensory Threshold (LST)

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

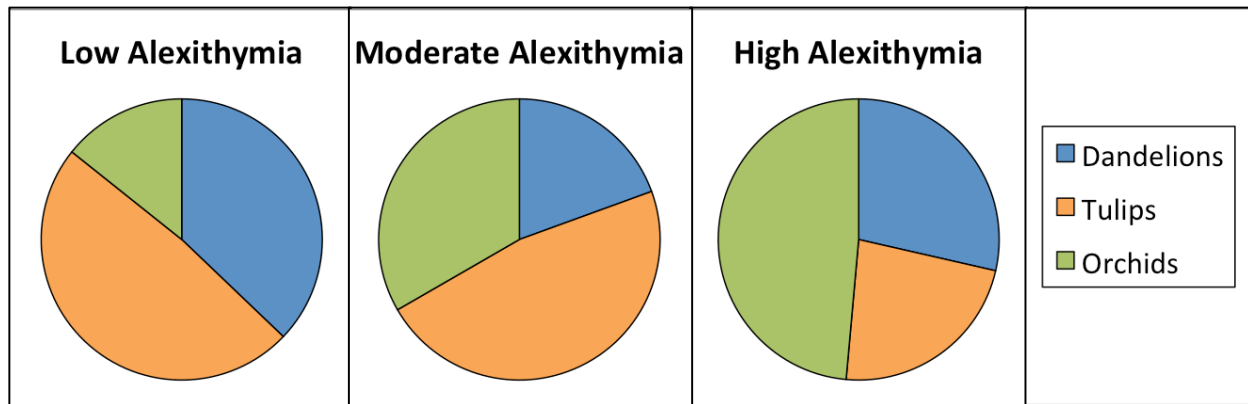


Figure 6. Proportion of Dandelions, Tulips, and Orchids in alexithymia groups. The proportion of Orchids increased from the Low Alexithymia, Moderate Alexithymia, to High Alexithymia groups.

Given the high rates of SPS in individuals with alexithymia, I considered the possibility that the observed links between task performance and alexithymic traits might, in fact, be related to individual differences in SPS. To test this, I re-ran the four regressions described above, including the three HSPS subscales (EOE, LST, and AES) as additional predictors. I confirmed that multicollinearity was not an issue before proceeding (variance inflation factor < 1.60 in all cases). The overall models of positive and IM scenes were still significant ($R^2 \geq .14, p \leq .04; f^2 \geq .16$) and, as can be seen in Table 3, EOT remained a significant negative predictor in both

analyses. I also observed, however, that scores on the EOE scale of the HSPS explained unique variance in judging the accuracy of positive scenes, with individuals scoring high on this subscale performing more poorly on the experimental task. None of the HSPS subscales improved prediction of accuracy in judging IM scenes.

Table 3.
Supplementary Analysis Testing Whether Sensory Processing Sensitivity Improves Predictors of Accuracy in Judgments of Positive and Implied Motion Scenes

		<i>b</i>	<i>SE b</i>	β	<i>p</i>
Positive Scenes	(Constant)	63.86	4.50		0.00
	PANAS Neg	0.13	0.20	0.06	0.52
	DIF	-0.02	0.11	-0.03	0.82
	DDF	-0.04	0.14	-0.03	0.79
	EOT	-0.28	0.11	-0.24	0.02
	EOE	-1.88	0.68	-0.32	0.01
	AES	0.39	0.60	0.06	0.52
	LST	0.04	0.39	0.01	0.92
Implied Motion Scenes	(Constant)	57.54	3.32		0.00
	PANAS Neg	0.00	0.15	0.00	1.00
	DIF	-0.02	0.08	-0.03	0.81
	DDF	-0.17	0.10	-0.18	0.09
	EOT	-0.20	0.08	-0.24	0.02
	EOE	-0.34	0.50	-0.08	0.51
	AES	0.21	0.44	0.05	0.64
	LST	-0.05	0.29	-0.02	0.85

Note. PANAS Neg: PANAS Negative Affect, Difficulty Identifying Feelings (DIF), Difficulty Describing Feelings (DDF), Externally-Oriented Thinking (EOT), HSPS: Highly Sensitive Person Scale: Ease of Excitation (EOE); Aesthetic Sensitivity (AES); Low Sensory Threshold (LST)

Discussion

This study was designed to investigate the impact of individual variations in alexithymic traits and stimulus characteristics on the processing of emotionally valenced scenes. Overall, I found that participants generally found positive scenes without IM easier to process than other types of scenes. Accounting for the strength of participants' alexithymic traits was important, however, as participants reporting moderate-to-high levels of alexithymia evaluated positively

valenced scenes and scenes with IM less accurately than those reporting low levels of this trait. Regression analyses revealed that EOT scores drove the relationship between alexithymia and accuracy in the evaluation of these two types of scenes. One aspect of SPS, namely being bothered by busy sensory environments (EOE), accounted for unique variance in how accurately positively valenced (but not IM) scenes were evaluated. I did not find evidence of the expected laterality effects in the emotional scenes task in the sample as a whole, or in subgroups distinguished by different levels of alexithymia. These key findings are discussed below.

Hemispheric Contributions to Task Performance

Contrary to an earlier report using the same paradigm (Hughes & Rutherford, 2013), I found that participants were faster to respond to images when a distractor was present (unilateral conditions) compared to when no distractor was present (bilateral condition). One possible explanation for this finding is that the emotional scenes task was relatively easy and could be completed well unilaterally. [Note that engagement of both hemispheres during cognitively simple tasks has been shown to attenuate performance; Weissman & Banich, 2000; Weissman, Banich, & Puente, 2000.] Another possible explanation for this unexpected result is that the presence of a distractor served as a nonspecific exogenous cue that primed participants to be more attentive to the task. A third possibility is that participants may have formed an expectation that a distractor would appear (as this was the case on two-thirds of the trials), and they hesitated to respond on no distractor trials because they were awaiting its presentation.

Discrepancies between the present work and that of Hughes and Rutherford (2013) could also stem from differences in stimulus properties. Although my stimuli were selected to be as similar as possible to those used by Hughes and Rutherford in terms of their mean valence and arousal, there were likely some cross-study differences in the precise test images selected, as I

set out to systematically manipulate the presence/absence of IM cues but Hughes and Rutherford did not. Cross-study differences in the proportion of scenes that motivated approach or avoidance responses (which could impact laterality effects; e.g., see Balconi, Vanutelli, & Grippa, 2017; Harmon-Jones & Gable, 2017), and/or in sample characteristics (e.g., sex distribution, alexithymic traits) may also have contributed to mixed findings. It is also possible, however, that this paradigm simply does not assess hemispheric asymmetries reliably.

Valence Processing

Overall, participants were faster and more accurate when judging positive, compared to negative, scenes. Processing of positive scenes may normally be prioritized in the visual cortex, as activity here is elevated when static scenes with positive (vs. negative or neutral) valence are presented briefly (Schettino, Gundlach, & Müller, 2019). This is important to note, as superior processing of negative stimuli is often emphasized in the literature, given the obvious evolutionarily advantage it confers (Borgomaneri et al., 2014). It is possible that negative stimuli captured my participants' attention more quickly than positive stimuli, even though they were slower/less accurate when *responding* to them; incorporating eye-tracking in future studies could help to test this. Responses to negative scenes may have been slower, overall, because a larger number of response options are weighed when we process them (e.g., positive stimuli generally motivate approach, whereas negative stimuli can motivate approach, avoidance, or freezing responses; Kuhbandner et al., 2016; Roelofs, 2017).

Unlike participants scoring low in alexithymia, those with moderate-to-strong alexithymic traits found positive scenes as difficult to evaluate as negative scenes. This might be expected if those with alexithymia generally pay less attention to positive stimuli than lexithymic individuals. This idea is suggested, indirectly, by the finding that alexithymic individuals tend to

score *low* on emotional intelligence (Parker, Taylor, & Bagby, 2001), a trait that is associated with attentional biases to positively valenced stimuli (Lea, Qualter, Davis, Pérez-González, & Bangee, 2018). When pleasant and unpleasant scenes are matched for intensity, typical adults show a pleasure bias as evidenced by increased responsivity within the frontoparietal and lateral occipital cortex (Frank & Sabatinelli, 2019). It may be that individuals with alexithymia experience a reduced pleasure bias. Indeed, individuals with stronger alexithymic traits judge positive and neutral scenes more negatively than those with fewer traits (Koven et al., 2014), perhaps reflecting reduced physiological resonance generated by these scenes, or greater physiological decoupling. Interestingly, EOT has been argued to underpin decoupling (Davydov et al., 2013). Thus, the findings here might reflect an overall reduced pleasure bias during positive scene processing at the neurological level and/or increased disconnect between physiological and subjective arousal in individuals exhibiting stronger EOT.

Reporting being able to vividly generate positive imagery and endorsing self-compassionate traits are associated with enhanced positive responses to soothing images (Wilson, Schwannauer, McLaughlin, Ashworth, & Chan, 2018). Interestingly, individuals with high (compared to low) levels of alexithymia report reduced vividness of imagery when imagining past and future happy events (Mantani, Okamoto, Shirao, Okada, & Yamawaki, 2005). Thus, an alternative interpretation of the current findings may be that participants endorsing stronger alexithymic traits found it challenging to imagine themselves within positively valenced scenes, which might have contributed to their undervaluation of these scenes.

The fact that the MA and HA groups were less accurate at evaluating positive scenes than the LA group means that the individuals in the former groups were more likely to describe these scenes as unpleasant. A possible consequence of undervaluing positive situations is that it may

limit approach (exploration) when one is in a novel environment. It could also contribute to the problems with cognitive reappraisal and emotion regulation that are frequently described in those with alexithymia (Walker et al., 2011). In this regard, it is important to comment on the fact that the MA and HA groups performed similarly on the emotional scenes task, even though the majority of individuals in the MA group actually scored in the lexithymic range on the TAS-20. This suggests that it may be important to control for sub-clinical alexithymic traits in future studies of emotion perception.

Why were *group differences* not apparent in judgments of negative scenes? The answer to this question may lie in the fact that the stimuli selected in the present work were relatively neutral in arousal. Deng, Ma, and Tang (2013) found that adults with and without alexithymia showed different patterns of neural activity when viewing both low- and high-intensity positive scenes, but group differences with negative scenes were only apparent with high-intensity stimuli. It may be that the arousal generated by negative stimuli is unusual in those with alexithymia (see Starita et al., 2018). Future studies investigating the possibly interactive effects of valence and arousal on scene perception in alexithymia are warranted.

Processing of Emotional Scenes Depicting IM

IM increased scene complexity, as evidenced by the fact that participants in the present study were generally slower and less accurate when evaluating IM-present scenes—particularly if they exhibited moderate-to-strong alexithymic traits. Viewing IM images normally produces stronger activity within the insula, medial temporal gyrus (Kolesar et al., 2016), fusiform gyrus (Michels, Lappe, & Vaina, 2005), and superior temporal sulcus (Kolesar et al., 2016; Kourtzi & Kanwisher, 2000; Vaina, Solomon, Chowdhury, Sinha, & Belliveau, 2001) than viewing images that do not depict IM. In future work, it would be of interest to determine if the strength of these

neural activations varies as a function of the strength of viewers' alexithymic traits.

The majority of IM scenes used in the present study depicted human activities (e.g., someone skiing) or full-body/facial displays of emotion (e.g., an angry attack; a crying child). Participants may have been simulating these actions (Borgomaneri et al., 2012) via activation of the mirror neuron system (Calbi, Angelini, Gallese, & Umiltà, 2017). This raises the possibility that atypicalities in motor simulation/embodiment may have contributed to problems the MA and HA groups experienced when attempting to classify IM scenes. Support for the idea that embodiment is altered in alexithymia comes from studies showing that those scoring high in alexithymia exhibit atypical facial motor responses to, and decreased mimicry of, facial expressions (Scarpazza, Làdavas, & Cattaneo, 2017; Scarpazza, Làdavas, & Di Pellegrino, 2015; Sonnby-Borgström, 2009), and show heightened brain activation in the somatosensory cortex and supplementary motor area when viewing angry and fearful faces (Ihme et al., 2014).

Atypical integration of IM and emotion cues could contribute to unusual patterns of embodiment in individuals with alexithymia. Preliminary support for this idea comes from recent work by Borhani, Làdavas, Maier, Avenanti, and Bertini (2015). They reported that viewers typically show slower RTs, lower accuracy, and heightened N190 amplitudes in both hemispheres when classifying images of bodies in action vs. at rest as emotional or non-emotional, but that only the RH showed differential responding to fearful actions—implicating it in this integrative process. They went on to show that exhibiting larger N190 amplitudes for emotional (particularly fearful) postures was characteristic of those reporting low, but not high, levels of alexithymia (Borhani et al., 2016). From an evolutionary perspective, atypicalities in the integration of motion and emotion cues could put those with alexithymia at a disadvantage.

For example, it might negatively impact how quickly they could evaluate whether an approaching conspecific poses a threat.

Some of the stimuli used in the present study featured manipulable objects, or nature scenes. There is reason to believe that we embody aspects of these stimuli as well (e.g., Kuehn et al., 2018). Proponents of grounded cognition argue that atypical embodiment of environmental cues could influence a range of perceptual and cognitive processes unrelated to emotion processing (Barsalou, 2008) including, for example, distance perception (Witt, Proffitt, & Epstein, 2004). These processes may be atypical in those with alexithymia, although to my knowledge this has not yet been tested directly.

Externally Oriented Thinking

I found that EOT was the main factor driving the relationship between alexithymia and task performance in the present study. Thus, individuals reporting stronger EOT rated positive scenes as being less pleasant and were less accurate in judging the valence of IM scenes, compared to those reporting weaker EOT. This was somewhat surprising given that, in a recent neurobiological review distinguishing the TAS-20 subscales, Goerlich (2018) concluded that variations in EOT have less of an effect on the functioning and structure of neural areas that are associated with emotional processing than variations in DDF or (to a lesser extent) DIF. The role of EOT makes sense, however, if this particular trait is more strongly associated with disrupted embodiment than the other alexithymia dimensions (as suggested by Grynberg & Pollatos, 2015). Complementing my findings, Demers et al. (2019) found that—in adolescents who engage in non-suicidal self-harm—higher scores on an alexithymia measure tapping into EOT (but not DIF/DDF) was associated with reduced neural responsivity to masked photographs of faces displaying happy expressions, suggesting they may be less reactive to positive stimuli.

Embodiment processes transform raw emotions into subjective feelings (Nummenmaa, Hari, Hietanen, & Glerean, 2018), which in turn, form the basis for ratings of pleasantness (Shiota et al., 2017). One possibility is that EOT is associated with diminished attention to one's embodied (feeling) state. This suggestion is consistent with how Preece, Becerra, Allan, Robinson, and Dandy (2017) characterize EOT in their attention-appraisal model of alexithymia. As noted in Chapter 1, these authors contend that EOT and DIF/DDF influence distinct stages of the emotion regulation process. Specifically, they suggested that EOT impacts the *attention stage* by reducing focus on one's emotional responses, whereas DIF and DDF (which limit the ability to understand one's emotional experience) negatively impact the *appraisal stage*. By not directing attention inward, those scoring high in EOT may find it difficult to assess how environmental and body-based cues resonate internally and this, in turn, may make it harder for them to evaluate emotional scenes.

Alexithymia and SPS

In the supplementary analyses, I found that individuals scoring high on the HSPS were over-represented in the HA group. This was likely due to the moderate-to-strong positive correlations seen between DIF/DDF scores and scores on the EOE subscale of the HSPS (see also Liss et al., 2008). These correlations suggest that problems with emotional appraisal are most evident in those who are strongly affected by busy sensory environments. The fact that both EOE and EOT were negative predictors of accuracy in judging positive scenes suggests that being hyper-reactive to sensory stimuli (high EOE) and/or failing to direct attention inward (high EOT) both contribute to the undervaluing of positive scenes. The fact that EOT was the only significant predictor of accuracy in the evaluation of IM scenes suggests that having a strong inward focus of attention may be particularly important for picking up the resonance generated

by the subtle motion cues present in these scenes. One could speculate that, had I used actual dynamic stimuli, EOE might have emerged as a second, significant predictor of performance, if the enhancement in scene complexity (and stronger activation of both sensory- and action-based neural pathways; Barsalou, 2008) generated by the addition of real motion made individuals scoring high on EOE uncomfortable. This is a question for future research.

The present results suggest that researchers interested in alexithymia should screen for SPS and vice versa, as a proportion of the population likely meet criteria for both traits due to the fact that both are characterized by atypicalities in sensory processing. I would predict that individuals displaying alexithymia and SPS would show relatively *weaker* EOT, and relatively *better* fantasizing abilities, compared to individuals who have alexithymia but not SPS, given that EOT and problems fantasizing are in many respects antithetical to some features of SPS. Indeed, individuals with SPS are typically characterized as introspective, “deep” processors with rich inner lives (Aron et al., 2012; Lionetti et al., 2018). The AES score of the HSPS (which was negatively correlated with EOT in the present sample) captures aspects of this cognitive style, albeit imperfectly.

Limitations and Future Directions

I chose to use IAPS images in the present work, in part, to keep my protocol as similar as possible to that used by Hughes and Rutherford (2013). Although the IM images that I selected appear to have captured some of the complexity and richness of natural scenes (as suggested by the fact that the presence of IM impacted task performance), future work that uses more ecologically valid stimuli (e.g., videos of emotional scenes; exposure to virtual reality or real-life situations) is warranted. Another limitation of the current work is that I did not include neutral scenes. It would be interesting to incorporate neutral stimuli into the study design to disentangle

the effects of IM and emotion. In past work (e.g., Kolesar et al., 2016), functional overlap has been observed between neural regions that process IM and emotion. I would expect that valenced IM scenes might elicit a different pattern of behavioural results than neutral IM scenes.

More research into how different aspects of alexithymia impact perceptual and cognitive functions is warranted. In particular, the possibility that different subtypes of alexithymia can be identified deserves more consideration. Identifying distinct alexithymia “profiles” that can be distinguished on variables such as interoceptive abilities (Brewer et al., 2016) or sensory processing styles more generally might help to explain discrepant results in the literature. Given the links between interoception and embodiment (Ondobaka, Kilner, & Friston, 2017), one might predict that EOT would be more strongly linked to interoceptive deficits than other aspects of alexithymia.

Finally, I have reviewed literature suggesting that understanding one’s subjective *feelings* about a scene likely requires processing of how the scene “resonates” in sensory/sensorimotor networks, in the autonomic nervous system, and in parts of the emotional brain (see Nummenmaa et al., 2018; Shiota et al., 2017). But it is important to note that top-down factors undoubtedly influence the extent to which we are aware of, and are able to articulate, how we feel (e.g., Gallese, 2014). It is quite possible that alexithymia reflects atypicalities in both bottom-up and/or top-down processes. It is also possible that subtypes of alexithymia may differ in the extent to which these two types of processes are compromised. Here, I have focused on bottom-up processes; examining whether top-down factors mediate the relationship between specific facets of alexithymia and outcomes in different areas is an important avenue for future research.

Conclusions

My findings suggest that properties such as negative valence and IM affect how people process emotional scenes. In line with previous recommendations (Borgomaneri et al., 2012), the current work highlights the importance of accounting for IM when investigating scene perception, or emotion processing more generally, using static images. I also found that individual differences in alexithymic traits (especially the strength of EOT) impacted task performance. Learning more about how individuals displaying specific traits, or alexithymia subtypes, respond to different environmental/contextual cues will enhance our understanding of the functioning of the social brain. It may also have important clinical implications, given that alexithymia is considered to be a significant, transdiagnostic risk factor for various forms of psychopathology (Grynberg et al., 2012; Preece et al., 2017).

CHAPTER 3: ALEXITHYMIA AND THE PROCESSING OF ENVIRONMENTAL AND BODY-BASED SENSORY CUES

Emotions are relatively automatic signals that are generated through integrating contextual environmental cues with the accompanying cognitive, motor, and physiological changes that occur in the body (Shiota et al., 2017). Emotions may be thought of as evolutionarily advantageous “gut responses” that help us to navigate our environment and keep us safe. Nummenmaa, Hari, Hietanen, and Glerean (2018) argue that emotions can be transformed into *feelings*, which they define as the “subjectively accessible phenomenological state of an individual” (p. 1), through the process of embodiment. Feelings include affective and non-affective states, and they can be reflected upon and discussed. Individuals “map” feeling states onto the body in characteristic ways. For example, feelings of anxiety are mapped primarily onto the torso and centered on the chest. Nummenmaa et al. have identified five distinct clusters of body maps for feelings: positive emotions (e.g., pride), negative emotions (e.g., sadness), cognitions (e.g., attending), somatic states and illnesses (e.g., dizziness), and homeostatic states (e.g., thirst).

Subjective evaluations of stimuli or events, including ratings of their pleasantness, are strongly based on the feeling states that they evoke (Shiota et al., 2017). If alexithymia is associated with atypicalities in the embodiment and awareness of, and the ability to describe, feeling states this might explain why alexithymic traits and associated sensory sensitivities influenced pleasantness ratings of certain emotional scenes in Chapter 2. The overarching focus of the work described in this chapter was to explore links between alexithymic traits and aspects of sensory processing that may impact embodiment.

Before reviewing past research examining links between these variables, I will provide an overview of some of the work that supports the view that embodiment is atypical in those with alexithymia. Embodiment and simulation can be explored using various paradigms, such as the rubber hand illusion (e.g., Rae, Larsson, Eccles, Ward, & Critchley, 2018) and the mental rotation of body parts (e.g., Olivier, Velay, Labiale, Celse, & Faure, 2004). In the section that follows, I focus on studies of *automatic mimicry* and how it impacts our ability to understand our own (evoked) states and helps us to correctly interpret the feelings of others.

Automatic Mimicry

Automatic mimicry includes motor mimicry (which has been studied extensively in emotion research) and autonomic mimicry (which has to date attracted less attention). In their *Neurocognitive Model of Emotion Contagion*, Prochazkova and Kret (2017) argue that integrating information derived from both of these forms of automatic mimicry contributes to emotion contagion which, in turn, underlies our ability to demonstrate affective empathy for others. As will be seen below, direct and indirect evidence links atypicalities in these two forms of automatic mimicry to alexithymia.

Motor Mimicry. Sensorimotor simulation, which is thought to underpin some aspects of embodiment (Körner, Topolinski, & Strack, 2015), is often reflected in observable behaviour—such as motor mimicry. Motor mimicry includes not only mimicry of facial or body movements, but also eye gaze synchrony and the establishment of eye contact. It has been said to reflect a dynamic blending between “self” and “other” (Gallese, 2009) that facilitates emotion recognition (Wood, Rychlowska, Korb, & Niedenthal, 2016), and strengthens social ties (Murata, Saito, Schug, Ogawa, & Kameda, 2016).

Theories of automatic motor mimicry usually implicate the mirror neuron system. The common coding principle (see Coey, Varlet, & Richardson, 2012) contends that when mirror neurons promoting motor execution are activated in response to observing another's action, these neural simulations facilitate our ability to understand that person's intentions and to make predictions about what they will do next. This view is echoed in the Embodied Simulation Account of social perception (Murata et al., 2016; Oberman & Ramachandran, 2007). Movement information, such as that conveyed in an unfolding facial expression, is received by the superior temporal sulcus of the perceiver (Prochazkova & Kret, 2017). This information then passes to the inferior parietal lobe, which subsequently activates the inferior frontal gyrus. The inferior frontal gyrus codes the information based on the goal of the action and develops a corresponding motor plan. This plan is then transferred back to the superior temporal sulcus, and a mimicry response is initiated through its connections with the anterior insula and amygdala. Engagement of the limbic system connects mimicry to an emotional response (Prochazkova & Kret, 2017).

Motor Mimicry in Alexithymia. There is indirect and direct evidence to suggest that motor mimicry is disrupted in people with alexithymia. For example, individuals with ASD—a condition that frequently presents with alexithymia (Berthoz et al., 2013)—often show atypical mimicry responses (Gallese, 2009; however see Fitzpatrick, Diorio, Richardson, & Schmidt, 2013). Social deficits seen in ASD have also been linked to alterations within the mirror neuron system (Williams, Whiten, Suddendorf, & Perrett, 2001).

More direct evidence comes from research finding that people with alexithymia show delayed mimicry of happy facial expressions (Scarpazza et al., 2017), and diminished mimicry of negatively valenced facial expressions of anger and fear (Sonnby-Borgström, 2009; Starita et al.,

2018). Ihme et al. (2014) suggested that atypical simulation might explain why participants in their study who reported difficulties describing their feelings needed more time to judge angry and fearful expressions. In support of this idea, they found that individuals exhibiting strong alexithymic traits showed heightened activation of the right somatosensory cortex and supplementary motor area when labeling these expressions.

Autonomic Mimicry and Responsivity. Even autonomic responses outside of conscious control (such as pupil dilation, blushing, and sweating) show mimicry or synchronization effects (Kret, 2015) that can affect emotion perception (Kret, 2017). Autonomic mimicry may allow us to simulate others' internal sensations, making us better able to comprehend and anticipate upcoming changes in their physical and emotional state (Ondobaka, Kilner, & Friston, 2017; Prochazkova & Kret, 2017). This would have clear evolutionary advantages. For example, detecting signs of strong arousal in another could help one to predict the likelihood that they might attack (Prochazkova & Kret, 2017). Automatically mimicking changes in another's pupil size (i.e., displaying "pupillary contagion") may also facilitate the transfer of emotion and arousal information during interpersonal interactions (Prochazkova & Kret, 2017). Pupillary contagion may also influence the impressions we form of others as suggested by the fact that, when interacting with a virtual partner, the strength of one's own pupillary contagion response predicts the extent to which one is likely to rate partners with dilating (vs. constricting) pupils as being more trustworthy (Kret, Fischer, & De Dreu, 2015).

Autonomic Mimicry and Reactivity in Alexithymia. I am not aware of any work directly exploring pupillary contagion or other forms of autonomic mimicry in people with alexithymia. However, Galazka et al. (2019) found that individuals with ASD showed comparable pupillary contagion to typical adults, despite the ASD group exhibiting shorter fixation duration on the

eyes overall. Among those with ASD, pupillary contagion was strongest in participants who exhibited the shortest fixation durations, suggesting that these individuals might cope with their increased arousal response by averting their gaze (see also Dalton et al., 2005). This is of interest given other work showing that shorter fixations on the eye region predict higher accuracy in emotion recognition in adults with alexithymia (Fujiwara, 2018).

Although autonomic *mimicry* (reflected in the generation of corresponding changes in autonomic responses between senders and receivers; Prochazkova & Kret, 2017) has not yet been studied in alexithymia, there is a sizeable literature showing that people with alexithymia often show atypical patterns of autonomic *reactivity* to emotionally valenced stimuli, which could affect their subjective experiences of emotions. The hypoarousal theory (see Donges & Suslow, 2017) contends that people with alexithymia experience blunted physiological arousal to emotion information, and are therefore slower to attend to and verbalize this information. Support for this theory comes from work showing that higher scores on the TAS-20 are related to reduced electrodermal responses during viewing of briefly presented, negatively valenced images (Pollatos, Schubö, Herbert, Matthias, & Schandry, 2008), judgments of emotional images (Gaigg, Cornell, & Bird, 2018), and completion of social stress tests (Kleiman et al., 2016; Pollatos et al., 2011). A clear challenge to the hypoarousal theory comes from work showing *increased* physiological responses in people with alexithymia when watching negatively valenced films (e.g., Bogdanov et al., 2013). Hyperarousal is also supported by some studies looking at heart rate and heart rate variability measures (Luminet, Rime, Bagby, & Taylor, 2004; Panayiotou & Constantinou, 2017), and at changes in electrodermal activity (Cecchetto, Korb, Rumiati, & Aiello, 2017).

The mixed results of studies investigating whether alexithymia is related to increased or decreased physiological responsivity to emotion information may reflect the use of different measures of physiological arousal (e.g., heart rate, heart rate variability, electrodermal response, electroencephalography) and/or tasks (e.g., stress induction, passively viewing distressing scenes). It may also reflect failure to account for levels of affective alexithymia (Bermond, Bierman, Cladder, Moormann, & Vorst, 2010; Kanbara & Fukunaga, 2016; Martínez-Velázquez, Honoré, Zorzi, Ramos-Loyo, & Sequeira, 2017), or for the relative strength of different alexithymic traits.

Chapter Overview

The information reviewed above supports the idea that the ways in which we respond to events at a motor and/or autonomic level shape our subjective feelings, and impact the inferences we make about others' feelings or characteristics. It also suggests that alexithymia may arise, at least in part, from atypicalities in these processes that disrupt embodiment.

Individual differences in embodiment are likely influenced by differences in how we characteristically *process* sensory information. In this regard, a large focus in the existing literature has been to explore possible links between alexithymia and atypicalities in the processing of body-based (interoceptive) cues. It is important to note, however, that although interoceptive and somatosensory inputs are undoubtedly important contributors to feeling states, they cannot be the only inputs. It has been shown, for example, that experiencing pure autonomic failure does not eliminate subjective feeling states (Heims, Critchley, Dolan, Mathias, & Cipolotti, 2004). Findings such as this suggest that integration of interoceptive, proprioceptive, *and* environmental cues is key during embodiment of feeling states (Fuchs & Koch, 2014; Nummenmaa et al., 2018; Shiota et al., 2017). Integration of these various cues is

also important for developing a coherent sense of self (Tsakiris, 2017). I suggest that one's general sensory processing style (including the *weighting* given to different sensory cues) may vary as a function of individual difference characteristics, such as the strength of specific alexithymic traits. This general idea was tested in the two studies included in this chapter.

Study 1

In Study 1, I evaluated the relationships between specific alexithymic traits and individual differences in how young adults process and respond to environmental and body-based sensory cues in a large, university sample. This was of interest given that these factors likely impact emotional embodiment. To provide context for this study, I begin with a brief overview of some of the existing work focusing on interoception, sensitivity to somatosensory and environmental cues, and sensory processing styles.

Interoception

Interoceptors are peripheral organs that transmit signals regarding physiological processes between the peripheral and central nervous systems (CNS; Pace-Schott et al., 2019). Interoception arises from bidirectional processing of visceral-afferent signals generated from these organs (Schulz & Vögele, 2015), and from processing signals arising from bodily homeostasis more generally (Khalsa, Adolphs, Cameron, Critchley, Davenport, et al., 2018). Conscious and sub-conscious interoceptive processes affect a wide range of affective and non-affective feeling states (Pace-Schott et al., 2019).

Although interoception is an umbrella construct that includes a variety of distinguishable processes (Khalsa et al., 2018), a prominent view is that it incorporates three fundamental and independent constructs: interoceptive accuracy (IA), interoceptive sensibility, and interoceptive awareness (Garfinkel & Critchley, 2013). IA refers to correct perception of internal body

sensations, which is typically measured through heartbeat tracking (counting) or heartbeat discrimination tasks (Garfinkel, Seth, Barrett, Suzuki, & Critchley, 2015). Garfinkel and Critchley (2013) define interoceptive sensibility as the ability to subjectively report on one's interoceptive abilities. This can be measured by assessing a person's confidence in how they have performed on an IA task, or by using self-report measures that tap into the tendency to be internally focused. Being able to accurately assess your own interoceptive competence (a metacognitive skill) is referred to as interoceptive awareness.

Perception of internal signals and emotional processes are often linked (e.g., describing having “butterflies” in your stomach when feeling nervous or excited), and there are strong connections between interoception and emotional processing (Bird & Viding, 2014). For example, IA has been positively associated with displaying greater topographical specificity and awareness of body sensations when experiencing emotional feeling states (Jung, Ryu, Lee, Wallraven, & Chae, 2017). IA is also associated with providing higher intensity ratings when viewing unpleasant emotional scenes (Pollatos, Traut-Mattausch, Schroeder, & Schandry, 2007). Interoceptive abilities also seem to be important when perceiving the emotional states of *others*. For example, IA is positively associated with emotional ToM abilities (Shah, Catmur, & Bird, 2017) and with empathy (Mul, Stagg, Herbelin, & Aspell, 2018). Indeed, it has been argued that IA may be fundamental to the generation of predictive models that are used to gauge how others think and feel (Ondobaka et al., 2017).

In addition to supporting emotion understanding, being able to perceive and make sense of your internal state is thought to contribute to emotion regulation (Murphy, Catmur, & Bird, 2018; Zamariola, Frost, Van Oost, Corneille, & Luminet, 2019). However, recent challenges to this idea come from work showing that exhibiting heightened attention to and increased

objective accuracy in classifying interoceptive cues is *not* associated with enhanced mood regulation (Zamariola, Luminet, Mierop, & Corneille, 2019). Thus, the links between interoception and emotion regulation are at this time inconclusive.

IA, interoceptive sensibility, and interoceptive awareness are dissociable constructs (Garfinkel et al., 2015); therefore it is important to distinguish between these different facets of interoception in research, and to be specific in their definition. [Indeed, there is inconsistency in how these terms are applied in the literature]. Another approach is to distinguish between one's *accuracy* in perceiving their internal signals, and the extent to which one *attends* to these signals (Murphy, Catmur, & Bird, 2019). Both accuracy and attention can be examined using objective performance measures (e.g., a heartbeat counting task) or subjective measures (e.g., self-report), which allows for potential assessment of four domains of interoceptive competence. Most previous work has focused on the objective accuracy and the subjective attention dimensions (Murphy, Brewer, et al., 2019). In the review that follows, I will specify the dimensions explored in the studies that relate to this topic.

Objective IA tasks (Zamariola, Maurage, Luminet, & Corneille, 2018), in particular the heartbeat tasks (Murphy, Brewer, Hobson, Catmur, & Bird, 2018; Zamariola, Maurage, et al., 2018), have received recent scrutiny concerning their reliability and validity. The heartbeat-counting task may not provide a “pure” measure of interoception (Desmedt, Luminet, & Corneille, 2018), and may rely strongly on exteroceptive processing (Murphy, Brewer, et al., 2018). Wittkamp, Bertsch, Vögele, and Schulz (2018) recommend using at least two objective measures when conceptualizing IA as a trait, and they note that situational factors can account for variance in task performance (see also Kanbara & Fukunaga, 2016). It is also methodologically difficult to assess IA objectively across different domains (which is why most

work has focused on cardiac sensations; Murphy, Brewer, Catmur, & Bird, 2017), but recent efforts have been made to address this (Critchley & Garfinkel, 2017; Murphy, Catmur, & Bird, 2018).

Focusing on individuals' subjective interoceptive experiences may be more enlightening. By adopting a self-report approach, a wider range of internal body sensations can be investigated. Recently, Murphy, Brewer, et al. (2019) developed the Interoceptive Accuracy Scale (IAS), which was meant to provide a domain-general measure of one's trait subjective IA. They found that scores on this scale were moderately associated in the predicted direction with another self-report measure of IA (the Interoceptive Confusion Scale; Brewer et al., 2016), and that they also predicted performance on an objective IA task. Thus, the IAS seems to provide an indirect index of general (i.e., both objective and subjective) IA functioning (Murphy, Brewer, et al., 2019). Scores on the IAS were unrelated to scores on a measure of subjective interoceptive attention (the Body Perception Questionnaire or BPQ; Porges, 1993). Although this may seem counterintuitive (as attention may seem to be a prerequisite step for IA to occur), it should be noted that measures of interoceptive attention often assess the *frequency* with which these cues are the focus of attention, rather than one's *capacity* to direct attention inward. Murphy, Brewer, et al. (2019) also point out that a person might be attentive to internal signals even if their perception of these signals is inaccurate.

Interoception in Alexithymia. In general, links between alexithymia and interoceptive atypicalities make sense, given that cortical areas that make up the “interoceptive cortex” (the insula, ACC, and prefrontal, somatosensory, and somatomotor cortices; Herbert & Pollatos, 2012) overlap with regions that often show aberrant activity in people with alexithymia when they engage in emotion processing (Deng et al., 2013; Donges & Suslow, 2017; Hadjikhani et

al., 2017; Heinzl et al., 2010; Jongen et al., 2014). Some argue that, in people with alexithymia, atypicalities in processing interoceptive states might contribute to problems simulating and empathizing with the feelings of others (Bird & Viding, 2014; Mul, Stagg, Herbelin, & Aspell, 2018; Saito, Yokoyama, & Ohira, 2016; Valdespino et al., 2017).

Alexithymia is often associated with deficits in objective IA (Herbert, Herbert, & Pollatos, 2011; Herbert & Pollatos, 2012; Murphy, Catmur, & Bird., 2018; Sowden, Brewer, Catmur, & Bird, 2016). It has also been suggested that difficulties in objective IA observed in ASD might reflect the unusually high incidence of alexithymic traits in this population; indeed, recent research suggests that alexithymia is a better predictor of impaired objective IA than ASD group membership (Brewer, Happé, Cook, & Bird, 2015) or traits (Shah, Hall, Catmur, & Bird, 2016). Murphy, Catmur, and Bird (2018) found that stronger alexithymic traits were associated with decreased IA in taste and muscular effort domains, and with reduced use of interoceptive cues when completing a respiratory IA task. These authors thus describe alexithymia as an index of “multidimensional, multi-domain, interoceptive impairment” (p. 405).

There are mixed findings regarding the relationships between alexithymia and *subjective* interoceptive abilities, which might be explained by lack of specificity in previous work on whether studies were measuring interoceptive attention or accuracy (Murphy, Catmur, & Bird., 2019). In developing the IAS, Murphy, Brewer, et al. (2019) found that stronger alexithymic traits were associated with lower scores on measures tapping into IA (the IAS and the Interoceptive Confusion Scale), but were unrelated to scores on a measure of subjective interoceptive attention (the BPQ). In other work, however, a positive relationship has been reported between attention to interoceptive signals (assessed with the Self-Awareness Questionnaire) and scores on specific subscales of the TAS-20—namely the DIF and DDF

scores (Longarzo et al., 2015). Recent findings also suggest that the nature of the relationship between specific alexithymic traits and interoceptive attention may change depending on the perceived valence of the interoceptive cue. Thus, Zamariola, Vlemincx, Luminet, and Corneille (2018) noted a positive relationship between DIF and heightened attention to *unpleasant* body sensations (perhaps reflecting hypersensitivity to sensations such as pain), but a negative relationship between DDF, EOT, and TAS-20 Total scores and attention to *neutral* body cues. [Note that the scale they used did not include the assessment of positively valenced cues.] Interestingly, Fournier, Luminet, Danbrun, Dutheil, Pellissier, and Modillon (2019) noted that two items from the DIF subscale of the TAS-20 seem tap directly into problems distinguishing between body sensations and feelings, and may represent a latent interoception factor. These authors found that scoring highly on this latent factor (reflecting problems in this area) was associated with increased reports of psychological and health difficulties. Finally, in a recent meta-analysis, Trevisan et al. (2019) reported a moderate, negative association between alexithymia and subjective IA. Although these authors found no overall support for a link with objectively measured IA, they note that problems with measurement error or other confounds may have contributed to this null finding.

Although the foregoing discussion supports the general conclusion that alexithymia is associated with atypical interoception, it is clear that the nature of the relationship depends on the way in which interoception is measured, the strength of specific alexithymic traits, and the nature of the interoceptive cue under study. Failing to account for these factors may explain why there are conflicting theories regarding the role of interoception in alexithymia (Scarpazza & di Pellegrino, 2018).

An alternative way of conceptualizing the interoceptive abilities of people with alexithymia might come from combining the four-factor model of interoception proposed by Murphy et al. (2019) with the attention-appraisal model of alexithymia proposed by Preece et al. (2017). Recall that Preece et al. (2017) argue that EOT disrupts one's ability to focus on affective feeling states (positive and negative emotions), whereas DIF and DDF disrupt the ability to think about these states. Similar relationships may be evident with non-affective feeling states (relating to somatic states/illnesses and homeostasis). That is, EOT might also limit one's ability to focus on these states (creating problems with interoceptive awareness or attention), whereas DIF and DDF might disrupt one's ability to accurately appraise them (creating problems with IA). The combination of these difficulties might result in overall interoceptive impairment and/or atypical weighting of interoceptive and other sensory cues.

Sensitivity to Somatosensory and Environmental Cues

There is evidence to suggest that somatosensory processing is atypical in people exhibiting alexithymia. In a recent study, Borhani, Ládavas, Fotopoulou, and Haggard (2017) administered a comprehensive battery of somatosensation tasks to adults exhibiting low and high levels of alexithymic traits. Group differences did not emerge on most of the tasks. However, the group scoring high in alexithymia exhibited hyposensitivity to warmth, compared to those scoring low in alexithymia. DIF and DDF scores, but not EOT scores, predicted warmth thresholds across participants in a follow-up study. Interestingly, these authors speculated that, in people with alexithymia, bottom-up deficits in detecting warmth could translate into atypical experiences and expressions of *emotional* warmth.

Challenges regulating responses to incoming sensory stimulation more generally have been conceptualized as a core component of alexithymia (Milosavljevic et al., 2016). Evidence

that individuals with alexithymia show atypical sensitivities to environmental cues comes from research examining this trait's relationship with SPS. Recall from Chapters 1 and 2 that SPS is a trait characterized by elevated emotional reactivity to, and deep cognitive processing of, environmental stimuli (Aron et al., 2012). SPS can be measured with self-report instruments such as the HSPS (Aron & Aron, 1997). In the supplementary analyses in Chapter 2, I found that many individuals who scored above the cut-score for alexithymia also scored highly on the HSPS, and that positive associations between problems with emotional appraisal and EOE largely drove this relationship. This is consistent with work of Liss et al. (2008). These authors argued that those who are easily overwhelmed by sensory stimulation might find it hard to identify and/or describe what they are feeling. In line with my findings in Chapter 2, Liss et al. also observed a negative relationship between EOT and scores on AES, suggesting that those who are externally oriented are less likely to be moved by the arts and music. It is possible that this reflects a failure to direct attention to how external cues resonate in one's body.

Sensory Processing Styles

Sensory processing styles refer to patterns in the way people process and respond to sensory information in their environment. In her model, which has motivated much research in this area, Dunn (1997) characterized sensory processing along two dimensions: one relating to neurological threshold and another to behavioural self-regulation (see Figure 7 for a schematic depiction of the model). The neurological threshold continuum describes the amount of sensory information required to activate the CNS: high neurological thresholds reflect hyposensitivity, and low neurological thresholds reflect hypersensitivity. The behavioural regulation continuum delineates how the individual responds to sensory information—either actively or passively. Active strategies are used when an individual attempts to control the amount of sensory

information that they receive by responding counter to their neurological threshold. Here, hyposensitivity is countered by actively seeking out stimulation (Sensation Seeking, or Seek), whereas hypersensitivity is countered by actively avoiding it and suppressing one's emotional reactions (Sensory Avoidance, or SA). When people use more passive strategies, they process the sensory information in line with their neurological threshold. Here, hyposensitivity simply leads to a lack of responding (Low Registration, or LR), while hypersensitivity leads one to become overstimulated and possibly shut down (Sensory Sensitivity, or Sen).

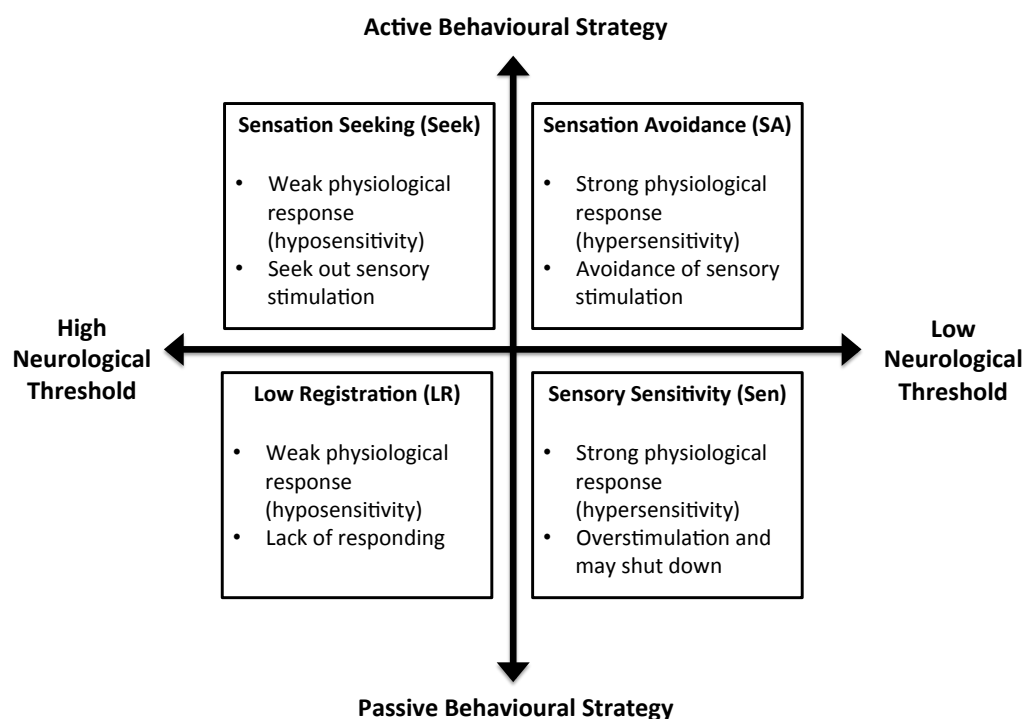


Figure 7. Sensory processing patterns based off of Dunn's (1997) model. Quadrants are delineated based on where a person's scores fall on the neurological threshold and behavioural strategy continuums.

An individual's sensory processing style can be assessed using the Adolescent/Adult Sensory Profile (AASP; Brown & Dunn, 2002; for information regarding its development see Brown, Tollefson, Dunn, Cromwell, & Filion, 2001) through which one can generate a profile

that depicts scores in each of the four quadrants. Items on the AASP tap into sensory processing from all five senses, as well as the processing of kinesthetic and movement cues. Elevated scores on LR, SA, and Sen are consistently associated with negative mental health outcomes; thus, these sensory tendencies are often marked by increased occurrence of depressed mood and hopelessness (Engel-Yeger, Gonda, et al., 2018; Serafini, Gonda, et al., 2017), anxiety (Engel-Yeger & Dunn, 2011a), posttraumatic stress (Engel-Yeger, Palgy-Levin, & Lev-Wiesel, 2013), and pain catastrophization (Engel-Yeger & Dunn, 2011b). Elevated scores in these quadrants also predict increased psychiatric symptomology (Engel-Yeger et al., 2016) and length of psychiatric episodes (Serafini, Engel-Yeger, Vazquez, Pompili, & Amore, 2017). These results suggest that, like alexithymia, higher scores in these quadrants may be transdiagnostic risk markers for psychopathology. Conversely, high Seek scores have been associated with increased resilience against psychopathology (Engel-Yeger et al., 2016; Serafini, Engel-Yeger, et al., 2017; Serafini, Gonda, et al., 2017), increased positive affect (Engel-Yeger & Dunn, 2011c), and more secure romantic attachment styles (Jerome & Liss, 2005). However, people scoring high in Seek may also be more likely to engage in risky behaviour that is positively reinforcing, such as problematic alcohol use (Sznitman & Engel-Yeger, 2017).

Relationships between alexithymic traits and sensory processing styles have been examined indirectly in a few studies involving clinical populations. In adolescents with ASD, co-occurring alexithymia predicted elevated scores on LR (Milosavljevic et al., 2016). Bashapoor, Hosseini-Kiasari, Daneshvar, and Kazemi-Taskooh (2015) observed heightened DIF and DDF, along with elevated scores on LR, Seek and SA, in men with substance dependence, compared to a control group. Using structural equation modeling, Serafini et al. (2016) showed that sensory quadrant scores mediated the relationship between alexithymic traits and quality of

life in participants with mood disorders. Finally, Serafini, Gonda, et al. (2017) looked at interactions between sensory processing styles and various traits, including alexithymia, in adults who were diagnosed with a major mood disorder. Here, DDF, DIF, and TAS-20 Total scores were all positively correlated with LR, and TAS-20 Total scores were also positively associated with Sen and SA. To my knowledge, no work has looked at the relationships between alexithymia and sensory processing styles (as defined by Dunn, 1997) in typical adults.

Key Questions Addressed in Study 1

In Study 1, I explored possible links between alexithymic traits and self-reported processing of and responsiveness to environmental and body-based sensory cues. To do this, I administered self-report measures of alexithymia, IA, SPS, and sensory processing style to a large, non-clinical sample of young adults. I then looked at the inter-relationships between scores on these measures. I sought to address three key questions: (1) What are the relationships between alexithymic traits, SPS, and IA?; (2) Do any features of SPS improve prediction of alexithymic traits above and beyond that accounted for by IA?; and (3) Do sensory processing styles mediate the relationship between IA and specific alexithymic traits?

Method

Participants

I tested 209 individuals recruited from the University of Manitoba's Introduction to Psychology participant pool. One participant was excluded because she did not complete the AASP. There were no other missing data, however seven participants were excluded because they did not achieve a score of three or more on a measure of conscientious responding (described below), suggesting that they were exhibiting poor effort. This left a final sample of

201 (112 women and 89 men, $M_{\text{age}} = 19.7$ years, $SD = 3.9$, range 17-52). Participants received credit toward a course requirement for taking part.

Procedures

The Psychology/Sociology Human Research Ethics Board at the University of Manitoba approved my testing protocol. Participants were tested in groups of approximately 30 in a computer lab. Participants provided informed consent, indicated their age and their biological sex, and then completed two sets of questionnaires. One set was administered using an online Qualtrics survey, and included items comprising the TAS-20 (Bagby et al., 1994), the IAS (Murphy, Brewer, et al., 2019), the HSPS (Aron & Aron, 1997), the Orienting Sensitivity (OS) subscale of the Adult Temperament Questionnaire (ATQ) – Short (Evans & Rothbart, 2007), the Conscientious Responders Scale (CRS; Marjanovic, Struthers, Cribbie, & Greenglass, 2014), and an additional measure included for exploratory purposes. In addition to the Qualtrics survey, participants completed the hardcopy version of the AASP (Brown & Dunn, 2002). Half of the participant groups completed the Qualtrics survey first; the other half began with the AASP. Completion of the testing protocol took approximately 45 minutes.

Materials

Toronto Alexithymia Scale (TAS-20). For a description of the TAS-20 please refer to Chapter 2 (p. 28).

SPS. Following recommendations of Aron et al. (2012), in this study I used two different measures to assess SPS: the HSPS and the OS subscale from the ATQ–short. Although I described the HSPS in the Method section in Chapter 2 (p. 29), I will remind the reader that (as per Lionetti et al., 2018): (a) the Total (mean) score on this 27-item inventory provides a general measure of SPS; (b) individuals scoring below the 30th percentile, between the 30th and 70th

percentile, and above the 70th percentile are referred to as Dandelions, Tulips, and Orchids, respectively; and (c) EOE, AES, and LST subscale scores can be derived by averaging responses across relevant items.

The EOE score reflects an individual's tendency to become overwhelmed by external and internal sensory cues, and LST items tap into the extent to which someone experiences unpleasant sensory arousal to external cues. Thus, together these scales focus on how affected one is by different types of higher intensity stimuli (e.g., environmental, interoceptive) and multi-tasking demands, and how one characteristically responds to them (e.g., whether one avoids watching violent television shows or being in overwhelming situations). The AES score reflects one's tendency to be "deeply moved by the music and the arts" (Lionetti et al., 2018, p. 2).

The 15-item OS subscale of the ATQ-short also yields a Total score and three subscale scores: Neutral Perceptual Sensitivity (NPS; 5 items), Affective Perceptual Sensitivity (APS; 5 items), and Associative Sensitivity (AS; 5 items). Items on this measure are responded to using a 7-point Likert scale, ranging from 1 = *Extremely untrue of you* to 7 = *Extremely true of you*.

The NPS subscale includes items that tap into one's explicit awareness of low-intensity/subtle environmental cues that are transmitted through the visual, auditory, tactile, and olfactory-gustatory modalities (e.g., the extent to which you notice people's eye colours). These items are solely focused on the degree to which one *notices* such cues, and not how *affected* one is by them.

The APS subscale taps into the degree to which one is aware of one's emotional response to low-intensity, non-social cues about one's surroundings (e.g., a room's colour or lighting, the weather), or conveyed through music or the visual arts; as such, it shares some overlap with the

AES scale from the HSPS. Finally, the AS subscale taps into the extent to which individuals engage in processes that are *not* driven by stimuli in the immediate environment, such as some aspects of problem solving, vivid imagery, and dreaming. Together, then, the items on these three scales capture aspects of aesthetic sensibility, the richness of one's inner life, and depth of processing.

Adolescent/Adult Sensory Profile (AASP). The AASP (Brown & Dunn, 2002) consists of 60 items that measure trait sensory processing styles in daily life along two dimensions: neurological threshold (high/low) and behavioural response style (active/passive). There are 15 items assessing each of the four quadrants defined in Dunn's (1997) model (Figure 7): LR, Seek, Sen, and SA. LR items tap into the extent to which an individual misses or is slow to respond to environmental stimuli. Seek items focus on one's proclivity to seek out and enjoy environmental stimuli. SA items inquire about attempts to avoid or reduce exposure to environmental stimuli. Finally, Sen items assess the degree to which one notices and is distracted or made uncomfortable by environmental stimuli. This questionnaire explores responses to sensory information in visual, auditory, tactile, and taste/smell domains, as well as cues related to movement processing (vestibular/proprioceptive). The authors of this measure explain that quadrant scores reflect processing styles that generalize across these sensory modalities.

Participants responded to each item using a 5-point Likert scale, ranging from 1 = *Almost never* to 5 = *Almost always*. The Total score computed for each quadrant can range from 5 to 75. In their standardization study, which included 950 adolescents/adults, Brown et al. (2001) found that the internal consistency within each quadrant ranged from an alpha of .64 to .78. These values were similar to the values of internal consistency observed by Pohl, Dunn, and Brown (2003). The AASP was determined to have good convergent and discriminant validity (Brown et

al., 2001).

Interoceptive Accuracy Scale. The IAS is a unidimensional self-report measure of IA (Murphy, Brewer, et al., 2019). It is comprised of 21 items that tap into one's perception of a wide range of bodily sensations (e.g., "I can always accurately perceive when I am hungry"). Participants responded to each item using a 5-point Likert scale ranging from 1 = *Strongly agree* to 5 = *Disagree strongly*. Scores can range from 21 to 105, and higher scores represent greater perceived IA. The IAS exhibits good internal consistency, test-retest reliability, and construct validity (Murphy, Brewer, et al., 2019).

Attention Checks: Conscientious Responders Scale. The CRS (Marjanovic et al., 2014) is a measure designed to assist researchers in detecting poor effort in participants' responding during surveys. The five items comprising the CRS were randomly dispersed throughout the items included in the Qualtrics survey. Each CRS item instructs participants to respond in a particular way—for example: *To respond to this question, please choose option number five, "slightly agree."* There are five response options for each item, and items are scored as correct or incorrect. In accordance with the recommendations of the authors of the scale, scoring 3/5 or greater is taken as evidence of sufficiently conscientious responding.

Results

The primary goal of this study was to examine associations between measures of alexithymia, sensitivity to environmental cues, and IA in a non-clinical, young adult sample whose TAS-20 scores spanned a large range. As outlined below, I used correlation, hierarchical regression, and mediation analyses (respectively) to address my three key questions. The analyses were completed using SPSS 25 (Armonk, NY: IBM Corp.) and MPlus Version 6.0 (Muthen & Muthen, 1998-2010). Unless otherwise indicated, an alpha level of .05 was adopted

for tests of significance. Before presenting my main findings (which are organized around my research questions), I provide an overview of the characteristics of my sample.

Sample Characteristics

Table 4 presents descriptive statistics for the final sample on the study variables. Regarding TAS-20 Total scores, 39% of the sample scored in the alexithymic range (≤ 51), 33% scored in the borderline range (52 - 60), and 28% met criteria for alexithymia (≥ 61). The percentage of participants falling in the borderline and alexithymic range is higher than percentages seen in published norms (Mattila et al., 2010), however similar subscale means have been reported in large university samples (Mei, Xu, Gao, Ren, & Li, 2018; Qualter, Quinton, Wagner, & Brown, 2009).

Table 4

Descriptive Statistics for Study Variables in the Full Sample (N = 201)

		M (SD)	Minimum	Maximum
TAS-20	Total	53.9 (10.6)	29.0	82.0
	DIF	18.5 (5.8)	7.0	34.0
	DDF	15.5 (4.6)	5.0	25.0
	EOT	19.9 (4.2)	8.0	31.0
HSPS	Total	4.0 (0.8)	1.5	6.7
	EOE	4.4 (1.0)	1.3	6.9
	AES	4.4 (0.9)	2.3	6.4
	LST	3.2 (1.3)	1.0	7.0
OS	Total	72.0 (10.6)	44.0	102.0
	NPS	23.6 (4.2)	12.0	35.0
	APS	23.8 (5.3)	8.0	35.0
	AS	24.7 (4.9)	11.0	35.0
IAS	Total	83.2 (10.0)	58.0	105.0
AASP	Seek	47.4 (7.3)	29.0	65.0
	LR	34.0 (6.8)	19.0	57.0
	Sen	38.8 (8.4)	17.0	66.0
	SA	40.0 (8.0)	22.0	61.0

Note: TAS-20: Toronto Alexithymia Scale; Difficulty Identifying Feelings (DIF); Difficulty Describing Feelings (DDF); Externally-Oriented Thinking (EOT); HSPS: Highly Sensitive Person Scale; Ease of Excitation (EOE); Aesthetic Sensitivity (AES); Low Sensory Threshold (LST); OS: Orienting Sensitivity: Neutral Perceptual Sensitivity (NPS); Affective Perceptual Sensitivity (APS); Associative Sensitivity (AS); IAS: Interoceptive Accuracy Scale; AASP: Adult/Adolescent Sensory Profile: Sensation Seeking (Seek); Low Registration (LR); Sensory Sensitivity (Sen); Sensory Avoidance (SA)

Question 1. What are the relationships between alexithymic traits, SPS, and IA?

As a first step I performed correlational analyses to explore the relationships between alexithymia, measures of SPS, and IA. As can be seen in Table 5, TAS-20 Total scores were positively correlated with HSPS Total scores, but not with OS Total scores. Closer inspection of subscales confirmed that the appraisal dimensions of alexithymia were mainly driving the association with HSPS Total scores through their strong *positive* relationship with EOE. These results support the view that these specific aspects of alexithymia are associated with hypersensitivity to environmental cues.

Table 5.

Intercorrelations between Study Variables

		TAS-20				HSPS				OS			
		Total	DIF	DDF	EOT	Total	EOE	AES	LST	Total	NPS	APS	AS
TAS-20	Total	--											
	DIF	.83**	--										
	DDF	.80**	.58**	--									
	EOT	.50**	0.09	0.13	--								
HSPS	Total	.34**	.47**	.32**	-.14*	--							
	EOE	.41**	.48**	.36**	-0.04	.89**	--						
	AES	.04	.22**	.15*	-.37**	.65**	.36**	--					
	LST	.21**	.28**	.17*	-0.05	.80**	.57**	.37**	--				
OS	Total	-0.04	0.14	0.07	-.37**	.37**	.16*	.61**	.25**	--			
	NPS	-.14*	-0.1	-0.05	-.18*	0.00	-0.08	.16*	0.01	.60**	--		
	APS	-0.06	0.11	0.01	-.32**	.44**	.25**	.60**	.31**	.82**	.25**	--	
	AS	0.1	.25**	.19**	-.30**	.33**	.15*	.54**	.20**	.77**	.17*	.47**	--
IAS	Total	-.27**	-.20**	-.18*	-.21**	-0.06	-0.11	0.11	-0.06	.23**	.15*	.29**	0.05

Note. TAS-20: Toronto Alexithymia Scale: Difficulty Identifying Feelings (DIF); Difficulty Describing Feelings (DDF); Externally-Oriented Thinking (EOT); IAS: Interoceptive Accuracy Scale; HSPS: Highly Sensitive Person Scale: Ease of Excitation (EOE); Aesthetic Sensitivity (AES); Low Sensory Threshold (LST); OS: Orienting Sensitivity: Neutral Perceptual Sensitivity (NPS); Affective Perceptual Sensitivity (APS); Associative Sensitivity (AS)

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

EOT was *negatively* associated with scores on the AES, APS, and AS scales, which—as suggested in the Method section—assess the richness of one’s inner life, including awareness of how deeply one resonates at an emotional level with the arts and music. These results support the view that EOT (the degree to which one is externally, as opposed to internally, focused) is in some respects antithetical to these specific aspects of SPS.

IA was negatively associated with TAS-20 Total and subscale scores; thus, consistent with past research (Murphy, Brewer, et al., 2019), those who scored lower on the IAS were more likely to be classified as alexithymic. An important, novel finding of the present study was that IA was also *positively* related to OS Total scores, and to scores on the NPS and APS subscales, specifically. This suggests a link between low IA and both a reduced sensitivity to subtle

environmental cues (NPS) and a weaker awareness of how they affect one at an emotional level (APS). IA was not associated with any subscales of the HSPS.

The foregoing illustrates why, when exploring the relationships between alexithymia and SPS, it is important to examine the subscales individually, rather than relying exclusively on Total scores. It also illustrates that it is important to supplement the HSPS with the OS in order to capture the full range of traits associated with SPS (as recommended by Aron et al., 2012). Had I not done this, I would not have noted the negative relationships between EOT and having a rich inner life, and between IA and sensitivity to subtle environmental cues. In short, including the OS scale allowed me to achieve a deeper appreciation of the similarities and differences between alexithymia and SPS.

Question 2. Do any features of SPS improve prediction of alexithymic traits above and beyond that accounted for by IA?

Previous reports suggest that alterations in interoceptive abilities are characteristic of people with alexithymia. To investigate whether accounting for particular traits associated with SPS improved prediction of alexithymic traits above and beyond that accounted for by IA, I ran a hierarchical multiple regression using the forced entry method. I entered IA as a predictor at Step 1, and subscale scores for the HSPS and the OS as predictors at Step 2. Both models were significant ($F > 9.08, p < .001$). As can be seen in Table 6, IA continued to predict TAS-20 Total scores following the introduction of the SPS measures in Step 2, but EOE and AS also accounted for unique variance. Scoring low in IA, or scoring high in EOE or AS, was associated with reporting stronger alexithymic traits. These results suggest that reduced IA may be just one facet of atypical sensory processing that can characterize people with alexithymia.

Table 6.
Hierarchical Model of Predictors of TAS-20 Total Scores

		<i>b</i>	<i>SE b</i>	β	<i>p</i>
Model 1	(Constant)	77.65	6.08		0.00
	IA	-0.29	0.07	-0.27	0.00
Model 2	(Constant)	55.06	7.77		0.00
	IA	-0.18	0.07	-0.17	0.01
	HSPS_EOE	0.38	0.07	0.42	0.00
	HSPS_AES	-0.16	0.15	-0.10	0.28
	HSPS_LST	-0.01	0.11	0.00	0.95
	OS_NPS	-0.17	0.17	-0.07	0.31
	OS_APS	-0.24	0.17	-0.12	0.16
	OS_AS	0.37	0.17	0.17	0.03

Note. $R^2 = .072$ and $f^2 = 15.47$ for Step 1; $\Delta R^2 = .176$ and $f^2 = 7.51$ for Step 2. TAS-20: Toronto Alexithymia Scale; IA: Interoceptive Accuracy; HSPS: Highly Sensitive Person Scale: Ease of Excitation (EOE); Aesthetic Sensitivity (AES); LST (Low Sensory Threshold); OS: Orienting Sensitivity; Neutral Perceptual Sensitivity (NPS); Affective Perceptual Sensitivity (APS); Associative Sensitivity (AS).

Question 3. Do sensory processing styles mediate the relationship between IA and specific alexithymic traits?

If IA is determined, in part, by one's *general* sensory processing style, one might predict that measures tapping into one's sensory profile would mediate the relationship between reduced IA and specific alexithymic traits. To investigate this, I tested a model in which the four AASP quadrant scores were entered as correlated mediators of the links between IA and TAS-20 subscale scores (DIF, DDF, EOT). Mediation fit statistics indicate a good fit if the Comparative Fit Index (CFI) is ≥ 0.95 , the Standardized Root Mean Square Residual (SRMR) is $\leq .08$, and the Root Mean Square Error of Approximation (RMSEA) is ≤ 0.05 (Gunzler, Chen, Wu, & Zhang, 2013; Hu & Bentler, 1999). Based on these indices, the model exhibited relatively good fit: $\chi^2(3) = 5.63$, $p = .13$; CFI = 0.99; SRMR = 0.024; RMSEA = 0.066. As shown in Figure 8, I observed significant indirect effects of IA on EOT through LR ($B = -.03$, 95% CI $[-.05, -.01]$) and Seek ($B = -.02$, 95% CI $[-.04, -.004]$); significant indirect effects of IA on DIF through LR

($B = -.04$, 95% CI $[-.07, -.01]$) and Sen ($B = -.03$, 95% CI $[-.07, -.004]$); and significant indirect effects of IA on DDF through LR ($B = -.03$, 95% CI $[-.06, -.01]$) and SA ($B = -.02$, 95% CI $[-.05, -.002]$). Low IA was linked to high EOT because both were associated with a general hyposensitivity to sensory cues (high LR) and a reluctance to seek out pleasurable stimuli (low Seek). Low IA was also linked to problems with emotional appraisal (high DIF/DDF) because both were associated with scoring high on LR and/or on measures associated with sensory hypersensitivity (Sen in the case of DIF, and SA in the case of DDF).

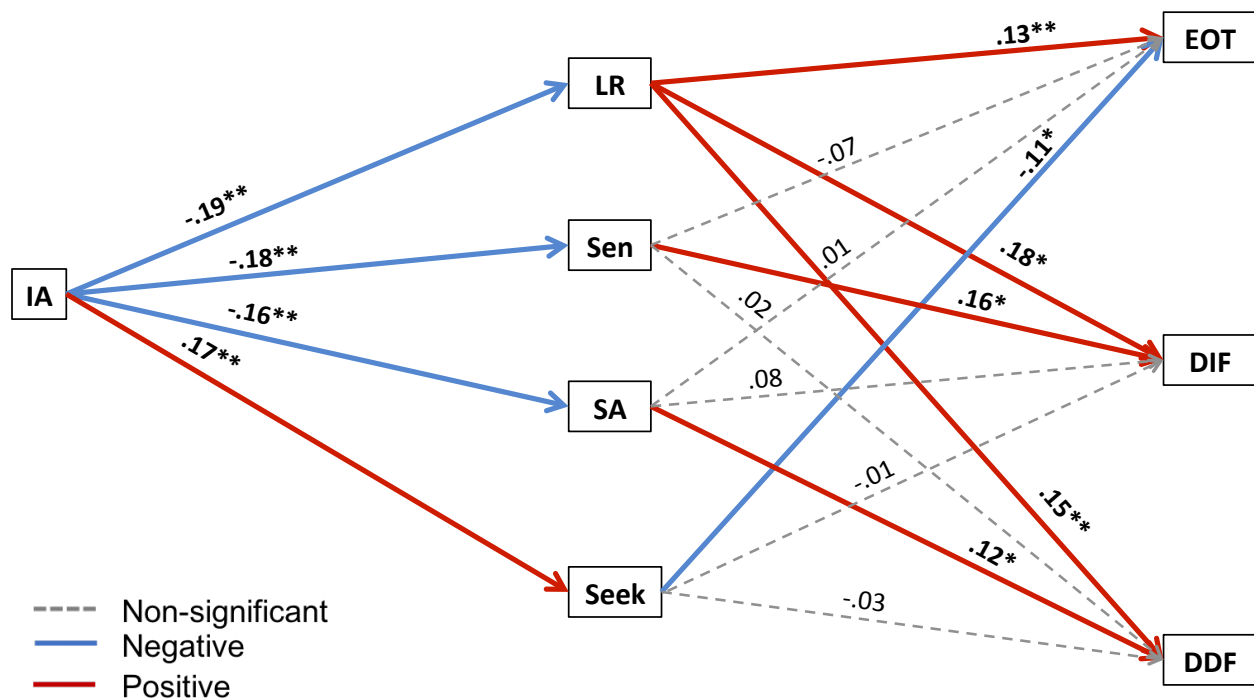


Figure 8. Mediation model evaluating the indirect effects of sensory profile quadrant scores as correlated mediators on the relationship between interoceptive accuracy and the subscales of the TAS-20. IA: Interoceptive Accuracy; Adolescent/Adult Sensory Profile: Low Registration (LR); Sensory Sensitivity (Sen); Sensation Avoidance (SA); TAS-20: Toronto Alexithymia Scale – 20. * $p < .05$; ** $p < .01$.

Discussion

The analyses described above provide several important insights into the relationships between alexithymic traits, IA, and sensory processing in a non-clinical, young adult sample. I

found that all TAS-20 subscales were associated with decreased IA, but that EOT and emotional appraisal showed distinctly different relationships with measures of SPS. Some aspects of SPS also accounted for unique variance in TAS-20 Total scores, above and beyond that attributable to IA. Finally, I also presented evidence that one's general sensory processing style can account for the relationship between IA and specific alexithymic traits. In the sections that follow, I integrate these findings, focusing on two main areas of discussion: the idea that the EOT and emotional appraisal dimensions of alexithymia are fundamentally distinct; and the idea that alexithymia is associated with particular ways of processing and/or integrating body-based and environmental cues.

EOT and Emotional Appraisal are Distinct

The current results support the view that alexithymia, as measured using the TAS-20, is a multifaceted trait. I extended previous findings by showing that these dimensions of alexithymia show different relationships to measures assessing how one processes and subjectively experiences sensory information. Specifically, EOT was distinguished from emotional appraisal (captured by the DDF/DIF subscales) in its relationship to features of SPS, and to specific aspects of individuals' sensory processing style more generally.

EOT is traditionally characterized as an externally-focused thinking style (Demers & Koven, 2015; Demers et al., 2019; Goerlich, 2018), but it has also been linked to reduced openness to new experiences (Ueno, Maeda, & Komaki, 2014), which is characterized in part by a lack of interest in novelty, and with limitations in imagination and the appreciation of art. This fits well with my findings that EOT was related to reduced sensation seeking tendencies and with having an impoverished inner life. The negative relationships I observed between EOT and both IA and the awareness of one's emotional response to music and the arts (AES/APS) also fit with

the suggestion by Preece et al. (2017) that those scoring high on EOT show reduced attention to their internal state (both physiological and emotional). These authors argue that failing to direct attention inward contributes (along with problems with emotion appraisal) to the difficulties with emotion regulation that are common in those with alexithymia.

According to Preece et al. (2017), different kinds of avoidance responses are key in the development and maintenance of alexithymia. They argue that when disruption is observed at the attention stage of emotion regulation (problems with EOT), this manifests in avoidance of *focusing on* emotions. My results exploring the relationships between TAS-20 subscales and sensory processing provide a more nuanced interpretation. I found that EOT was associated with hyposensitivity to sensory information (high LR), and with a lower tendency to seek out pleasurable experiences (low Seek). It might be, then, that people exhibiting strong EOT do not focus on their emotions because they simply fail to register or are slow to respond to events happening around them and/or the emotional resonance they generate. In keeping with this idea, Davydov, Luminet, and Zech (2013) observed that women scoring high (vs. low) in EOT showed reduced physiological reactivity when viewing sad films that were chosen to elicit either increased or decreased arousal in typical viewers. Scoring high on EOT has also been associated with less effective processing of threat-related facial expressions (Donges & Suslow, 2017), and with lower activation within neural emotion networks during emotion perception tasks (see Goerlich, 2018).

Preece et al. (2017) went on to suggest that disruptions at the appraisal stage are associated with avoidance in *thinking about* emotional experiences. Again, my findings provide a more nuanced interpretation. The results of my mediation analysis suggest that sensory hypersensitivity can result in an increased tendency to avoid unpleasant sensory stimulation

(which predicts difficulties *identifying* feelings) and/or to be easily overwhelmed by sensory stimulation (which predicts difficulties *describing* feelings). Interestingly, problems in both of these processes were also associated with high LR scores, and sensory profiles characterized by peaks in LR, Sen, and SA were not uncommon in people who scored in the alexithymic range (see Study 2). Although this combination of quadrant scores may seem odd, Jerome and Liss (2005) argue that scoring high on LR can actually be a sign of an under- or an extremely over-aroused system. In the latter case, the system might respond by shutting down, which could contribute to slowed responding (assessed by some items in the LR subscale) and/or create the *appearance* of hyposensitivity. It is also possible that some individuals vacillate between states of over- and under-arousal, or weight information coming in through particular sensory channels unevenly, making them hypersensitive to some types of cues, but hyposensitive to others (as has been described in ASD; Marco, Hinkley, Hill, & Nagarajan, 2011).

If high LR scores can arise for different reasons, this might explain why EOT and emotional appraisal—which I argued above were linked with hypo- and hypersensitivity, respectively—are both *positively* associated with scores on the LR subscale. It may also explain why alexithymia has been associated with both hyposensitivity (Donges & Suslow, 2017; Gaigg et al., 2018; Goerlich, 2018; Kleiman et al., 2016; Pollatos et al., 2008, 2011) and hypersensitivity (Bogdanov et al., 2013; Cecchetto et al., 2017; Luminet, Rimé, Bagby, & Taylor, 2004; Panayiotou & Constantinou, 2017) across different studies on emotion processing; and why heightened LR, Sen, and SA have all been linked to alexithymia in various clinical groups (Bashapoor et al., 2015; Engel-Yeger, Bloch, et al., 2018; Milosavljevic et al., 2016; Serafini et al., 2016).

The view of alexithymic traits offered here might also help us to better understand the scene perception results reported in Chapter 2. The significant, negative relationship between Seek and EOT uncovered in the present investigation suggests that those who have a weaker inner focus (strong EOT) are less likely to seek out pleasant sensory stimuli. If this lack of interest arises because they resonate weakly with such stimuli (due to sensory hyposensitivity) it might explain why, in the scene perception task, stronger EOT predicted undervaluing of *positive* scenes. The current results also suggest that scoring high on EOT is associated with reporting reduced sensitivity to *subtle* environmental cues (NPS and APS). This hyposensitivity may have affected how those scoring high in EOT resonated with subtle IM cues in the scene perception task and this, in turn, may have reduced their overall ability to evaluate the valence of these scenes accurately.

Interoception, Sensory Processing, and Cue Integration

Interoceptive deficits have been theorized to be archetypal of alexithymia (Brewer et al., 2016). I used a recently developed self-report measure of IA and replicated findings that alexithymic traits are inversely related to IA (Murphy, Brewer, et al., 2019). However, I also found that features of participants' general sensory processing style related to both IA and alexithymic traits in particular ways. Specifically, my findings extend the literature by showing that (a) hypersensitivity to environmental cues improves prediction of alexithymic traits, above and beyond that accounted for by interoceptive impairment (regression analysis); and (b) an individual's *general* sensitivity and way of responding to sensory stimuli can account for the links between IA and specific alexithymic traits (mediation analysis).

I argue that a person's general sensory processing style largely determines how that individual embodies information about the current context. Integration and appropriate

weighting of interoceptive and exteroceptive information is key in embodiment (Füstös, Gramann, Herbert, & Pollatos, 2013), and in developing a coherent sense of self. Indeed, Seth and Friston (2016) conjecture that a person's embodied self is generated from integrating predictions across proprioceptive, exteroceptive, and interoceptive dimensions. Although interoceptive cues originate from the body, afferent pathways transmitting this information to the CNS interact with processing of external sensory information (Pace-Schott et al., 2019). Some work suggesting that these interactions are important come from research on the rubber hand illusion, an effect that is thought to reflect multisensory integration and simulation. In these studies, participants have a rubber hand positioned in front of them, while their real hand is hidden. When the rubber hand and the participant's (unseen) hand are stroked synchronously, they are more likely to report that the rubber hand feels like their own hand (or is closer to their seen hand), compared to when the rubber hand is stroked asynchronously (Tsakiris, Tajadura-Jiménez, & Costantini, 2011). This effect is thought to arise because integration of visual and tactile cues in the synchronous condition strengthens embodiment. Using this paradigm, Tsakiris et al. (2011) found that people with low IA were more strongly influenced by exteroceptive than interoceptive information, as evidenced by their enhanced sensitivity to the rubber hand illusion. Conversely, people with high IA weighted internal and external cues more evenly, resulting in a weaker rubber hand illusion. Manipulating feelings of body ownership with this illusion (i.e., enhancing weighting of exteroceptive cues) is associated with improved accuracy on a heartbeat counting task in those who have low (but not high) baseline IA (Filippetti & Tsakiris, 2017). These authors speculate that those with lower IA use visual and tactile information about their bodies to help them more accurately represent their internal states. According to this view,

exteroceptive cues may resonate more strongly in people who have low IA, but processing both types of information remains strongly interconnected.

Multisensory cue integration is also evident in studies of the enfacement illusion (see Apps, Tajadura-Jiménez, Sereno, Blanke, & Tsakiris, 2015). In this paradigm, participants view the face of another being stroked synchronously or asynchronously with their own face. During the synchronous (compared to asynchronous) condition, participants are more likely to report that their partner's face is more similar to their own, suggesting that this illusion increases blurring between self and other. In his review on work with this illusion, Tsakiris (2017) notes that increased IA is related to the strength of this illusion, as is the case with the rubber hand illusion. Together, the findings from these two illusions emphasize that integrating interoceptive and environmental cues is key in embodiment, and that individual differences in IA influence the weighting given to different sensory cues. Tsakiris (2017) concludes that exteroceptive processing relates to the *adaptability* in one's sense of self, and interoceptive processing relates to the *stability* in one's sense of self.

I speculate that biases in environmental and interoceptive processing and/or atypical weighting or integration of these cues might be associated with stronger alexithymic traits. Hatfield, Brown, Giummarra, and Lenggenhager (2019) postulated that people on the autism spectrum (many of whom have alexithymia) preferentially process local, rather than global, interoceptive cues (which parallels that described in their processing of exteroceptive cues; Castelli, Frith, Happé, & Frith, 2002). This local bias, in combination with problems integrating interoceptive signals, makes it challenging for these individuals to generate an overall composite of their internal state. These authors posit that problems integrating interoceptive cues are likely driven by atypicalities within the anterior and posterior insula in this population, and that these

deficits could lead to problems with emotion understanding. Similar factors may contribute to the development of alexithymia in people who do not have ASD. Consistent with this, Shalev (2019) conjectures that alexithymia is in part driven by deficits in multisensory cue integration, and Murphy, Catmur, and Bird (2018) found that participants with stronger (compared to weaker) alexithymic traits were more likely to prioritize exteroceptive information when completing an IA task.

Study 2

Overall, the results of Study 1 suggested that the EOT and appraisal dimensions of alexithymia are distinct in a general sample, with each showing unique relationships to certain aspects of sensory processing. My findings also reinforce the idea that it is important to examine the interrelationships between variables of interest, rather than studying each individually. In Study 2, I explored the possibility that these interrelationships may vary across distinct subgroups of individuals. I tested this idea by applying a statistical technique called latent profile analysis (LPA) to the data collected for Study 1.

LPA can be used to categorize participants coming from a heterogeneous sample into more homogenous subgroups based on their responses on continuous variable measures (Berlin, Williams, & Parra, 2014). Thus, in Study 2 I used LPA to explore the possibility that there might be specific subgroups of individuals who could be distinguished by variation in the *relative strength* of EOT and problems with emotional appraisal, and by differences in their IA and sensory profiles. I expected to find distinct subtypes of individuals with alexithymia and/or alexithymia. The current work extends previous subtyping research in this field, which I briefly summarize next.

Subtyping Research using the Amsterdam Model of Alexithymia

Most of the subtyping literature on alexithymia has used Bermond and Vorst's (2001) BVAQ to quantify alexithymic traits. As briefly described in Chapter 1 (p. 12), the BVAQ samples both cognitive and affective alexithymic traits. A cognitive composite score can be obtained using scores on three subscales (verbalizing, identifying, and analyzing feelings), and an affective composite is derived from scores on the remaining two subscales (emotionalizing and fantasizing). The cognitive composite of the BVAQ is positively related to TAS-20 total scores (e.g., Berthoz, Perdereau, Godart, Corcos, & Haviland, 2007; Müller, Bühner, & Ellgring, 2004; Vorst & Bermond, 2001). Individuals who score high on the affective dimension (not measured by the TAS-20) report flattened affect and have reduced imaginative abilities. In the Amsterdam model, subtypes can be identified by categorizing individuals based on the relative strength of their cognitive and affective traits.

By applying factor analysis and principal component analyses to BVAQ scores, Bermond et al. (2007) identified two subtypes of alexithymia. Type I was characterized by difficulties articulating emotion cognitions (high scores on the cognitive dimension) and reduced awareness of emotional arousal (high scores on the affective dimension). The Amsterdam group has suggested that people exhibiting Type I may appear taciturn, experience and present a restricted range of emotions, and experience significant interpersonal difficulties stemming from their lack of emotion understanding (Moormann et al., 2008). In contrast, people exhibiting Type II experience deficits in the cognitive dimension but show intact or, indeed, *elevated* awareness of emotional arousal (Bermond et al., 2007). These individuals may be prone to problems coping with stress and exhibit high levels of neuroticism. Both Types I and II have been linked to specific patterns of personality disorders and psychopathology (Moormann et al., 2008).

Although consensus is not universal (see below), most work on subtyping using the BVAQ recognizes at least these two subtypes of alexithymia (e.g., Berthoz & Hill, 2005; Goerlich-Dobre et al., 2014; Larsen et al., 2003; Vorst & Bermond, 2001). Some researchers, however, suggest that heightened scores on the affective, but not cognitive, dimension should constitute Type III alexithymia (Bermond et al., 2006). Moormann et al. (2008) also recognize two other subtypes—lexithymics (who score low on both dimensions) and modals (who score in the average range on both dimensions)—as well as a “mixed” class who do not fit into any category. However, they point out that, because those with Type III, lexithymic, and modal profiles do not suffer from problems with affect regulation and have generally good psychological health it may be misleading to refer to them as examples of “alexithymia types” (p. 40).

A compromise may be to simply suggest that individuals can differ in their *alexithymia profiles*. I argue that doing so may be important in future work, given preliminary evidence that different alexithymia profiles may have distinct neural substrates (Goerlich-Dobre et al., 2015) and patterns of autonomic reactivity (Bermond, Bierman, Cladder, Moormann, & Vorst, 2010). Bermond et al. (2010) used the top and bottom 30% of their sample distribution of cognitive and affective BVAQ scores to create four extreme groups (three alexithymic and one lexithymic). They found an inverse relationship between pre-task *baseline* electrodermal response and cognitive alexithymia. Specifically, lower baseline electrodermal response was associated with higher cognitive alexithymia. In contrast, whereas affective alexithymia was unrelated to baseline electrodermal response, higher scores on this dimension were associated with lower electrodermal responses during passive viewing of fearful images.

Although using the BVAQ to measure alexithymic traits has been fruitful, it is not clear how separate the cognitive and affective dimensions (as measured by this instrument) are. Indeed, overlap, particularly with regard to the “analyzing” subscale, has been noted (de Vroeghe et al., 2018). Preece et al. (2017) also describe several limitations regarding the way in which the BVAQ measures the emotionalizing dimension (see also Watters, Taylor, Quilty, & Bagby, 2016). In this regard, it is interesting to note that an earlier version of the Toronto Alexithymia Scale included a “difficulties fantasizing” subscale, similar to that included in the BVAQ (Taylor, Ryan, & Bagby, 1985), but this subscale was removed during the development of the TAS-20 due to low psychometric support. This has led some to suggest that constricted fantasizing abilities may not constitute a core component of alexithymia (Preece et al., 2017).

In addition to the issues raised above, work using the BVAQ does not always support the distinction between Type I and Type II alexithymia. For example, using confirmatory factor analysis in a large sample, Bagby et al. (2009) did not find support for the emergence of these subtypes. These authors conceptualize alexithymia as a dimensional, rather than taxonic, construct (see also Parker, Keefer, Taylor, & Bagby, 2008).

Subtyping using the Toronto Model of Alexithymia

A few studies have used the TAS-20 (sometimes in combination with other measures) to delineate subtypes of alexithymia. For example, Lane et al. (2015) review studies that have used the TAS-20 and the Levels of Emotional Awareness Scale (LEAS) scale (Lane et al., 1990). In the LEAS one is presented with vignettes of interactions between dyads, and the participant is then asked how they (as the protagonist), and how the other character, would feel in each scenario. Scores on this measure might provide a measure of affective ToM (understanding how others feel). Lane et al. (2015) proposed the existence of anomic and agnosic forms of

alexithymia, with the former being associated with problems naming emotions but intact ToM, and the latter with impaired abilities to mentally represent emotions (due to problems with multisensory integration) and impaired ToM.

Other subtyping work comes from Kajanoja, Scheinin, Karlsson, Karlsson, and Karukivi (2017). These authors input the TAS-20 subscales and several mental health variables obtained from 113 adults into a cluster analysis, and two subtypes or clusters of alexithymia emerged. One (more common in men than women) was characterized by elevated DDF and EOT scores, and was negatively correlated with empathy; the other was marked with strong DIF, and individuals in this cluster frequently reported experiencing depression and anxiety symptoms.

Key Questions Addressed in Study 2

Some limitations of the previous subtyping literature in alexithymia include the reliance on the BVAQ (given concerns about some of its psychometric properties; e.g., de Vroege et al., 2018) and the use of “extreme” scores or median split procedures to delineate subtypes of participants. As suggested by Bagby et al. (2009), a more refined analysis using an approach such as LPA seems warranted. However, it appears from the previous discussion that there may be merit, if utilizing the TAS-20, to include additional measures that capture characteristics associated with alexithymia that are poorly sampled in this questionnaire. This was the approach taken in the present study, which I conducted using the data collected in Study 1 (refer to that study for a full description of the Methods).

Instead of focusing on ToM abilities (as in the work of Lane et al., 2015, discussed above), I incorporated measures related to sensory processing. In particular, given the current interest in exploring links between alexithymia and IA (e.g., Brewer et al., 2016) and the results of Study 1 (which demonstrated links between specific alexithymic traits and different aspects of

one's sensory processing style more generally), my LPA included subscale scores from the TAS-20, scores on the IAS, and quadrant scores from the AASP. Including all four AASP scores was particularly important here as, to my knowledge, most research using the AASP (including that described in Study 1) has only examined relationships between specific variables and individual quadrant scores. Although this can be informative, Brown and Dunn (2002) emphasize the importance of considering the full *sensory profile* when trying to describe an individual's sensory processing style.

Overall, Study 2 was designed to answer two key questions: (1) Can subtypes of individuals be identified based on the input variables listed above?; and, if so, (2) How do the observed subclasses differ with regard to their latent profiles? In addition to performing contrasts designed to answer the second question, I also compared the observed subclasses on measures of SPS. This was of interest given its links to alexithymia (see Chapter 2, and Chapter 3, Study 1), and given that some subscales of the HSPS and OS tap into aspects of SPS that are antithetical to alexithymia (e.g., having a rich inner life) but not fully captured by either the BVAQ or the TAS-20.

Results and Discussion

I have organized the presentation of my results and discussion around the two key questions listed above. The analyses described in this section were completed using MPlus Version 6.0 (Muthen & Muthen, 1998-2010) and SPSS 25 (Armonk, NY: IBM Corp.). Unless otherwise indicated, an alpha level of .05 was adopted for tests of significance.

Question 1. Can Subtypes of Individuals be Identified Based on their Alexithymic Traits, IA, and Sensory Processing Styles?

As noted above, to address this question I conducted an LPA using subscale scores on the TAS-20, IAS, and AASP as input variables. I first examined the fit statistics for a two-class model, and then increased the number of classes by one until the best fitting model was identified. As discussed in Berlin et al. (2014), selecting the optimal number of classes to fit the data is a complicated task, and when doing so the researcher should consider the particular research question, theory based on previous research, the meaning of the model, and observed fit statistics (see also Nylund, Asparouhov, & Muthén, 2007). The first fit statistic examined here was entropy, which provides a standardized measure of classification accuracy (see Berlin et al., 2014); here, higher entropy values indicate a better fitting model (Wang, Deng, Bi, Ye, & Yang, 2017). The remaining fit statistics examined here were the sample size adjusted Bayesian Information Criterion (ABIC; Sclove, 1987), the approximate p -value for the Bootstrapped Likelihood Ratio Test (BLRT; McLachlan & Peel, 2000), and the Lo-Mendell-Rubin Adjusted Likelihood Ratio Test (LMR-LRT; Lo, Mendell, & Rubin, 2001). Smaller ABIC values indicate better fit (Nylund et al., 2007). The BLRT and LMR-LRT tests are used to compare improvement in fit between models; here, statistically significant p -values indicate better fit for the current (k) model than the preceding ($k-1$) model. Nylund et al. (2007) compared these two tests and recommended the BLRT over the LMR-LRT, as the former more accurately identified the correct number of classes in their simulation study across several models tested.

Model fit was first evaluated based on theoretical meaningfulness and the distinctiveness of latent profiles. This is a main consideration when determining the number of latent subgroups supported by the data (Yang, 2006). Next, I examined the fit statistics presented in Table 7. The models (as a whole) had good classification quality. Although entropy remained high and relatively stable across the 3- to 6-class models, ABIC values and the BLRT results indicated

that each successive model provided a better fit than the one before. One could argue that the 6-class model provided the best fit to the data on statistical grounds, however I retained the 5-class model for two key reasons. First, as will be shown below, the latent class profiles for the 5-class model were very distinctive and theoretically meaningful. Second, the 6-class model included one class that was quite small (6% of the total sample), suggesting possible overfitting (Wang & Wang, 2012; Wickrama, Lee, O’Neal, & Lorenz, 2016).

Table 7
Fit Statistics for 2- to 6-class Latent Profile Models (N = 201)

Model	ABIC	Change in ABIC	Entropy	BLRT <i>p</i> -value	LMR-LRT <i>p</i> -value
2-Class	10498.05	0.00	0.72	<.001	0.001
3-Class	10447.52	-50.53	0.80	<.001	0.053
4-Class	10424.24	-23.28	0.81	<.001	0.320
5-Class	10407.59	-16.65	0.79	<.001	0.300
6-Class	10393.03	-14.56	0.79	<.001	0.580

Note: ABIC: Bayesian Information Criterion; BLRT: Bootstrapped Likelihood Ratio Test; LMR-LRT: Lo-Mendell-Rubin Adjustd LRT Test

Class sizes, sex distributions, and descriptive statistics for the input variables are shown in Table 8 for the 5-class model. The sex distributions varied somewhat across classes, $\chi^2(4) = 11.50$, $p = .022$, but only Class 4 included a significantly higher proportion of women than men (72% vs. 28%; one-sample binomial test, $p = .01$).

Table 8

Descriptive Statistics for Input Variables in the Five Classes and Kruskal-Wallis H Values for Group Comparisons

	Class 1	Class 2	Class 3	Class 4	Class 5	
Sample size	21	25	89	39	27	
(% of total sample)	(10.4%)	(12.4%)	(44.3%)	(19.4%)	(13.4%)	
Sex distribution (% women)	52.4	32.0	52.8	71.8	66.7	
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	H(4)
DIF	-.83 (.66)	-1.27 (.69)	.07 (.76)	.39 (.77)	1.03 (.79)	86.6*
DDF	-.80 (.75)	-1.13 (.64)	-.01 (.82)	.63 (.72)	.81 (.89)	77.3*
EOT	-.70 (1.09)	-.20 (.93)	.10 (.90)	.59 (.72)	-.44 (1.13)	30.8*
IAS	.45 (.91)	.98 (.78)	-.11 (.92)	-.77 (.72)	.19 (.92)	53.6*
Seek	-.29 (.68)	.40 (.86)	.15 (.92)	-1.00 (.65)	.82 (.83)	66.2*
LR	-.35 (.98)	-1.04 (.68)	-.08 (.83)	.24 (.74)	1.16 (.85)	66.7*
Sen	.53 (.54)	-1.31 (.56)	-.40 (.60)	.69 (.73)	1.13 (.87)	118.4*
SA	.87 (.59)	-1.28 (.53)	-.47 (.60)	.78 (.61)	.94 (.78)	134.5*

Note: Values shown for LPA input variables are mean Z-scores (*SD* indicated in brackets). Difficulty Identifying Feelings (DIF); Difficulty Describing Feelings (DDF); Externally-Oriented Thinking (EOT); Interoceptive Accuracy Scale (IAS); Sensation Seeking (Seek); Low Registration (LR); Sensory Sensitivity (Sen); Sensory Avoidance (SA)

* $p < .001$

As a preliminary step I examined the proportion of participants in each class who met criteria for being classified as alexithymic, borderline, or alexithymic based on TAS-20 Total scores (Parker, Keefer, Taylor, & Bagby, 2008), and the proportion who would be classified as Dandelions, Tulips, or Orchids based on HSPS Total scores (as per Lionetti et al., 2018). This information is presented in Table 9, which also provides mean total and subscale scores for the HSPS and the OS expressed as z scores based on the distribution of scores for each variable in the full sample ($N = 201$).

Table 9

Characteristics Associated with Alexithymia and SPS in the Five Latent Classes

		Class 1 Lexithymic Orchids	Class 2 Lexithymic Dandelions	Class 3 Modal	Class 4 Alexithymic Tulips	Class 5 Alexithymic Orchids
TAS-20 Classification ^a	% Lexithymic	90.5	100.0	34.8	2.6	7.4
	% Borderline	9.5	0.0	40.4	43.6	40.7
	% Alexithymic	0.0	0.0	24.7	53.8	51.9
HSPS Classification ^b	% Dandelion	14.3	84.0	37.1	10.3	0.0
	% Tulip	28.6	8.0	48.3	59.0	22.2
	% Orchid	57.1	8.0	14.6	30.8	77.8
HSPS	Total	0.50 **	-1.19 ***	-0.24 **	0.33 **	1.04 ***
	EOE	0.29	-1.21 ***	-0.11	0.27 *	0.86 ***
	AES	0.26	-0.48 *	-0.16	-0.07	0.86 ***
	LST	0.77 ***	-0.89 ***	-0.37 ***	0.51 ***	0.71 ***
OS	Total	0.43	0.13	-0.20	-0.25	0.56 **
	NPS	0.31	0.45 *	-0.10	-0.23	0.00
	APS	0.49 *	0.05	-0.22	-0.21	0.60 ***
	AS	0.13	-0.15	-0.11	-0.10	0.55 **

Note: Percentage of individuals in each class who would be classified as Lexithymic, Borderline, and Alexithymic based on total TAS-20 scores, and who would be classified as Dandelions, Tulips, and Orchids based on total HSPS scores. Values shown for HSPS and OS variables are mean Z-scores. HSPS: Highly Sensitive Person Scale; Ease of Excitation (EOE); Aesthetic Sensitivity (AES); Low Sensory Threshold (LST); OS: Orienting Sensitivity Scale; Neutral Perceptual Sensitivity (NPS); Affective Perceptual Sensitivity (APS); Associative Sensitivity (AS). The HSPS and OS values represent mean Z scores.

Value significantly different from zero (one-sample *t*-test): **p* < .05, ***p* < .01, ****p* < .001

Classes 1 and 2 were overwhelmingly lexithymic. They differed in that Class 1 scored significantly above and Class 2 scored significantly below the mean for the HSPS Total score. The majority of those in Class 1 were Orchids and the majority of those in Class 2 were Dandelions. Most individuals in Class 3 had TAS-20 scores that put them in, or close to, the borderline range. Their mean HSPS Total scores fell within 0.24 SD of the mean, and they were most frequently classified as Tulips. Classes 4 and 5 included the largest proportion of alexithymic individuals, but Class 4 scored lower on the HSPS than Class 5. The majority of those in Class 4 were Tulips, and the majority of those in Class 5 were Orchids. Only Class 5

showed elevated OS Total scores, and their APS and AS subscale scores were significantly above the mean.

To recap, the LPA revealed five theoretically meaningful subtypes of individuals: two lexithymic and two alexithymic classes with differing levels of SPS, and a group that scored in the mid-range on both measures. To capture the distinguishing features of the different classes, in the remainder of this chapter I will refer to Class 1 as *Lexithymic Orchids*, Class 2 as *Lexithymic Dandelions*, Class 3 as *Modal*, Class 4 as *Alexithymic Tulips*, and Class 5 as *Alexithymic Orchids*. As will be seen in the next section, these five classes showed very distinctive latent profiles.

Question 2. How do the Observed Subtypes Differ with Regard to their Latent Profiles?

I ran a series of post-hoc tests to explore how the classes differed with respect to their scores on the LPA input variables. I first converted the input variables to Z-scores (using data from the full sample) to place them on a common scale, and then plotted the latent profiles of each class (see Figures 9 and 10). One-sample *t*-tests were used to determine if particular classes scored above, at, or below the mean score on each variable (circled points on the two figures are significantly different from zero, $|t| \geq 2.36$, $p \leq .045$). Because the classes had unequal sample sizes, I used Kruskal-Wallis tests to determine if they scored differently from one another on any variable (see Table 8 for *H* statistics), and significant effects were followed up with Dunn-Bonferroni pairwise comparisons (adjusted *p*-values reported). Finally, I used repeated measures ANOVAs to determine if Z scores on subscales of the TAS-20, and of the AASP, differed *within* a given class; Bonferroni corrections were applied to these follow-up tests. I will first summarize the performance of the Modal group. Following this, I will summarize key contrasts that highlight similarities and differences in the latent profiles of (a) the two lexithymic groups

(Classes 1 and 2); (b) the two alexithymic groups (Classes 4 and 5); and (c) the two groups of Orchids (Classes 1 and 5).

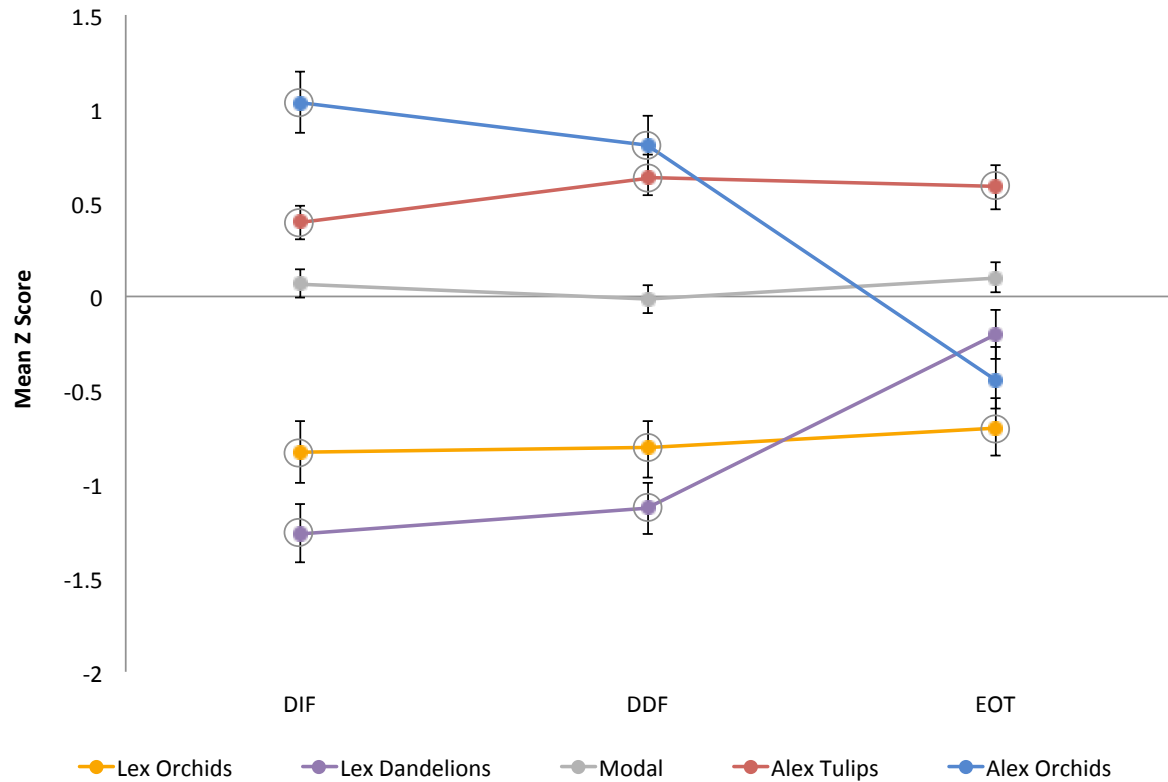


Figure 9. Mean Z-scores on the Toronto Alexithymia Scale – 20 (TAS-20) subscales, for each class (SE indicated). DIF: Difficulty Identifying Feelings; DDF: Difficulty Describing Feelings; EOT: Externally-Oriented Thinking. Circled points are significantly different from zero, $|t| \geq 2.97, p \leq .008$.

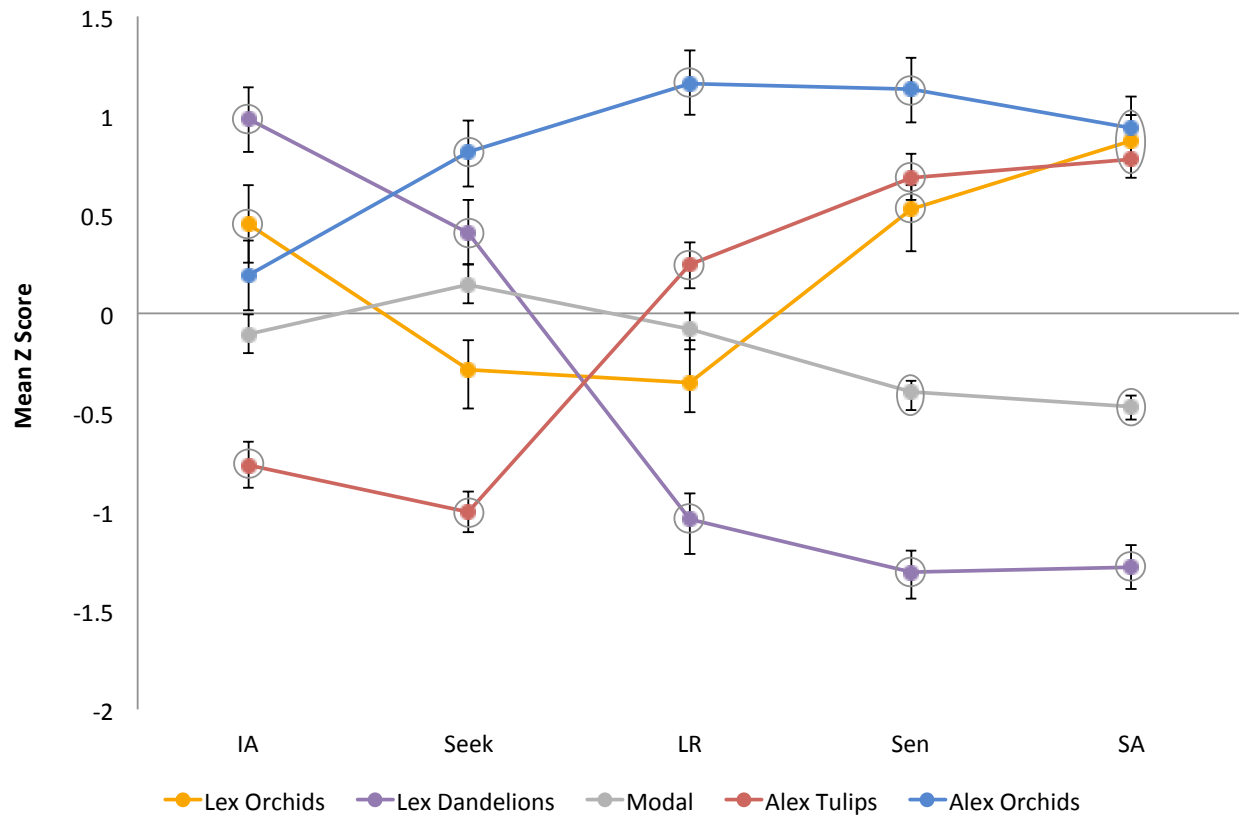


Figure 10. Mean Z-scores on the interoceptive accuracy (IA) scores and Adolescent/Adult Sensory Profile quadrants for each class (SE indicated). Seek: Sensation Seeking; LR: Low Registration; Sen: Sensory Sensitivity; SA: Sensory Avoidance. Circled points are significantly different from zero, $|t| \geq 2.10, p \leq .045$.

Modal Group. The Modal group exhibited TAS-20 subscale and IA scores that were comparable to the overall means for these variables. They scored lower in Sen and SA than on LR and Seek, $F(3, 264) = 14.5, p < .001, \eta_p^2 = .142$, and their scores on Sen and SA were significantly below the mean. Thus, the largest class of individuals ($n = 89$) in this university sample scored close to the mean on most measures, but reported a lower-than-average tendency to be overwhelmed by and to avoid sensory stimulation. This group may be similar to the

“Modal” type described by Moormann et al. (2008), who scored in the average range on both the cognitive and affective composites of the BVAQ.

Lexithymic Group Comparisons. Whereas the Lexithymic Orchids scored uniformly low on all TAS-20 subscales, the Lexithymic Dandelions had average-range EOT scores, but low DIF and DDF scores, $F(2, 48) = 21.4, p < .001, \eta_p^2 = .471$. Both groups showed above-average IA [$t \geq 2.29, p \leq .034$]. The Lexithymic Orchids scored higher than the Lexithymic Dandelions on the Sen and SA scales of the AASP ($p < .001$). Sen and SA scores were higher than LR and Seek scores in the former group, $F(3, 60) = 16.6, p < .001, \eta_p^2 = .454$, but Seek scores were higher than all other scores in the latter group, $F(3, 72) = 42.0, p < .001, \eta_p^2 = .636$.

My results suggest that subtyping lexithymic individuals on the basis of their EOT scores may be quite meaningful. Lexithymic Orchids (who had low EOT scores) showed stronger signs of neural hyper-reactivity (higher Sen and SA) and a slightly weaker tendency to seek out pleasurable sensory stimulation (lower Seek) than Lexithymic Dandelions. Their stronger inner focus might cause Lexithymic Orchids to be more *affected by* certain kinds of stimuli or situations, potentially increasing their risk for certain mental health problems—a point I will return to in Chapter 4.

Alexithymic Group Comparisons. The Alexithymic Tulips had uniformly high scores on the three TAS-20 subscales. In contrast, the Alexithymic Orchids reported problems with DIF and DDF but had average EOT scores, $F(2, 52) = 21.8, p < .001, \eta_p^2 = .456$. Despite not reporting a strong external focus, I would still consider the latter class to have alexithymia given that problems with emotion understanding and affect regulation lie at the heart of this trait (see also Moormann, 2008, p. 40). It is worth restating that some researchers have suggested that certain “traditional” components of alexithymia (such as reduced fantasizing abilities) do not

seem to be central to its presentation (Preece et al., 2017). I would argue that a problem with emotional appraisal is the *sine qua non* of alexithymia. Consistent with the attention-appraisal model of alexithymia proposed by Preece et al. (2017), difficulties in emotion understanding and regulation could arise if there is a failure to attend to embodied feeling states (high EOT) that disrupts subsequent emotional appraisal (high DIF/DDF), as seen in the Alexithymic Tulips. However, impairment at only the latter stage could also interfere with emotion understanding and affect regulation; I suggest that this is the case in Alexithymic Orchids. Future studies could explore the possibility that these two alexithymia subtypes differ with regard to other features associated with alexithymia, such as flattened affect and/or impaired fantasy. Given the “rich inner lives” of those with SPS, a group difference in fantasizing, at least, seems likely.

In addition to scoring differently on EOT, the two alexithymic groups had different sensory profiles, with Alexithymic Orchids scoring high on all AASP measures, and the Alexithymic Tulips scoring high on Sen and SA, in the average range on LR, and well below average on Seek [$F(3, 114) = 70.4, p < .001, \eta_p^2 = .650$]. Group differences were evident on the latter two variables ($p \leq .001$). The pattern seen in Alexithymic Orchids may seem rather odd, as it suggests both a pattern of hypersensitivity (high Sen and SA) and hyposensitivity (high LR and Seek). As suggested earlier, however, those who are more attuned to their body’s response to a given stimulus or situation may also be more likely to “shut down” when they feel uncomfortable—a characteristic that might be misinterpreted as a sign of sensory hyposensitivity (Jerome & Liss, 2005). Alternatively, the Alexithymic Orchids may orient strongly to some channels of sensory information, but weakly to others.

It is also possible that these two classes can also be distinguished based on how they process social vs. non-social cues. Cuve, Gao, and Fuse (2018) presented a two-pathway model

to help explain emotion recognition deficits that are often seen in individuals with ASD that bears some resemblance to Dunn's model of sensory processing. It includes hypo- vs. hyperarousal on one axis, and avoidance vs. orientation (attention) to social cues, such as gaze, on the other. Cuve et al. argue that people with ASD *who also have emotion recognition deficits* (a feature associated with comorbid alexithymia; e.g., Cook et al., 2013), frequently experience *either* hypoarousal (resulting in a passive failure to make eye contact) or hyperarousal (resulting in active gaze avoidance). It may be that the Alexithymic Orchids fail to orient to *social* cues such as gaze (which might increase their LR scores) because they are frequently distracted and potentially overwhelmed by *non-social* cues (raising their Sen and SA scores). In contrast, Alexithymic Tulips may be highly sensitive to both social and non-social cues in the environment and turn to active strategies—such as gaze avoidance—to try to reduce their arousal levels. Testing this idea by performing a detailed comparison of how Alexithymic Orchids and Tulips divide their attention between social and non-social cues (e.g., using eye tracking) would be an interesting direction for future research.

Cuve et al. (2018) speculated that alexithymic traits and associated interoceptive difficulties likely influence where someone with ASD falls in the two-dimensional space defined in their model. As suggested above, I conjecture that one's general sensory processing style is perhaps more important to consider. Nonetheless, the stronger outer focus of the Alexithymic Tulips could, in theory, make them less aware of how both affective and non-affective feeling states resonate in their bodies. This would explain why IA was significantly lower in the Alexithymic Tulips than in Alexithymic Orchids ($p < .001$). The fact that *below average IA* was only evident in the Alexithymic Tulips is important, given that interoceptive deficits are becoming widely considered a hallmark of alexithymia (Brewer et al., 2016; Herbert et al., 2011;

Murphy et al., 2017; Murphy, Catmur, et al., 2018; Sowden et al., 2016). It is possible that studies in which alexithymia was not found to be associated with interoceptive deficits (e.g., Nicholson et al., 2018) involved samples with a preponderance of Alexithymic Orchids, who have average IA.

In an intriguing recent study, it was reported that viewing a photograph of an individual with direct (compared to averted) gaze *improves* performance on a heartbeat counting task, especially for individuals with low baseline IA (Isomura & Watanabe, 2020). These authors speculate that direct gaze communicates a sender's desire to connect with a receiver (the viewer), which increases the receiver's attention to their own interoceptive states. This effect may be less evident in people with higher baseline IA because they are already quite attuned to their internal selves. Isomura and Watanabe suggest that "listening" to one's own bodily cues when interacting with others is important in developing empathy for them. It would be very interesting to test Alexithymic Tulips and Orchids with this paradigm. I would expect that Alexithymic Tulips might benefit more from direct gaze than the Alexithymic Orchids, if the latter group has higher baseline IA and (as suggested above) displays a reduced tendency to orient to social cues.

Based on the foregoing, and the results presented in Chapter 2, I would predict that Alexithymic Tulips would scan and evaluate emotional scenes differently from Alexithymic Orchids. In Alexithymic Tulips the combination of high EOT and low IA might also lead to greater instability in the sense of self and a blurring of the lines between self and other (see Lombardo et al., 2010 and Tsakiris, 2017 regarding the role of low IA, in particular). This form of alexithymia might create additional problems with aspects of mentalizing and empathy (Lane, Hsu, Locke, Ritenbaugh, & Stonnington, 2015). I return to this point in Chapter 4. Pursuing the possibility that there are subtypes of alexithymia when investigating relationships with these

variables seems warranted, as accounting for different subtypes might explain some mixed results in the literature, particularly given that EOT (the TAS-20 score that best distinguished the two alexithymic subgroups) has been shown to predict deficits in ToM (Lyvers, Kohlsdorf, & Edwards, 2017) and is negatively associated with emotion contagion (Grynberg, Luminet, Corneille, Grèzes, & Berthoz, 2010; Lyvers et al., 2017).

Orchid Group Comparisons. Although Lexithymic and Alexithymic Orchids both showed signs of sensory avoidance and susceptibility to overstimulation, only the alexithymic group scored higher on LR. I argued above that—when seen in the context of elevated SA and/or Sen—high LR scores *might* reflect a tendency to shut down when experiencing sensory discomfort (see also Jerome & Liss, 2005). Lexithymic Orchids might be able to overcome this (maladaptive) response tendency by virtue of having superior emotion regulation skills. If so, one would predict that they would have a lower risk of experiencing mental health problems, compared to Alexithymic Orchids.

The two groups had comparable IA scores. However, Alexithymic Orchids were more likely than Lexithymic Orchids to seek out pleasurable sensory experiences. While not tested here, this might make them less likely to ‘pause to check’ in novel situations. If so, this particular feature of SPS (Aron et al., 2012) might apply most strongly to those Orchids who do *not* have alexithymia.

General Discussion

In this chapter I investigated relationships between alexithymic traits and the processing of body-based and environmental sensory cues. The results of my two studies provide several novel insights and lay the groundwork for future research in this area. The classes identified in my subtyping analysis were highly distinguishable based on unique combinations of their

alexithymia and SPS profiles. For this reason, researchers who are interested in either of these constructs should consider measuring both. It seems likely that subtypes identified through this process will vary not only with respect to their sensory profiles and IA, but also with respect to other factors such as developmental history, childhood experiences, and mental health outcomes (Aron et al., 2012; Lyvers et al., 2019).

Exploring whether different subtypes of participants within the sample could be distinguished based, in part, on sensory profiles was important. Again, a person's sensory *profile* is determined by the particular combination of scores they obtain on the AASP. To my knowledge, existing research exploring the relationships between alexithymia and sensory processing (as measured using the AASP) has been limited by reliance on correlational or regression-based designs that focus on individual quadrant scores. Although it may seem counterintuitive, as discussed above it is possible to obtain any combination of scores across the quadrants (Brown & Dunn, 2002). Although undertaking a detailed analysis of profiles was beyond the scope of this dissertation, doing so would be an important goal for future research. Profile analysis is also important in clinical practice, as it informs intervention planning at an individual level (Brown & Dunn, 2002).

Interestingly, I found that low IA was only evident in one of the two subtypes of alexithymia identified in the current study. Thus, not *all* individuals with alexithymia seem to experience a “general failure in interoception” (Brewer et al., 2016). I speculate that the more universal problem in alexithymia relates to atypical weighting and/or embodiment of body-based and environmental sensory cues. The way in which this presents, however, seems to vary by subtype. This could explain why some research exploring the relationship between alexithymia and the strength of the rubber hand illusion (assumed to reflect multisensory cue integration)

have been mixed, with some groups finding stronger (Georgiou, Mai, & Pollatos, 2016) or weaker (Grynberg & Pollatos, 2015) illusions in those with alexithymia, and others finding no significant relationship between these variables (Perepelkina, Boboleva, Arina, & Nikolaeva, 2017). Subjective feeling states are derived from integrating internal and external signals, and appropriate integration of these signals and developing cohesive awareness of feeling states is a crucial step in being able to identify and talk about feelings (Nummenmaa et al., 2018; Shiota et al., 2017). Atypical weighting and integration of cues and the corresponding disruptions in feeling states might result in problems with emotion understanding in those with alexithymia. However, the way in which this is expressed may depend on one's alexithymia profile. Future research might involve having individuals topographically map their feeling states (Nummenmaa et al., 2017; Jung et al., 2017) and exploring the relationships between alexithymic traits and each of the five clusters of feeling states identified by Nummenmaa et al. (2017).

Limitations and Future Directions

Traditional measures of interoceptive abilities such as heartbeat tracking tasks seem to have inherent problems with their reliability and validity. In fact, only approximately 40% of variation on a single objective IA task reflects trait abilities (Wittkamp et al., 2018). For this reason, and because subjective IA in alexithymia has received relatively little research attention, I chose to investigate IA using self-report. It is important to recall, however, that alexithymia has also been linked to deficits in interoceptive *awareness* (Longarzo et al., 2015; Scarpazza et al., 2015; Zamariola, Vlemincx, et al., 2018). It is possible that the alexithymia subtypes I identified would present differently in this distinct domain, in addition to differing in IA.

A limitation of the AASP is that it also relies on subjective report, thus adding measures of physiological responsivity and/or other indices of sensory processing or simulation (e.g.,

facial mimicry) would be interesting. It would also be interesting to study the ways in which individuals belonging to the subtypes identified in this study perform on emotion perception tasks. Extending research on perception of positive emotions would be important here, as this has been traditionally understudied (Shiota et al., 2017).

Finally, the data from both studies came from the same sample, and the sample size was relatively small for LPA (although see Nylund et al. 2007 for a simulation study with a sample of 200). As such, replication of these findings is needed before firm conclusions can be drawn.

Conclusion

The main takeaway from this chapter is that alexithymia is a multifaceted trait that can present differently with respect to sensory processing and interoceptive abilities. Understanding the ways in which alexithymia presents is important because this might allow for the development of more personalized clinical interventions for alexithymic individuals who are experiencing mental health problems. This topic will be explored in more detail in my concluding chapter.

CHAPTER 4: GENERAL DISCUSSION

My doctoral dissertation contributes to the body of literature investigating links between alexithymia and atypicalities in emotion processing, and in the processing of environmental and body-based sensory information. My findings across all studies provide novel insights into the emotion understanding difficulties that often mark people with alexithymia, the conceptualization of this trait, and how patterns amongst variables emerge in non-clinical, young adult samples.

In Chapter 2, I used a perceptual task to compare how adults with low, moderate, and higher levels of alexithymic traits categorized the pleasantness of emotional scenes. I manipulated stimulus complexity by selecting positively and negatively valenced images with and without IM, and investigated how this affected task performance. Overall, I found that participants more precisely evaluated the valence of positive scenes without IM compared to other kinds of scenes. I also found that people with stronger alexithymic traits rated positive and IM scenes less accurately than people with weaker alexithymic traits; these effects were mainly driven by EOT. A component of SPS—the tendency to become overwhelmed by external and internal sensory cues—also predicted undervaluation of positive scenes.

In Chapter 3, I used a survey-based approach to investigate the relationships between alexithymic traits, subjective IA, SPS, and sensory processing styles in a large university sample. This allowed me to better understand how these constructs are associated with one another in young adults. I then used LPA to determine if different subtypes of participants would emerge based on patterns in their responses on several of these measures. The subtyping analysis revealed two groups of lexithymic and two groups of alexithymic individuals, along with one group that scored in the moderate range on most measures. Most notably, the two alexithymia

subtypes differed not only with regard to their alexithymia “profiles,” but also in their expression of traits consistent with SPS, IA, and sensory processing styles.

Below I briefly review the key conclusions arising from the research comprising my dissertation. I then identify some of the strengths and limitations of my research, and recommend some new directions for future research in basic sciences that were not discussed in previous chapters. Finally, I turn my focus to potential clinical implications and applications of my research.

Alexithymia is a Multifaceted Trait

The value in teasing apart the TAS-20 into its subscales was underscored across all studies comprising this thesis. Stronger EOT negatively predicted task performance in Chapter 2, possibly because this trait was associated with disrupted embodiment of emotional scenes, and/or with failing to attend to the ways in which these scenes resonate in the body. I also observed, in Chapter 3, that different alexithymic traits were associated with distinct self-reported patterns of sensory responsivity. Namely, EOT was related to a general hyposensitivity to sensory cues and a reluctance to seek out pleasurable stimuli, whereas DIF and DDF were associated with sensory hypersensitivity. Finally, I found that the two classes of alexithymic individuals that emerged using LPA could be distinguished based in part on the degree to which they endorsed EOT. I conjecture that difficulties *appraising* one’s emotions (DIF/DDF) are essential components of alexithymia, which may or may not be accompanied by difficulties *attending* to one’s emotions (EOT). As discussed in previous chapters, the importance of distinguishing between the TAS-20 subscales has recently been underscored from neurobiological (Goerlich, 2018), perceptual (Donges & Suslow, 2017), and neurophysiological (Davydov et al., 2013) standpoints, however more research in this area is needed.

Processing of Environmental and Body-Based Cues is Atypical in Alexithymia

Despite the fact that several internal organs generate electrical signals that are sent to the brain (much in the same way that external sensory signals are relayed), measuring interactions between interoceptive and exteroceptive processing has traditionally been neglected in cognitive neuroscience research (Azzalini, Rebollo, & Tallon-Baudry, 2019). Here, I have argued that an individual's general sensory processing style (as measured using the AASP), including how the individual weights and integrates internal and external sensory cues, is a key determinant of embodiment, and that these processes may be disrupted in alexithymia (see also Shalev, 2019). This idea would help account for the problems (described in Chapter 2) that participants with stronger alexithymic traits exhibited when categorizing IM scenes, if integrating subtle IM cues with other stimulus characteristics (such as valence), and with one's visceral or emotional responses to these stimuli, was important when accurately completing the scene perception task. I speculate that enhancing the resonance produced by environmental stimuli, for example by using dynamic stimuli, might result in even stronger group differences.

Deficits in sensory integration have clear real world implications, given that integrating motion and emotion cues (e.g., when processing unfolding facial expressions) is important for navigating the social world. My findings in Chapter 3 stress the relevance of assessing the processing of both interoceptive and exteroceptive information. As argued elsewhere (Azzalini et al., 2019), it will be important, in future, to investigate how self-reported atypicalities in these processes contribute to natural variation in a range of perceptual and cognitive functions.

Alexithymic Traits Affect Processing of Positive Stimuli

The results of Chapter 3 clearly showed that many individuals with alexithymia find sensory stimulation aversive (as evidenced by high SA and Sen). This may be especially true for

high intensity, negatively valenced affective information, as ample research suggests that perceptual deficits in alexithymia are seen with such stimuli (e.g., Donges & Suslow, 2017). My studies extend these findings by suggesting that challenges in emotion processing in alexithymia are *also* seen with positive stimuli. Namely, I found that participants with stronger EOT undervalued positive scenes (Chapter 2), and that elevated EOT was also associated with a decreased tendency to seek out enjoyable sensory experiences (Chapter 3). Thus, the EOT component of alexithymia in particular seems to be related to atypical processing of, and responsiveness to, *positively* valenced information. In general, there is paucity of research studying positive compared to negative emotions (Frank & Sabatinelli, 2019), and the existing research on positive emotions has mainly focused on joy/happiness (Shiota et al., 2017). This is unfortunate, given that positive emotions, which can be distinguished visually on the basis of facial and body-based cues, produce distinct physiological responses (e.g., emotions of amusement, awe, contentment, interest, love, and pride; Campos et al., 2013; Shiota et al., 2017) and feeling states (Shiota et al., 2017). Alexithymia has also been associated with atypical neural activation when processing positive emotional stimuli (Van der Velde et al., 2013), reduced experience of positive emotions, and increased problems differentiating high-arousal, positive emotions (Duarte & Pinto-Gouveia, 2017). More research should explore how alexithymic traits affect processing of the wide range of emotions that belong to the “positive emotion family tree” (Shiota et al., 2017, p. 624).

Campos et al. (2013) found that it is important to integrate information from facial and upper body movements to distinguish between several positive emotions accurately (e.g., amusement was often conveyed by a combination of smiling, head bouncing, and a dropped jaw). As articulated earlier, problems integrating (especially subtle) motion cues and the

emotional resonance they produce may be disrupted in alexithymia. Using static photographs (especially those depicting only the face) to investigate perception of positive emotions in people with alexithymia might mask some of the difficulties they experience in natural social situations. Thus, incorporating a wider range of dynamic, whole-body displays of positive emotions in future work may expand our understanding of emotion perception in people with alexithymia. Measuring physiological responsivity to different positive emotions during these tasks might also allow us to develop more nuanced tests of the hypo- and hyperarousal theories of alexithymia. It may also prove fruitful to utilize new measures of alexithymia that allow for separate assessment of difficulties in the appraisal of positively vs. negatively valenced stimuli—such as the Perth Alexithymia Questionnaire (Preece et al., 2018)—when conducting future research in this area.

Strengths of Dissertation and Additional Future Directions for Basic Science Research

A strength of my dissertation is that I used a combination of experimental and self-report measures to arrive at a better understanding of the construct of alexithymia. Both studies highlighted the fundamental distinction between EOT and emotional appraisal subscales of the TAS-20. In addition, using different samples of participants, I replicated the relationships between alexithymia and SPS. It proved to be important to measure SPS in both studies, as EOT and EOE both significantly predicted performance on my scene perception task, and my two alexithymia subtypes showed different SPS profiles. Thus, future researchers should consider screening for both alexithymia and SPS in studies on perception and cognition, as these variables may account for unique variance in performance.

The task I used in Chapter 2 did not appear to assess hemispheric laterality reliably. Therefore, future work might explore hemispheric contributions to emotion processing in alexithymia using other approaches, such as the divided visual field paradigms and/or brain

imaging. Studies of this sort could contribute to further development of theories on hemispheric specialization in emotion processing, such as the model presented by Shobe (2014). It may be that work in this area will shed light on additional differences in emotion processing that distinguish individuals with different alexithymia profiles. Future research might also investigate IM processing or representational momentum in alexithymia by exploring different sensory modalities (see Hubbard, 2014; and Merz, Meyerhoff, Spence, & Frings, 2019 for work with auditory and tactile stimuli, respectively), and by manipulating characteristics such as implied *speed* or IM coherence (Jia et al., 2019), or whether images depict animate beings or inanimate objects (Lu et al., 2016).

The subtyping analysis allowed me to more closely evaluate patterns in the relationships between alexithymia, IA, and sensory processing styles. However, I acknowledge that the sample size for the LPA analysis was relatively small and that my findings would need to be replicated before firm conclusions are drawn. LPA also utilizes only cross-sectional data and, as such, does not inform theories regarding the causes of, or developmental changes in, alexithymia. Future research might use longitudinal designs to see whether relationships between alexithymia and sensory processing change over time, and whether these changes are linked to corresponding changes in embodied cognition (e.g., Costello & Bloesch, 2017; Kuehn et al., 2018).

I used a self-report measure of IA in Chapter 3, and I found that only one of the two observed classes of alexithymic participants scored low on this measure. However, incorporating objective or other subjective measures tapping into different aspects of interoception, such as interoceptive *awareness*, might have revealed that one or both classes showed atypicalities in this domain as well. I also used self-report measures of sensory

processing. Combining data of this sort with psychophysical testing, and with objective physiological measures such as electrodermal responses or facial electromyography, is warranted.

Predictive coding frameworks have been applied to the study of interoception (see Seth & Friston, 2016). These frameworks are supported by research suggesting that interoceptors generate signals based on the brain's *expectations* for how the one should feel (Seth & Friston, 2016; Pace-Schott et al., 2019). Prediction errors (i.e., differences between expected and actual states) are used to update high-level representations of interoceptive experiences, on a continuous basis. As the influence of expectations on interoceptive experiences is strongest when the prediction errors are small, having weak interoceptive expectations and/or problems adjusting these expectations may significantly interfere with predictive coding. It may also increase one's risk of psychopathology (Paulus, Feinstein, & Khalsa, 2019). People with high levels of alexithymia might often make large prediction errors, which could lead them to perceive the body-based cues as unreliable (Pollatos & Herbert, 2018). They may compensate for this by weighting information from other modalities (such as vision) more heavily. Interestingly, Pollatos and Herbert (2018) conjecture that this compensatory strategy might strengthen EOT tendencies. It would be interesting to explore how alexithymia affects predictive coding (in interoceptive and other sensory domains) in future work—this may be an avenue through which alexithymia and negative mental health outcomes are linked.

Clinical Implications and Applications

Relationships between Alexithymia, SPS, and Mental Health. As described in Chapter 1, alexithymia is a risk factor for negative mental health outcomes. This trait is associated with a range of factors that might contribute to psychopathology, including difficulties

regulating emotions (Laloyaux, Fantini, Lemaire, Luminet, & Larøi, 2015; Preece et al., 2018; Swart et al., 2009), experiential avoidance (Panayiotou et al., 2015), reduced awareness of one's emotions (Aaron et al., 2018), and increased psychological inflexibility (Duarte & Pinto-Gouveia, 2017). Learning more about mental health outcomes in alexithymia is important; for example, some work suggests that low mood and level of impression management mediate the link between EOT and hyperarousal and hypoarousal responses, respectively (Davydov et al., 2013). Sensory processing styles characterized by elevated LR, Sen, and SA (Engel-Yeger et al., 2016) have also been identified as risk factors for mental illness; thus, individuals with alexithymia who exhibit these features might be at particularly high risk for psychopathology. Further examination of the relationship between alexithymia and interoception is also warranted, as alexithymia partially accounts for the relationship between interoceptive awareness and anxiety (Palser et al., 2018), and alexithymia and interoception deficits are both associated with psychopathology more broadly (Murphy et al., 2017).

Further characterizing specific subtypes of alexithymia may refine our understanding of links between *particular* mental health outcomes and this trait. For example, in subtyping work using the BVAQ, Moormann et al. (2008) people with Type I might present as cold and withdrawn (e.g., schizoid personality traits), whereas those with Type II might show heightened emotional instability and borderline personality traits. Moormann et al. also suggest that those with Type II, who are characterized by typical or *heightened* affect and problems verbalizing emotions, might be more susceptible to anxiety, obsessive compulsive, and psychosomatic disorders. This is consistent with other work showing that DIF and (in some cases) DDF predict depressed mood and anxiety (Kajanoja, Scheinin, Karlsson, Karlsson, & Karukivi, 2017; Suslow

& Donges, 2017) and social anxiety (Dalbudak et al., 2013), whereas EOT does not (Demers & Koven, 2015; Li, Zhang, Guo, & Zhang, 2015; Suslow & Donges, 2017).

Although EOT was not related to negative mental health outcomes in the above studies, it does not appear to be generally associated with *resilience* to psychopathology either. However, Kajanoja et al. (2017) speculate that high EOT may protect individuals *with alexithymia* from experiencing increased psychological distress; based on this, one might predict that Alexithymic Tulips would have somewhat better mental health outcomes than Alexithymic Orchids.

However, although Wiebe et al. (2017) found that EOT was associated with reduced visual attention to depressive stimuli (which could potentially protect the individual from low mood in the short-term), they argued that a pattern of employing avoidant attention strategies might contribute to interpersonal difficulties with people with stronger EOT, and limit their opportunities to learn effective coping strategies when faced with stress in the long-term. In addition to the above, high scores on EOT (but not on the appraisal subscales of the TAS-20) have been associated with heightened substance use in men (Kajanoja, Scheinin, Karukivi, Karlsson, & Karlsson, 2019), and EOT has also been found to mediate the relationship between alcohol misuse and problems with facial expression recognition (Lyvers, McCann, Coundouris, Edwards, & Thorberg, 2018). In view of the foregoing, it may be most accurate to say that the *type* of psychopathology observed in alexithymia may vary depending on one's specific alexithymia profile.

Degree of SPS is also important to consider when considering links between alexithymia and mental health outcomes. For example, Liss et al. (2008) reported that individuals scoring high on both DIF and EOE were at increased risk for experiencing anxiety problems. It is important to note, however, that whether SPS is associated with positive or negative

psychological outcomes depends largely on a person's life experiences (Aron et al., 2012).

When people with SPS are raised in supportive environments they thrive, potentially because they learn effective ways to regulate their responses to negatively valenced stimuli, and show enhanced reward responses to positive stimuli (Acevedo, Jagiellowicz, Aron, Marhenke, & Aron, 2016). In these cases, this trait may confer protection against psychopathology (Greven et al., 2019). On the other hand, when a highly sensitive person encounters threatening experiences (such as traumatic events), that person may show increased neuroticism (Aron et al., 2012) and emotion dysregulation, and be at a higher risk for developing mental illness (Greven et al., 2019). Recall that emotional neglect (Aust et al., 2013) and other suboptimal environmental factors (Darrow et al., 2014) have also been associated with increased risk for alexithymia. Kajanoja et al. (2017) also found that the alexithymia subtype that emerged in their research with greater psychiatric morbidity also reported more early life adversity. It is possible, then, that the combination of SPS and experiencing negative childhood experiences might predispose one to develop alexithymic traits which, themselves, have negative consequences for mental health.

More research is needed to elucidate the role that the variables explored in the present study contribute to different *patterns* of psychopathology. Given the literature described above, I speculate that exhibiting a combination of problems with emotional appraisal, a relatively strong inner focus (weak EOT), SPS, and a low neurological threshold (high Sen and SA) would strongly lend itself to psychopathology. This combination of characteristics most closely maps onto the Alexithymic Orchids in my subtyping analysis, and I predict that they would have the highest rates of anxiety and depression out of the classes observed in Chapter 3 (followed by the Alexithymic Tulips, who exhibit strong EOT and moderate SPS). Given theorized links between SPS, alexithymia, and early childhood experiences, I would further predict that Alexithymic

Orchids might be the group most likely to report increased rates of early traumatic experiences and challenging upbringings. The Alexithymic Orchids bear some similarity with Type II alexithymia, and the Alexithymic Tulips with Type I alexithymia described by Moormann et al. (2008). Thus, the former class may be at increased risk of borderline personality disorder, and the latter with schizoid personality disorder. The Lexithymic Orchids might represent individuals who are highly sensitive, but who have experienced more positive upbringings and thus are better able to appraise and regulate their affect. I expect that the group with the lowest rates of anxiety and depression would be the Lexithymic Dandelions, given their heightened abilities to identify and describe their emotions, strong IA, and low SPS. This class also exhibited a sensory profile that might increase resilience to these kinds of mental health problems (scoring low on LR, Sen, and SA, and high on Seek). This class bears some resemblance to Type III alexithymia, which Moormann et al. suggest is characterized by dampened emotional responses but an intact ability to identify and articulate emotions. Given these characteristics, Moormann et al. suggest that Type III individuals might be the most emotionally manipulative and endorse antisocial traits. Although the Modal group might experience mild problems with anxiety and depression, they would likely be at the lowest risk for personality disorders. These predictions could be tested in future research. If supported, the findings would further emphasize the importance of subtyping research from a clinical perspective.

Clinical Applications. Given that alexithymia is a transdiagnostic risk factor for physical and mental health problems, screening for alexithymia would be helpful in identifying individuals who are most at risk for developing psychopathology, or who have elevated suicide risk (De Berardis et al., 2017). This awareness of risk could be used to encourage the use of

psychological resources to improve mental health resilience. Additionally, I recommend that pediatricians screen for SPS, and for negative childhood experiences using measures such as the Center for Youth Wellness Adverse Childhood Experiences Questionnaire (Purewal et al., 2016). Doing so would likely help to streamline referrals to programs designed to prevent negative physical and mental health outcomes, and may help to reduce health care costs (Purewal et al., 2016).

Alexithymia is associated with poor outcomes in therapy (Ogrodniczuk, Piper, & Joyce, 2011) and lower therapeutic alliance (Quilty, Taylor, McBride, & Bagby, 2017). However, screening clients for alexithymia and SPS might help psychological practitioners to determine which therapeutic interventions might best fit a particular client. Parenting interventions in childhood that promote emotion awareness and communication, and foster nurturing and supportive home environments, would be especially helpful in children with SPS (Acevedo et al., 2016), and might safeguard them from developing alexithymia later in life. As adults, people with alexithymia may benefit from cognitive behavioural therapy (see Ogrodniczuk et al., 2011), behavioural interventions (Darrow & Follette, 2014), and self-compassion therapies (Duarte et al., 2017). Therapeutic interventions to develop emotional schemas and reduce avoidance of emotions have also been recommended (Preece et al., 2017), and treatments that are tailored to enhance awareness of and responses to emotional experiences may be the most successful in people with alexithymia. Because psychological inflexibility is thought to mediate the relationship between alexithymia and dampened experience of positive emotions (Duarte et al., 2017), interventions that improve psychological flexibility might be useful in this population. Duarte et al. (2017) recommend mindfulness-based interventions such as Acceptance and Commitment Therapy (Hayes, Strosahl, & Wilson, 1999). Practicing attending to and labeling

one's emotions non-judgmentally through mindfulness may be particularly helpful to enhance emotion awareness in people reporting high levels of DIF and DDF (Norman, Marzano, Coulson, & Oskis, 2019). Recently, Parkinson, Kornelsen, and Smith (2019) observed that trait mindfulness affected neural resting state networks in meditation-naïve adults. They found that one's tendency to observe internal and external stimuli was associated with increased functional activity within the insula, perhaps reflecting enhanced interoceptive abilities. Trait mindfulness was also associated with regions that are implicated with cognition, emotion, and sensation, which potentially allow mindful individuals to effectively *integrate* multisensory cues. Thus, mindfulness interventions (Hanley, Mehling, & Garland, 2017) or biofeedback training protocols (Meyerholz, Irzinger, Witthöft, Gerlach, & Pohl, 2019; Pace-Schott et al., 2019) that focus on heightening IA could also be beneficial in alexithymic individuals with low IA (i.e., the Alexithymic Tulips). In a similar vein, regular yoga practice has been hypothesized to improve wellbeing (in part) through decreasing interoceptive prediction errors by promoting precise attention to internal cues and facilitating integration between bottom-up and top-down processing (Gard, Noggle, Park, Vago, & Wilson, 2014). Interventions that incorporate enhancing interoceptive abilities (Khoury, Lutz, & Schuman-Olivier, 2018) and facilitate multisensory integration have merit, and might improve one's ability to regulate their physiological emotional responses (Grynberg & Pollatos, 2015).

Concluding Remarks

My dissertation has provided novel contributions by exploring the ways in which alexithymic traits affect the evaluation of emotional scenes, and relate to atypicalities in self-reported processing of environmental and body-based cues. Taken together my results highlight the importance of assessing alexithymia as a multifaceted trait and suggest that disruptions in cue

integration and embodiment may underlie some of the emotional difficulties in this population. Understanding how alexithymic traits influence these factors in typical adults lays the groundwork for exploration in clinical populations, such as in individuals on the autism spectrum. The current work provides new insights into the conceptualization of alexithymia and a useful framework for clinical research and intervention.

Appendix A

Stimuli selected from the IAPS

Negative								Positive							
File ID	Implied Motion	M Val	M Aro	File ID	Implied Motion	M Val	M Aro	File ID	Implied Motion	M Val	M Aro	File ID	Implied Motion	M Val	M Aro
9560	No	2.12	5.5	1271	Yes	3.19	5.37	1720	No	6.79	5.32	1595	Yes	6.22	4.79
9145	No	3.2	5.05	1301	Yes	3.7	5.77	7270	No	7.53	5.76	7470	Yes	7.08	4.64
3230	No	2.02	5.41	9326	Yes	2.21	5.89	2058	No	7.91	5.09	8420	Yes	7.76	5.56
2375.1	No	2.2	4.88	2717	Yes	2.58	5.7	2550	No	7.77	4.68	8496	Yes	7.58	5.79
2345.1	No	2.26	5.5	2276	Yes	2.67	4.63	2160	No	7.58	5.16	4622	Yes	7.46	4.11
2053	No	2.47	5.25	9429	Yes	2.68	5.63	8540	No	7.48	5.16	5623	Yes	7.19	5.67
3220	No	2.49	5.52	2981	Yes	2.76	5.97	2075	No	7.32	5.27	8116	Yes	6.82	5.97
3215	No	2.51	5.44	6825	Yes	2.81	5.36	2158	No	7.31	5	8021	Yes	6.79	5.67
2710	No	2.52	5.46	9415	Yes	2.82	4.91	4610	No	7.29	5.1	8208	Yes	6.79	5.17
9043	No	2.52	5.5	9424	Yes	2.87	5.78	2352.1	No	7.27	5.16	8033	Yes	6.66	5.01
3160	No	2.63	5.35	9427	Yes	2.89	5.5	4641	No	7.2	5.43	8041	Yes	6.65	5.49
3185	No	2.81	5.48	9530	Yes	2.93	5.2	1340	No	7.13	4.75	8205	Yes	6.62	4.17
9041	No	2.98	4.64	8230	Yes	2.95	5.91	2391	No	7.11	4.63	8220	Yes	6.5	5.19
9160	No	3.23	5.87	2691	Yes	3.04	5.85	2222	No	7.11	4.08	8460	Yes	6.4	4.55
9046	No	3.32	4.31	9102	Yes	3.34	4.84	4250	No	6.79	5.16	8280	Yes	6.38	5.05
2278	No	3.36	4.55	9592	Yes	3.34	5.23	2155	No	6.78	5.43	8032	Yes	6.38	4.19
2312	No	3.71	4.02	6211	Yes	3.62	5.9	8330	No	6.65	4.06	8467	Yes	6.35	5.12
9445	No	3.87	4.49	9596	Yes	3.65	5.13	8158	No	6.53	6.49	2056	Yes	6.34	4.63
2795	No	3.92	4.7	9230	Yes	3.89	5.77	4525	No	6.51	5.17	8320	Yes	6.24	4.27
9901	No	2.27	5.7	2745.2	Yes	3.91	5.17	4600	No	6.41	4.83	8117	Yes	6.02	5.3
9340	No	2.41	5.16	5973	Yes	3.51	5.78	5830	No	8	4.92	5260	Yes	7.34	5.71
9900	No	2.46	5.58	5961	Yes	3.52	5.8	5700	No	7.61	5.68	5270	Yes	7.26	5.49
9611	No	2.71	5.75	9922	Yes	2.78	5.21	5199	No	6.93	4.7	5910	Yes	7.8	5.59
9610	No	2.89	5.23	9925	Yes	2.84	5.59	5890	No	6.67	4.6	5480	Yes	7.53	5.48
7135	No	3.17	5.36	9330	Yes	2.89	4.35	5849	No	6.65	4.89	7492	Yes	7.41	4.91
2692	No	3.36	5.35	9930	Yes	3.12	5.71	5628	No	6.51	5.46	5450	Yes	7.01	5.84
6020	No	3.41	5.58	9621	Yes	3.22	5.76	5665	No	6.15	4.02	7489	Yes	6.54	4.49
7136	No	3.47	5.01	2715	Yes	3.28	4.35	8531	No	7.03	5.41	8251	Yes	6.16	6.05
6610	No	3.6	5.06	9341	Yes	3.38	4.5	5215	No	6.83	5.4	7505	Yes	6.1	4.72
7520	No	3.83	4.57	6940	Yes	3.53	5.35	7240	No	6.02	5.51	5836	Yes	7.25	4.28
M		2.92	5.18			3.13	5.40			7.03	5.08			6.82	5.10
SD		0.57	0.46			0.42	0.48			0.50	0.52			0.53	0.59

Note: File IDs refer to filenames in the IAPS dataset. Mean valence (M Val) and mean arousal (M Aro) ratings are based on published IAPS norms (Lang, Bradley, & Cuthbert, 2008).

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