Facial Emotion Recognition and Reflexive Facial Mimicry in Individuals with a History of Non-suicidal Self-injury

Laura Ziebell

Thesis submitted to the University of Ottawa
in partial Fulfillment of the requirements for the
Doctorate of Philosophy Degree in Clinical Psychology

Department of Psychology
Faculty of Social Science
University of Ottawa

Acknowledgements

Completing this dissertation represents a labour of love and a triumph over numerous obstacles. First, I consider myself honoured to have had the opportunity to work under the supervision of Dr. Charles Collin. He is an incredible supervisor who can see one's potential and has the gentle ability to foster that potential to grow. Charles, thank you for always believing in me and inspiring me to continue with research throughout my life. Your kindness, intellect and genuine care for your students is truly remarkable. I cannot express my gratitude enough to you for your mentorship, reassurance, careful instruction, and friendship. I could not have completed this degree under the mentorship of any other supervisor. Thank you for helping me navigate my way through this journey.

In addition to my thesis supervisor, I would also like to thank my committee members: Dr. Jean-François Bureau, Dr. Pierre Gosselin, and Dr. Ken Campbell for their excellent ideas, constructive feedback, and expertise to improve the quality of this thesis. Also, I would like to thank my external committee member, Dr. Caroline Blais for agreeing to review this thesis.

Moreover, I would also like to thank my lab and office mates: Chantal, Dhrasti, Beth, Heather, Fatou and Ashley for their help and friendship. Thank you to my clinical cohort who have always been there for me, especially Julian, Kelly, Sabrina and Fiona. A special thank you to my fellow interns, Sean, Orrin-Porter, Yara, Georden, and Jessica.

Finally, I could not have accomplished this dream without the love, support and encouragement from my friends and family. I would especially like to thank Jamie for the many years of support and encouragement. Also, thank you to Simon for your kindness and care. Lastly, I am eternally grateful to my parents who have loved and supported me throughout this process.

Abstract

Non-suicidal self-injury (NSSI) has been regarded as a dysfunctional coping strategy for managing intensely difficult feelings and is a growing area of concern in clinical and non-clinical populations alike. Individuals who engage in NSSI often report significant interpersonal difficulties, with studies showing that they have impaired social interactions. Attending to the emotional expressions of others is important for appropriate social functioning, and subtly mimicking the expressions of others is an unconscious behaviour that encourages empathy and interpersonal bonding. Differences in emotion recognition and reflection can impact social behaviour, yet little research has assessed how individuals with a history of NSSI (HNSSI) process facial expressions of emotion. In this thesis, the results of three studies designed to investigate potential differences in emotion recognition and emotion mimicry in individuals with a history of NSSI compared to controls are reported. Results from Study 1 revealed that when presented with colourful, dynamic morphing stimuli showing emotional expressions, HNSSI participants were able to correctly categorize negative expressions like anger, disgust, sadness, and the ambiguous emotion of surprise at a lower stimulus intensity compared to controls; They also correctly categorized fear with greater accuracy, though at the same intensity as controls. However, in Study 2, when static, greyscale images were obscured with varying levels of fractal noise, HNSSI individuals did not show superior signal-proportion thresholds. These results may suggest that higher-order elements of visual and cognitive processing are evoked by more realistic social stimuli. In the third study, HNSSI participants were found to produce significantly less electrical activity in the corrugator muscle in response to viewing angry stimuli, and significantly less of an expected relaxation in muscle activity in response to viewing happy stimuli. Complementing these results, it was found that endorsing social influence as a motivator

for engaging in NSSI was associated with less mimicry, whereas endorsing emotion regulation as a motivator was associated with greater incongruent muscle response when viewing happy faces. These observed differences in facial mimicry between HNSSI and controls may be related to some of the observed relationship difficulties experienced by this group. Results from this research may help us to better understand NSSI behaviour, as well as help to inform and further develop therapies intended to address it.

Table of Contents

List of Tables

Chapter 2

Chapter 3

Chapter 4

List of Figures

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Chapter 1: General Introduction

Non-suicidal self-injury (NSSI) is an increasingly prevalent and clinically significant behaviour observed in adolescents and young adults. The most frequently reported function for engaging in this behaviour is emotion regulation (Andover & Morris, 2014; Hasking, Whitlock, Voon & Rose, 2017; Jacobson & Gould, 2007; Klonsky, 2007; Klonsky, 2009; Taylor et al., 2018). Emotion regulation refers to an individual's ability to understand and accept his or her emotional experience, engage in healthy strategies to manage uncomfortable emotions, and use appropriate behaviour when feeling distressed. Thus, emotion regulation occurs when someone overrides their initial spontaneous emotional response (Eysenck & Keane, 2000). Individuals with good emotion regulation skills are able to control urges and inhibit impulsive behaviours like self-harm during times of emotional distress. Thus, NSSI is thought to be a maladaptive coping strategy for managing aversive emotions and expressing intensely difficult feelings, which can contribute to intra- and interpersonal difficulties (In-Albon, Bürli, Ruf & Schmid, 2013; Inckle, 2011; Nock 2010).

A hypothesized consequence of emotional dysregulation observed in individuals who have engaged in NSSI is an overall greater emotional sensitivity (Linehan, 1993). In line with this hypothesis, common reasons for engaging in NSSI behaviour are to decrease affect arousal, provide relief from negative feelings, and relief from interpersonal difficulties (Brain, Haines & Williams, 1998; Haines, et al., 1995; Hilt, Cha & Nolen-Hoeksema, 2008). However, deficits in emotion regulation and greater emotional sensitivity can also affect interpersonal relationships. Theorists have speculated that difficulty managing emotions may influence recognizing facial expressions as well as naturally reflecting emotion expressions in social exchanges. Indeed, social interaction difficulties reported by individuals who engage in NSSI (Hilt, Cha & Nolen-

Hoeksema, 2008; Vonderlin et al., 2011) could, in part, be a result of hypersensitivity to the facial emotions expressed by others and/or a violation of social rules guiding social behaviour, such as the robust effect of mimicking facial expression (Dimberg, 1990; Hess & Bourgeois 2010; In-Albon et al., 2013). The research reported in this thesis investigates whether individuals who have a history of engaging in NSSI (HNSSI) display greater sensitivity than controls in recognizing facial expressions of emotion. It also explores the efficiency of individuals with a history of NSSI in identifying facial expressions of emotion via an Ideal Observer analysis. Finally, it examines whether those with HNSSI exhibit differences in the degree to which they mimic facial expressions of emotion compared to non-self-injuring individuals, as well as whether any observable differences in emotion mimicry are correlated with commonly reported functions for engaging in NSSI.

Developing a better understanding of any underlying differences in emotion recognition and emotion mimicry in individuals with a history of NSSI may also help to better understand the etiology and triggers of negative emotions for these individuals, which could in turn inform the development of more successful NSSI-specific treatments. At present, there are limited effective treatments and no psychopharmacological interventions for NSSI (Plener et al., 2018; Hawton et al, 2015). Psychotherapeutic approaches such as dialectical behaviour therapy (DBT) and mentalization-base therapy (MBT) have been shown to be the most effective in treating NSSI; However, there is a limited understanding of how these interventions enact change for individuals who self-injure. Nonetheless, a better understanding of how individuals who self-injure recognize and implicitly respond to the emotions of others may help to better inform elements of these therapies related to emotion regulation strategies, interpersonal effectiveness skills, and the practice of mentalization, which is the interpretation of behaviour by focusing on

mental states of others and oneself (Bateman, 2006).

1.1 Non-Suicidal Self-Injury

The behaviours that constitute NSSI must first be clarified, as researchers have long struggled to agree upon a definition of this behaviour (Andover et al., 2012; Silverman, Berman, Sanddal, O'Carroll & Joiner, 2007). NSSI falls under the broad category of deliberate self-harm, which covers a range of behaviours, including actions with and without an intent to die, as well as behaviours that do not involve direct, external tissue damage (Klonsky, Muehlenkamp, Lewis & Walsh 2011). For example, overdosing, abuse of medication, abuse of drugs and alcohol as a means to self-harm, suicidal behaviour and non-suicidal self-injury all fall under the broad category of deliberate self-harm.

The current definition of NSSI that is most widely accepted in research is the direct, repetitive, intentional injury to one's own body that results in immediate tissue damage without intent to die, and is not a socially accepted practice within one's culture (Nixon & Heath, 2009). This behaviour excludes practices such as ear piercing, tattooing, circumcision, or cultural healing rituals (American Psychiatric Association, 2013; Lloyd-Richardson et al., 2007). It also excludes behaviours such as drug abuse and binge drinking, which fall under the broader category of deliberate self-harm, but do not necessarily distinguish between non-suicidal and suicidal behaviours (Nock & Favazza, 2009). Intent to die by suicide is sometimes ambiguous for both individuals who attempt suicide and those who engage in NSSI; however, the lack of suicidal intent is a key characteristic used to distinguish between NSSI and suicidal actions (Andover et al., 2012).

It is well established that the most common method of NSSI is cutting or severe

scratching of the skin (Klonsky, 2011), however, cutting is not the only method used by people who engage in NSSI. Other common forms of the behaviour include carving skin, burning, banging or hitting, and interfering with wound healing. Reports among studies including both clinical samples and college students indicate that the methods used most by those who self-injure include skin cutting, scraping or carving. Banging, bruising and self-hitting, as well as burning and inserting objects into skin also occur less frequently, while breaking bones reportedly occurs with even lower frequency (Briere & Gil, 1998; Gratz, 2001; Nijman et al., 1999; Robertson et al., 2013). These injuries can be done anywhere on the body, but common locations include arms, hands, wrists, thighs and stomach. The behaviour also typically develops in early adolescence somewhere between 12 to 15 years old (Andover et al., 2012; Kitchener & Jorm, 2010; Nock, 2009). Overall prevalence rates for adolescents in the community tend to average around 15-20% for engagement in NSSI at least once in their lifetime (Heath et al., 2009; Jacobson & Gould, 2007; Muehlenkamp & Gutierrez, 2004; Nock & Favazza, 2009), and the community prevalence rate for Canadian youth has been estimated at around 15% (Laye-Gindhu & Schonert-Reichl, 2005). Higher rates have been reported among Canadian adolescents in clinical settings with one estimate being approximately 24% (Armiento et al., 2016). In general, populations receiving treatment report higher rates of NSSI, with some estimates ranging between 40% and 60% for inpatient units (Claes, Vandereycken & Vertommen, 2007; Kaess et al., 2013). Worldwide lifetime prevalence estimates are 17.2% among adolescents, 13.4% among young adults (mean age 18 and 24 years) and 5.5% among adults over 25 (Swannell et al., 2014). Although one study examining the general population found that the majority of adolescent self-injury remitted within a short period of time (Moran et al., 2012), other findings have suggested that a history of self-injury is an important clinical marker for

subsequent suicide and a strong predictor of suicidality (Cheung et al., 2013; Garrison et al., 1993; Tang et al., 2011; Whitlock & Knox, 2007; Wilkinson et al., 2011).

1.2 NSSI in the DSM-5

Non-suicidal self-injury now appears in the fifth edition of the Diagnostic and Statistical Manual (DSM-5) of mental disorders under a section entitled "conditions for further study". This is a category of conditions on which future research is encouraged, but where there is currently insufficient evidence to warrant inclusion as a mental disorder diagnosis of its own (American Psychiatric Association, 2013).

The NSSI-specific DSM-5 criteria state that intentional self-inflicted damage must occur on 5 or more days in the last year to be considered problematic. This is an important criterion for distinguishing those who have engaged in the behaviour and stopped from those who are chronic injurers; a one-time occurrence of NSSI should not be considered pathological (Plener & Fegert, 2012). Moreover, the DSM-5 criteria acknowledge the role of emotion dysregulation and the impact of interpersonal difficulties in engaging in the NSSI behaviour by stating that individuals who engage in it expect to: 1) relieve negative feelings or cognitive states; 2) resolve an interpersonal difficulty; and/or 3) induce a state of positive feeling. The criteria also state that the intentional self-injury can be associated with negative feelings or thoughts (e.g., depression, anxiety, tension, anger, generalized distress, or self-criticism) or interpersonal difficulties immediately before the self-injurious act (American Psychiatric Association, 2013).

NSSI is also currently listed in the DSM-5 as one of the nine symptoms of Borderline Personality Disorder (BPD). However, approximately 50% of those who engage in NSSI do not suffer from BPD (Herpertz, 1995; Nock et al., 2006). Although NSSI and BPD do often co-occur, they also regularly occur independently. Suggestions have been made that NSSI should be

considered a separate syndrome (Favazza & Rosenthal, 1990, 1993; Herpertz, 1995; Kahan & Pattison, 1984; Muehlenkamp, 2005; Pattison & Kahan, 1983), and more recent research continues to support the notion that NSSI frequently occurs in individuals who do not meet diagnostic criteria for BPD (Selby et al., 2012). This provides support for the idea that there is utility in understanding NSSI as its own diagnostic category. Indeed, considerable research supports the classification of NSSI as a distinct entity that can occur independently of BPD and suicide yet carries clinical significance for a growing number of youth (Glenn & Klonsky, 2013; Muehlenkamp, 2005; Nock et al., 2006; Zetterqvist, 2015).

1.3 Emotion Regulation and Social Influence in NSSI

The most frequently reported function for engaging in NSSI behaviour is emotion regulation, however, it is likely that NSSI serves multiple functions simultaneously (Klonsky, 2007). For example, NSSI can also be motivated by interpersonal influence, sometimes known as social influence (Muehlenkamp et al., 2012). Some self-injurers also use NSSI behaviours to influence or manipulate people in their environment. Ways in which NSSI can be used to affect people's behaviour include getting care from loved ones and increased social support; getting attention from adults or peers (Whitlock, 2009); communicating feelings (Muehlenkamp et al., 2012); bonding with friends to fit in (Muehlenkamp et al., 2012); or other reinforcing responses from authority figures or peers. For some adolescent girls who have experienced interpersonal distress in the form of peer victimization, engaging in NSSI has been associated with social reinforcement (Hilt, Cha, & Nolen-Hoeksema, 2008).

The research examining interpersonal difficulties of those engaged in NSSI report pervasive relationship problems within the family and with peers compared to healthy controls (Turner et al., 2016; Vonderlin et al., 2011). Those engaged in NSSI are also more likely to

experience bully victimization compared to other at-risk youth (Tanner et al., 2016). In fact, interpersonal problems appear to be more pronounced in NSSI than in other conditions (Eisenberg et al., 2014; Tanner et al., 2016; Turner et al., 2016), and interpersonal sensitivity appears uniquely associated with NSSI when compared to other types of problematic behaviours (Kim et al., 2015). Since NSSI is a relatively high-cost method for attempting to have interpersonal needs met (Nock, 2008), the elevated level of interpersonal difficulties in this population may signal differences in interpersonal skills. For example, the cognitive vulnerability–stress model (Guerry & Prinstein, 2010) suggests that people engaged in NSSI tend to make more negative attributions when encountered with interpersonal stressors. The developmental model for NSSI (Yates, 2004) suggests that traumatic experiences in childhood, such as maltreatment, could lead to impairments in the skills that are important for meeting emotional and interpersonal needs. Taken together, this research suggests that individuals with NSSI may have difficulty with their ability to experience and interpret interactions with others as supportive. Possible cognitive biases have been proposed, such as negative attribution biases or increased sensitivity to rejection signals, which may help to explain why individuals engaged in NSSI experience greater difficulties perceiving positive and supportive relationships (Turner, 2017). Indeed, heightened sensitivity to even the most minute expressions of a negative emotion, which would go unnoticed by anyone else, may be perceived and reacted to by NSSI individuals with greater emotional sensitivity. It is also possible that the social interaction difficulties experienced by this population may be related to violations of expected social rules such as mimicry, which could intensify relationship difficulties even further (In-Albon et al., 2013). Challenging interpersonal experiences may both contribute to the development and maintenance

of NSSI as an antecedent (e.g., rejection, conflict) and a consequence (e.g., support) of the behaviour (Nock, 2008; Nock, 2009; Yates, 2004).

Not surprisingly, social interactions and emotion regulation are intrinsically linked, since the way people regulate their emotions can also affect their relationships with others. For example, through the processes of contagion and appraisal, increased sensitivity to emotions signaling rejection by others may in turn increase the frequency and intensity of negative emotions experienced by the perceiver. Additionally, emotional suppression in social interactions can decrease emotion-expressive behaviour, and mask important social signals between interaction partners (Butler et al., 2003). Those who suppress emotions also tend to have poorer social support and are less likely to be liked by others (Gross, 2002).

Herpertz (1995) developed an affect regulation model to describe how implicit affect regulation (i.e., appraisal, attention bias and anticipation of reaction), as well as explicit affect regulation (i.e., suppression and re-evaluation) mechanisms are influenced by arousal, emotional sensitivity, and the use of regulation strategies. This model, as seen in Figure 1, demonstrates how difficulties with regulating emotions can influence both an individual's internal state, as well as their reactions to others. When considered with elements of facial emotion recognition and facial mimicry in a social setting, it has been hypothesized that facial emotion recognition and mimicry may occur between the steps of apperception and arousal (In-Albon et al., 2013). Implicit affect regulation, such as appraisal, biases in attention and anticipation of a reaction may link to facial recognition and facial mimicry. The emotion dysregulation experienced by individuals engaging in NSSI may include emotion-linked cognitive processes, facial and muscle reactions, action urges, physiology, and emotion-linked actions when engaged in social interactions as seen in those experiencing BPD (Crowell et al., 2009).

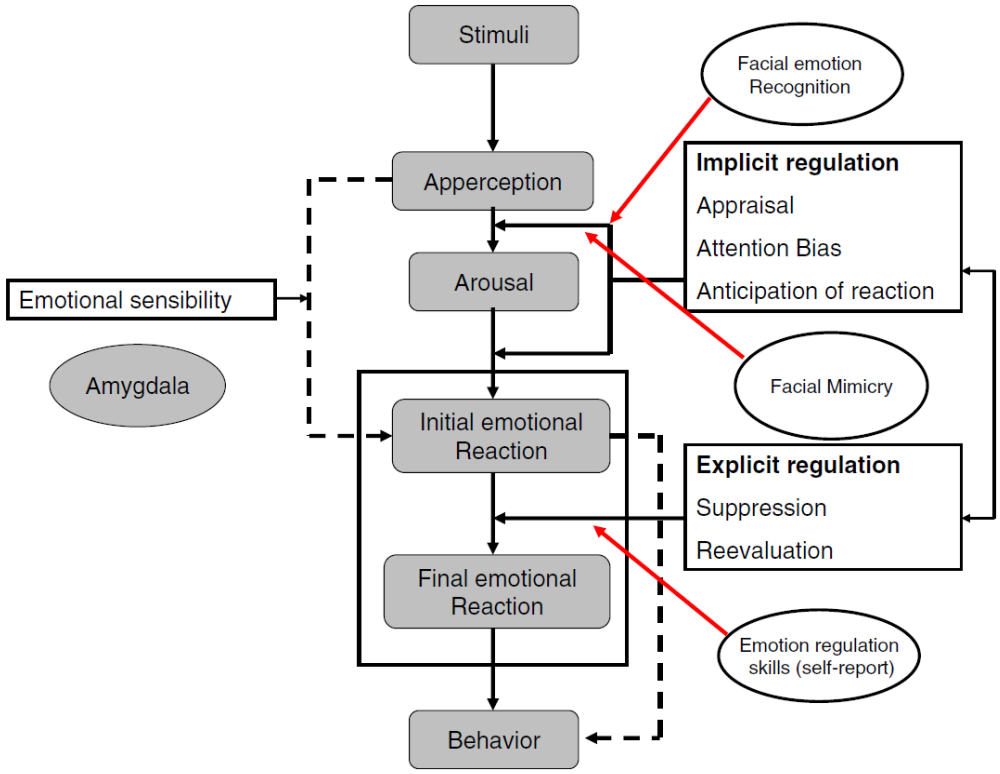


Figure 1. Herpert's affect regulation model. This model includes components of facial emotion recognition, facial mimicry and emotion regulation skills. Reproduction of original figure from In-Albon et al., 2013.

1.4 NSSI and Emotion Recognition

The role of emotion dysregulation in NSSI behaviours is centrally linked to Linehan's (1993) biosocial theory and has received considerable attention as a risk factor and correlate of NSSI (Hamza & Willoughby, 2015; Klonsky, 2009; Klonsky, Glenn, Styler, Olino, & Washburn, 2015). According to Linehan's theory, individuals engaging in NSSI behaviour have significant difficulty with emotion regulation due to a transactional process between a biological predisposition for high emotional reactivity and a social learning history of emotional invalidation from their families. An emotionally invalidating environment occurs when an

individual's emotional experiences are not responded to appropriately or consistently (Linehan, 1993; In-Albon et al., 2013). This type of environment does not allow an individual to learn how to adaptively regulate intense emotions. As a result, these individuals rely on impulsive, short-term strategies, such as NSSI, to regulate emotions (In-Albon et al., 2013). Anger, anxiety, and frustration often precede engagement in NSSI, followed by temporary relief and calm, but ultimately result in sadness, guilt, anger, disgust and anxiety in the long term (Klonsky, 2007).

Emotion awareness is associated with greater social competence (Hubbard & Coie, 1994) and emotion regulation is intricately linked with emotion perception (Gross, 2013; Gross, 2015). If emotional facial expressions are not recognized correctly, emotion regulation and emotion recognition can be influenced. Several studies examining patients who engage in NSSI have found that these individuals are not able to perceive their own feelings at all, or sometimes the opposite, they perceive their feeling too strongly and aversively (Stiglmayr, Grathwol, Linehan, Ihorst, Fahrenberg & Bohus, 2005; Nock & Mendes, 2008). According to the biosocial theory (Linehan 1993), greater sensitivity to emotion stimuli is a direct consequence of the emotion dysregulation characterized by NSSI. Thus, we would expect individuals with a history of NSSI to be more sensitive to emotion signals, especially those of a negative nature.

In individuals with BPD (of which NSSI is a frequent symptom), emotion dysregulation has been linked to dysregulation across cognitive processes, neurochemistry and physiology, facial and muscle reactions, and emotion-linked actions (Crowell et al., 2009). However, studies on facial emotion recognition in adolescents and adults with BPD have shown inconsistent results. A study conducted by Jovev and colleagues (2011) predicted increased emotion sensitivity in adolescents with BPD based on Linehan's (1993) theoretical framework by hypothesizing earlier response times to an emotion recognition task and more accurate

recognition responses on the task compared to controls (Jovev et al., 2011). Contrary to their predictions, the BPD group exhibited somewhat longer response latencies for the recognition of fear and disgust. They also observed that the BPD group rated disgust and happiness as less positive than the control group, suggesting a possible negative bias in appraising social cues (Meyer et al., 2004). Robin et al. (2012), who also investigated adolescents with BPD, found that they were less sensitive to facial expressions of anger and happiness (i.e., they required more intense facial expressions to correctly identify these emotions than control participants), but did not show impairments recognizing fully expressed emotions. In adults with BPD, Lynch et al. (2006) reported a heightened sensitivity to facial expressions, whereas Domes et al. (2008) reported a comparable emotion detection threshold in BPD and non-clinical controls. A meta-analysis conducted by Daros, Zakzanis, and Ruocco (2013) examined ten studies on facial emotion recognition in individuals with BPD. Their results showed that patients with BPD less accurately recognized facial displays of anger and disgust compared to controls. However, their most pronounced deficit was misidentifying neutral facial expressions. These results suggest more subtle impairments in labelling accuracy in BPD, as well as a tendency to interpret ambiguous faces in a more negative way. A subsequent review of twenty-five studies conducted by Mitchell et al. (2014) of emotion recognition in BPD concluded that despite differences in methodology, there were no significant recognition impairments for any negative emotions between BPD and healthy controls. However, there was consistent evidence supporting a negative response bias to neutral and ambiguous facial expressions.

Compared to research on BPD, there has been a paucity of work on NSSI in particular. Indeed, to date, there are just two studies examining facial emotion recognition capabilities in an NSSI population, both involving adolescent in-patient participants. In-Albon, Ruf and Schmid

(2015) hypothesized that female adolescents engaging in NSSI would have more difficulty recognizing facial expressions, as measured by the intensity of expression at which they could accurately identify an emotion. They also predicted a decline in emotion recognition, mean emotion intensity before first correct response, and accuracy following a sad mood induction compared to a neutral mood. Contrary to their predictions, adolescents engaging in NSSI showed no general deficits accurately recognizing emotional facial expressions, and no significant differences in intensity of emotion required for accurate identification between adolescents with NSSI disorder, clinical controls without NSSI, and nonclinical controls. All groups correctly recognized emotions at similar stages of emotional expressivity, and mood induction did not affect recognition or accuracy. However, adolescents with NSSI disorder did rate the valence and arousal of emotions as significantly more unpleasant for neutral and happy expression and significantly more arousing for angry, sad and happy expressions compared to the non-clinical control group.

Seymour et al. (2016) examined facial emotion recognition in three groups: 1) inpatient adolescents engaging in NSSI, 2) inpatient adolescents who attempted suicide, and 3) typically developing controls. Facial expression recognition ability was assessed using DANVA-2, a computer-based behavioural task in which participants were asked to identify 2-second static photographs of child and adult faces expressing happiness, sadness, anger, or fear at high and low intensities. Their results showed that adolescents with NSSI made more errors on child fearful and adult sad face recognition compared to the typically developing controls. They concluded that adolescent inpatients engaged in NSSI showed greater deficits in emotion face recognition compared to controls, but not when compared to inpatient adolescents who attempted suicide.

1.5 Emotion Mimicry

Facial emotion mimicry (or automatic facial expression) is the involuntary imitation of facial expressions of another person through the activation of facial muscles (Hess & Fischer, 2013). The movement of facial muscles in response to another person's expressions can be either visible (overt) or non-visible (covert) and often occurs at an unconscious level (Hess & Bourgeois, 2010). In instances where emotion mimicry is covert and movement of the skin is not easily perceptible, muscle activation can be measured using Electromyography (EMG). While the activation of any of the dozens of muscles in the face could in principle be measured with this technique, two are most commonly assessed: The *zygomatic major* and the *corrugator supercilii*. The *zygomaticus major* is responsible for stretching the lips to create a smile and the *corrugator supercilii* is responsible for lowering the brows in response to fear, anger, and sadness (Gosselin & Kirouac, 1995). In 1982, Dimberg used EMG equipment to systematically demonstrate that individuals responded with elevated activity in the *zygomaticus major* muscle in response to happy facial expressions and elevated activity in the *corrugator supercilii* muscle in response to angry facial expressions. Thus, Dimberg's study (1982) suggests that individuals tend to mimic the facial expressions they observe.

Following this early research, the mimicking behaviours elicited by other facial emotions such as happy, angry, sad, fearful, disgusted, and surprised were examined (Lundqvist & Dimberg, 1995). Results revealed that expressions of happiness and anger produced larger activity in the *zygomaticus major* and *corrugator supercilii* respectively, as compared to EMG activity in response to neutral expressions. The *corrugator supercilii* also produced elevated activity in response to sad expressions and decreased activity in response to happy expressions (Lundqvist & Dimberg, 1995). A review of research has suggested that sufficient evidence only

exists for the emotion mimicry effect in *corrugator supercilii* and *zygomaticus major* muscles in response to anger and happiness (Hess & Fischer, 2013), and that further investigation is still necessary to confirm emotional mimicry effects for disgust, anxiety, sadness, and other emotions. However, a consistent conclusion that has been observed throughout EMG studies is that activity of *corrugator supercilii* and *zygomaticus major* can differentiate positive and negative facial expressions (Jiang et al., 2015). It has also been shown that facial mimicry is more pronounced in response to dynamic facial expressions compared to static images (Rymarczyk et al., 2011).

In the past, mimicry reactions were thought to be an automatic response based on a link between perception and behaviour. Perception of a specific facial expression was thought to automatically evoke the same expression in the perceiver (Chartrand & Bargh, 1999). However, current models suggest that emotion mimicry is more complex than this simple link. Indeed, facial mimicry effects can vary across contexts, as one's own emotions can influence emotion mimicry. For example, being in a good relationship (Fischer, Becker & Veenstra, 2012) or belonging to a social group (Bourgeois & Hess, 2008; van der Schalk et al., 2011) can increase facial mimicry, whereas having a negative attitude toward someone can inhibit it (Moody et al., 2007; Bourgeois & Hess, 2008; Likowski et al., 2008).

Hess and Fischer (2013) considered emotion mimicry to be a case of embodied simulation, in which we understand the affect of others by simulating the affect ourselves. This process allows the perceiver to simulate the emotion on a motor, somatosensory, and affective level to deduce its meaning and reward value (Niedenthal et al., 2010; Zajonc et al., 1989). Research has shown that both voluntary and involuntary facial expression of emotion plays a key role in the recognition of others' emotions and contributes to the process of "embodiment of

emotions" (Künecke et. al., 2014; Schneider et. al., 2013; Sel et al., 2015). Thus, mimicking behaviours appear to be a key factor in successful interactions, as this process supports empathy and emotional understanding, as well as eliciting liking and rapport in those we converse with (Dimberg et al., 2000; Hatfield et al., 1994). However, the imitation of positive emotions is more likely to lead to liking and affiliation than the imitation of negative emotions such as anger and disgust, which are generally viewed more negatively (van Kleef, 2009). Some evidence suggests that the expression of fear may in fact serve as an affiliative stimulus by encouraging approach rather than avoidance in the perceiver (Marsh et al., 2005; Marsh et al., 2007). Nonetheless, the act of mimicking emotions, both positive and negative, may help build relationships through affective empathy, which means to feel what others are feeling.

Emotion mimicry has also been thought to facilitate emotion recognition by facial muscles functioning as a feedback system for an individual's own experience of emotions (Dimberg, 1982; Dimberg et al., 2000; Hatfield et al., 1994). Indeed, blocking facial mimicry has led to less accurate identification of happiness (Oberman et al., 2007; Niedenthal et al., 2010; Maringer et al., 2011) and slower recognition of happy, sad and fearful emotions (Lydon & Nixon, 2014). However, some studies of emotion mimicry have found no association between the degree of facial mimicry and the level of emotion recognition (Fischer, et al., 2012; Hess & Blairy, 2001).

A recent systematic review was conducted by Davies, et al., (2016) on automatic facial expressions of emotion (i.e. mimicry) in people with non-psychotic disorders, as very little is known outside of schizophrenia or depressive disorders. Results from this review revealed altered emotion expression across all disorders included, except anxiety disorders. In depression, decreased facial expression was mainly evident for positive affect, and in eating disorders

decreased facial expression was observed in response to both positive and negative stimuli. Overall, the data included in the review pointed toward decreased facial emotion expressivity in individuals with different non-psychotic disorders (Davies, et al., 2016). Interestingly, a bias towards attenuated expression has also been reported in people in remission and those at risk for mental illness, particularly schizophrenia (Mattes et al., 1995; Walker et al., 1993).

Rosenthal et al., 2008 reviewed two studies that examined facial emotion expression in a BPD population with EMG and observational coding. Results from both studies reported an attenuation of positive and negative facial expressions in the BPD groups (Herpertz et al., 2001; Renneberg, Heyn, Gebhard, & Bachmann, 2005). Two further studies examining emotional expression in a BPD population found no group differences for *zygomaticus* activity during positive emotions, but increased *corrugator* activity for negative emotions when pictures of disgust, anger and sadness were displayed (Matzke et al., 2014; Staebler et al., 2011). However, activity of the *levator labii* (a muscle of the upper lip related to disgust) did not differ between groups. Staebler et al. (2011) used a virtual ball-tossing game to induce social exclusion and coded facial emotion expressions. They found fewer positive expressions, consistent with Herpertz et al. (2001) and Renneberg et al. (2005), and significantly more mixed emotional expressions compared to the control group. However, they also found an increase in negative expression, in keeping with the findings observed by Matzke et al. (2014).

Social interaction problems are often a trigger for NSSI, so developing a better understanding of what contributes to these social problems is important. As demonstrated by the reviewed literature, a crucial aspect of social interaction and emotion regulation is facial mimicry, which encourages empathy and functions as a social catalyst. Because mirroring facial expressions of emotion is a robust effect in healthy individuals, and generally decreased facial

emotion expressivity has been documented in individuals with different non-psychotic disorders, it is of interest to determine if blunted or incongruent affect in facial mimicry is observed in individuals with a history of NSSI. If so, altered facial expressivity may be a contributor to impaired social interactions and social rejection that can trigger NSSI behaviours and perpetuate a cycle of self-harm (In-Albon et al., 2013).

1.6 Clinical Implications of the Proposed Research

If emotions are identified incorrectly, or if an individual is hypersensitive to emotions, this can lead to an increase in emotional arousal and a worsening of mood state. Hence, sensitivities or deficits in emotion categorization can contribute to a vicious circle of self-injury that may lead to misperceptions and increased negative emotions (In-Albon et al., 2013). If individuals who have engaged in NSSI display differences in facial emotion recognition and expression, then future treatment and prevention of NSSI might benefit from developing training modules in which individuals practice recognizing initial facial expressions, respond to them appropriately and extend this learning into interpersonal situations. Implementing biofeedback procedures may also help a patient recognize or improve their sensitivity to their own emotions and help them with identifying and responding to the emotions of others in an appropriate manner (In-Albon et al., 2013). If those engaging in NSSI show deficits in emotion mimicry and their motivations are strongly linked to social influence, social skills training may also be helpful to prevent and/or better express heightened emotions. Results of this research are intended to expand the paucity of research that exists in this emerging field. Ultimately, this research may help to better understand NSSI behaviours and eventually improve treatment and prevention measures.

1.7 The Present Thesis

The primary goal of this research was to establish whether individuals with a history of engaging in NSSI show differences in facial emotion recognition and facial emotion mimicry. To investigate these hypotheses, three experiments were carried out. The first experiment examined emotion categorization capabilities of individuals with a history of NSSI using a morphing paradigm in which minimum facial expression intensity, accuracy of categorization, and reaction time were recorded. The second experiment took a psychophysical approach to the same question. Participants were presented with static faces at different emotion intensities and increasing levels of luminance noise to determine their threshold signal-to-noise ratio for recognizing emotional expressions. In addition, participants' results were compared to that of an Ideal Observer algorithm. This allowed for any differences in performance due to variations in the quality of information in the stimuli to be factored out, thus providing greater confidence that differences between conditions are due to differences in human processing, and not to the images being presented. The final experiment evaluated the implicit emotion mimicry of individuals with a history of NSSI by presenting them with videos of faces morphing from neutral to a prototypical emotion expression. It also investigated if commonly reported functions for engaging in NSSI were correlated with emotion mimicry responses.

It should be noted that data collection for study 1 and 3 occurred in one 3-hour testing session and included some overlap of participants. All participants in study 1 received the exact same procedure, in which EMG data were first collected for study 3 through stimulus observation before engaging in the categorization task of study 1. However, after EMG data collection, an appropriate break occurred to remove equipment and prepare for the second phase of data collection. Not all participants who completed the EMG phase could be included in study

3 due to high EMG impendence or poor signal quality. Hence, additional participants were collected through identical study procedures to ensure adequate sample size for study 3. The additional participants for study 3 simply did not move on to compete the categorization task afterward. This resulted in an overlap of 18 participants between study 3 and study 1. The study procedure did not vary in any systematic way between HNSSI and control groups. Data collection for study 2 occurred during a separate testing session.

1.8 References

Achaibou, A., Pourtois, G., Schwartz, S., & Vuilleumier, P. (2008). Simultaneous recording of EEG and facial muscle reactions during spontaneous emotional mimicry. *Neuropsychologia, 46*, 1104–1113.

Aldinger, M., Stopsack, M., Barnow, S., Rambau, S., Spitzer, C., Schnell, K., & Ulrich, I. (2013). The association between depressive symptoms and emotion recognition is moderated by emotion regulation. *Psychiatry Research*, *20,* 59-66.

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Andover, M. S., & Morris, B. W. (2014). Expanding and clarifying the role of emotion regulation in nonsuicidal self- injury. *Canadian Journal of Psychiatry, 59*, 569– 575.

Andover, M. S., Morris, B. W., Wren, A., & Bruzzese, M. E. (2012). The co-occurrence of non-suicidal self-injury and attempted suicide among adolescents: distinguishing risk factors and psychosocial correlates. *Child and Adolescent Psychiatry and Mental Health*, *6*, 11.

Armiento, J., Hamza, C. A., Stewart, S. L., & Leschied, A. (2016). Direct and indirect forms of childhood maltreatment and nonsuicidal self-injury among clinically-referred children and youth. *Journal of Affective Disorders*, *200*, 212-217.

Bateman A. (2006). *Mentalization-based treatment for borderline personality disorder: A practical guide*. Oxford: Oxford University Press.

Bourgeois, P., & Hess, U. (2008). The impact of social context on mimicry. *Biological Psychology, 77*, 343-352.

Brain, K. L., Haines, J., & Williams, C. L. (1998). The psychophysiology of self-mutilation: evidence of tension reduction. *Archival Suicide Research, 4*, 227–242.

Briere, J., & Gil, E. (1998). Self-mutilation in clinical and general population samples: prevalence, correlates, and functions. *American Journal of Orthopsychiatry, 68*, 609-620.

Burns, J., Dudley, M., Hazell, P., & Patton, G. (2005). Clinical management of deliberate self-harm in young people: the need for evidence-based approaches to reduce repetition. *Australia and New Zealand Journal of Psychiatry, 39,* 121-128.

Butler, E. A., Egloff, B., Wilhelm, F. H., Smith, N. C., Erickson, E. A., & Gross, J. J. (2003). The social consequences of expressive suppression. *Emotion, 3*, 48-67.

Carlson, J. G., Singelis, T. M., & Chemtob, C. M. (1997). Facial EMG responses to combat-related visual stimuli in veterans with and without posttraumatic stress disorder. *Applied Psychophysiology and Biofeedback*, *22*, 247-259.

Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: The perception-behaviour link and social interaction. *Journal of Personality and Social Psychology, 76*, 893-910.

Cheung, Y. T. D., Wong, P. W. C., Lee, A. M., Lam, T. H., Fan, Y. S. S., & Yip, P. S. F. (2013). Non- suicidal self- injury and suicidal behavior: Prevalence, co- occurrence, and correlates of suicide among adolescents in Hong Kong. *Social Psychiatry and Psychiatric Epidemiology, 48*(7), 1133–1144.

Claes, L., Houben, A., Vandereycken, W., Bijttebier, P., & Muehlenkamp, J. (2010). Brief report: The association between non-suicidal self-injury, self-concept and acquaintance with self-injurious peers in a sample of adolescents. *Journal of Adolescence*, *33,* 775-778.

Claes, L., Vandereycken, W., & Vertommen, H. (2007). Self- injury in female versus male psychiatric patients: A comparison of characteristics, psychopathology and aggression regulation. *Personality and Individual Differences, 42*(4), 611– 621.

Cloutier, P. F., & Nixon, M. K. (2003). The Ottawa self-injury inventory: A preliminary

evaluation. Abstracts to the 12th International Congress European Society for Child and Adolescent Psychiatry. *European Child & Adolescent Psychiatry*, *12*(Suppl. 1), 1–94.

Cole, P. M., Michel, M. K., & Teti, L. O. D. (1994). The development of emotion regulation and dysregulation: A clinical perspective. *Monographs of the Society for Research in Child Development*, *59*, 73–102.

Crowell, S. E., Beauchaine, T. P., & Linehan, M. M. (2009). A biosocial developmental model of borderline personality: Elaborating and extending Linehan's theory. *Psychological Bulletin, 135*, 495–510.

Daros, A. (2012). *Emotion Perception in Borderline Personality Disorder* (Master's Thesis). Retrieved from ProQuest Dissertation and Theses Global. (Accession Order No. AAT MR92890)

Daros, A. R., Zakzanis, K. K., & Ruocco, A. C. (2013). Facial emotion recognition in borderline personality disorder. *Psychological Medicine*, *43,* 1953-1963.

Davies, H., Wolz, I., Leppanen, J., Fernandez-Aranda, F., Schmidt, U., & Tchanturia, K. (2016). Facial expression to emotional stimuli in non-psychotic disorders: A systematic review and meta-analysis. *Neuroscience & Biobehavioural Reviews*, *64*, 252-271.

de Wied, M., van Boxtel, A., Matthys, W., & Meeus, W. (2012). Verbal, facial and autonomic responses to empathy-eliciting film clips by disruptive male adolescents with high versus low callous-unemotional traits. *Journal of Abnormal Child Psychology*, *40*, 211-223.

Dimberg, U. (1982). Facial reactions to facial expressions. *Psychophysiology, 19*, 643–647.

Dimberg, U. (1990). For distinguished early career contribution to psychophysiology: award address, 1988: facial electromyography and emotional reactions. *Psychophysiology*, *27*(5), 481-494.

Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious facial reactions to emotional facial expressions. *Psychological Science*, *11*, 86-89.

Domes, G., Czieschnek, D., Weidler, F., Berger, C., Fast, K., & Herpertz, S. C. (2008). Recognition of facial affect in borderline personality disorder. *Journal of Personality Disorders, 22,* 135-147.

Eisenberg, D., Golberstein, E., & Whitlock, J. L. (2014). Peer effects on risky behaviors: New evidence from college roommate assignments. *Journal of Health Economics*, *33*, 126-138.

Ekman, P. (1993). Facial expression and emotion. *American Psychologist, 48*, 384-392.

Eysenck, M. W., & Keane, M. T. (2000). *Cognitive psychology: A student's handbook*. Taylor & Francis.

Favazza, A. R., & Rosenthal, R. J. (1990). Varieties of pathological self-mutilation. *Behavioural Neurology*, *3,* 77-85.

Favazza, A. R., & Rosenthal, R. J. (1993). Diagnostic issues in self-mutilation. *Psychiatric Services*, *44,* 134-140.

Fenske, S., Lis, S., Liebke, L., Niedtfeld, I., Kirsch, P., & Mier, D. (2015). Emotion recognition in borderline personality disorder: Effects of emotional information on negative bias. *Borderline Personality Disorder and Emotion Dysregulation*, *2,* 1-12.

Fischer, A. H., Becker, D., & Veenstra, L. (2012). Emotional mimicry in social context: The case of disgust and pride. *Frontiers in Psychology, 3*, 475.

Foa, E. B., Gilboa-Schechtman, E., Amir, N., & Freshman, M. (2000). Memory bias in generalized social phobia: Remembering negative emotional expressions. *Journal of Anxiety Disorders, 14*, 501-519.

Fridlund, A. J., & Cacioppo, J. T. (1986). Guidelines for human electromyographic research. *Psychophysiology, 23,* 567–589.

Garrison, C. Z., Addy, C. L., McKeown, R. E., Cuffe, S. P., Jackson, K. L., & Waller, J. L. (1993). Nonsuicidal physically self- damaging acts in adolescents. *Journal of Child and Family Studies, 2*(4), 339–352.

Geisler, W. S. (2004). Ideal observer analysis. In J.S. Werner & L.M. Chalupa (Eds.), *The visual neurosciences*, (pp. 825–837). Cambridge: MIT Press.

Geisler, W. S. (2011). Contributions of ideal observer theory to vision research. *Vision Research, 51*, 771-781.

Glenn, C. R., & Klonsky, E. D. (2013). Nonsuicidal self-injury disorder: An empirical investigation in adolescent psychiatric patients. *Journal of Clinical Child & Adolescent Psychology, 42*, 496-507.

Gosselin, P., & Kirouac, G. (1995). Le décodage de prototypes émotionnels faciaux / The decoding of facial emotional prototypes. *Canadian Journal of Experimental Psychology/Revue Canadienne De Psychologie Expérimentale, 49*, 313-329.

Gratz, K. L. (2001). Measurement of deliberate self-harm: Preliminary data on the deliberate self-harm inventory. *Journal of Psychopathology and Behavioural Assessment*, *23*(4), 253-263.

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology*, *2*, 271–299.

Gross, J. J. (2002). Emotion regulation: affective, cognitive, and social consequences. *Psychophysiology, 39*, 281-291.

Gross, J. J. (2013). Emotion regulation: Taking stock and moving forward. *Emotion*, *13,* 359-365.

Gross, J. J. (2015). Emotion regulation: Current status and future prospects. *Psychological Inquiry, 26*, 1-26.

Guerry, J. D., & Prinstein, M. J. (2010). Longitudinal prediction of adolescent nonsuicidal self-injury: Examination of a cognitive vulnerability-stress model. *Journal of Clinical Child and Adolescent Psychology, 39*(1), 77–89.

Haines, J., Williams, C. L., Brain, K. L., & Wilson, G. V. (1995). The psychophysiology of self-mutilation. *Journal of Abnormal Psychology, 104*, 471–489.

Hall, E. T. (1959). *The silent language*. Garden City, NY: Double Day.

Hamza, C. A., & Willoughby, T. (2015). Nonsuicidal self-injury and affect regulation: Recent findings from experimental and ecological momentary assessment studies and future directions. *Journal of Clinical Psychology*, *71*, 561-574.

Hamza, C. A., Willoughby, T., & Heffer, T. (2015). Impulsivity and nonsuicidal self-injury: A review and meta-analysis. *Clinical Psychology Review*, *38*, 13-24.

Harrison, A., Sullivan, S., Tchanturia, K., & Treasure, J. (2009). Emotion recognition and regulation in anorexia nervosa. *Clinical Psychology & Psychotherapy*, *16,* 348-356.

Harrison, A., Sullivan, S., Tchanturia, K., & Treasure, J. (2010). Emotional functioning in eating disorders: Attentional bias, emotion recognition and emotion regulation. *Psychological Medicine, 40,* 1887-1897.

Hasking, P., Whitlock, J., Voon, D., & Rose, A. (2017). A cognitive-emotional model of NSSI: Using emotion regulation and cognitive processes to explain why people self-injure. *Cognition and Emotion*, *31*(8), 1543–1556.

Hatfield, E., Cacioppo, J. T., & Rapson, R. L. (1994). *Emotional contagion: Studies in emotion*

and social interaction. New York, NY: Cambridge University Press.

Hawton, K., Witt, K. G., Salisbury, T. L. T., Arensman, E., Gunnell, D., Townsend, E., ... & Hazell, P. (2015). Interventions for self-harm in children and adolescents. *Cochrane Database of Systematic Reviews*, (12).

Heath, N., Schaub, K., Holly, S., & Nixon, M. K. (2009). Self-injury today review of population and clinical studies in adolescents. In M. K. Nixon & N. Heath (Eds.), *Self-injury in youth the essential guide to assessment and intervention,* (pp. 9-27). New York, NY: Routledge.

Hermans, E., van Wingen, G., Bos, P., Putman, P., & van Honk, J. (2009). Reduced spontaneous facial mimicry in women with autistic traits. *Biological Psychology, 80*, 348–353.

Herpertz, S. (1995). Self-injurious behaviour Psychopathological and nosological characteristics in subtypes of self-injurers. *Acta Psychiatrica Scandinavica*, *91,* 57-68.

Herpertz, S. C., Werth, U., Lukas, G., Qunaibi, M., Schuerkens, A., Kunert, H. J., Freese, R., Flesch, M., Mueller-Isberner, R., Osterheider, M., & Sass, H. (2001). Emotion in criminal offenders with psychopathy and borderline personality disorder. *Archives of General Psychiatry*, *58*, 737-745.

Hess, U., & Blairy, S. (2001). Facial mimicry and emotional contagion to dynamic emotional facial expressions and their influence on decoding accuracy. *International Journal of Psychophysiology, 40*, 129-141.

Hess, U., & Bourgeois, P. (2010). You smile–I smile: Emotion expression in social interaction. *Biological Psychology, 84*, 514-520.

Hess, U., & Fischer, A. (2013). Emotional mimicry as social regulation. *Personality and Social Psychology Review, 17*, 142-157.

Hilt, L. M., Cha, C. B., & Nolen-Hoeksema, S. (2008). Nonsuicidal self-injury in young adolescent girls: Moderators of the distress-function relationship. *Journal of Consulting and Clinical Psychology, 76*, 63-71.

Hubbard, J. A. & Coie, J. D. (1994). Emotional correlates of social competence in children's peer relationships. *Merrill-Palmer Quarterly*, *40*, 1-20.

In-Albon, T., Bürli, M., Ruf, C., & Schmid, M. (2013). Non-suicidal self-injury and emotion regulation: A review on facial emotion recognition and facial mimicry. *Child and Adolescent Psychiatry and Mental Health*, *7,* 1-11.

In-Albon, T., Ruf, C., & Schmid, M. (2015). Facial emotion recognition in adolescents with nonsuicidal self-injury. *Psychiatry Research*, *228,* 332-339.

Inckle, K. (2011). The first cut is the deepest: A harm-reduction approach to self-injury. *Social Work in Mental Health, 9*, 364-378.

Jacobson C. M., & Gould, M. (2007). The epidemiology and phenomenology of nonsuicidal self-injurious behaviour among adolescents: A critical review of the literature. *Archives of Suicide Research, 11*, 129–147.

Jiang, M., Rahmani, A. M., Westerlund, T., Liljeberg, P., & Tenhunen, H. (2015, October). Facial Expression Recognition with sEMG Method. In *Computer and Information Technology; Ubiquitous Computing and Communications; Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing, 2015 IEEE International Conference,* 981-988.

Jovev, M., Chanen, A., Green, M., Cotton, S., Proffitt, T., Coltheart, M., & Jackson, H. (2011). Emotional sensitivity in youth with borderline personality pathology. *Psychiatry Research, 187*, 234-240.

Kaess, M., Parzer, P., Mattern, M., Plener, P. L., Bifulco, A., Resch, F., & Brunner, R. (2013). Adverse childhood experiences and their impact on frequency, severity, and the individual function of nonsuicidal self- injury in youth. *Psychiatry Research, 206*(2– 3), 265– 272.

Kahan, J., & Pattison, E. M. (1984). Proposal for a distinctive diagnosis: The deliberate self-harm syndrome (DSH). *Suicide and Life-Threatening Behaviour*, *14,* 17-35.

Kim, K. L., Cushman, G. K., Weissman, A. B., Puzia, M. E., Wegbreit, E., Tone, E. B., … Dickstein, D. P. (2015). Behavioral and emotional responses to interpersonal stress: A comparison of adolescents engaged in non- suicidal self- injury to adolescent suicide attempters. *Psychiatry Research*, *228*, 899-906.

Kitchener, B., & Jorm, A. (2010). Deliberate self-injury. In *Mental health first aid Canada for adults who interact with youth,* Mental Health Commission of Canada.

Klonsky, E. D. (2007). The functions of deliberate self-injury: A review of the evidence. *Clinical Psychology Review, 27*, 226-239.

Klonsky, E. D. (2009). The function of self-injury in young adults who cut themselves: Clarifying the evidence for affect-regulation. *Psychiatry Research, 166*, 260–268.

Klonsky, E. D. (2011). Non- suicidal self- injury in United States adults: Prevalence, sociodemographics, topography and functions. *Psychological Medicine,* 41(9), 1981-1986.

Klonsky, E. D., & Glenn, C. R. (2009). Assessing the functions of non-suicidal self-injury: Psychometric properties of the Inventory of Statements about Self-Injury (ISAS). *Journal of Psychopathology and Behavioural Assessment, 31*, 215-219.

Klonsky, E. D., Glenn, C. R., Styler, D. M., Olino, T. M., & Washburn, J. J. (2015). The

functions of nonsuicidal self-injury: Converging evidence for a two-factor structure. *Child and Adolescent Psychiatry and Mental Health*, *9*, 44.

Klonsky, E. D., Muehlenkamp, J., Lewis, S. P., & Walsh, B. (2011). *Nonsuicidal self-injury advances in psychotherapy evidence-based practice*. Toronto, ON: Hogrefe Publishing.

Kucharska-Pietura, K., Nikolaou, V., Masiak, M., & Treasure, J. (2004). The recognition of emotion in the faces and voice of anorexia nervosa. *International Journal of Eating Disorders, 35,* 42-47.

Künecke, J., Hildebrandt, A., Recio, G., Sommer, W., & Wilhelm, O. (2014). Facial EMG responses to emotional expressions are related to emotion perception ability. *PloS ONE*, *9*(1), e84053.

Laye-Gindhu, A., & Schonert-Reichl, K. (2005). Nonsuicidal self-harm among community adolescents: Understanding the "whats" and "whys" of self-harm. *Journal of Youth and Adolescence, 34*, 447-457.

Lieb, K., Zanarini, M. C., Schmahl, C., Linehan, M. M., & Bohus, M. (2004). Borderline personality disorder. *Lancet, 364,* 453–461.

Likowski, K. U., Mühlberger, A., Seibt, B., Pauli, P., & Weyers, P. (2008). Modulation of facial mimicry by attitudes. *Journal of Experimental Social Psychology, 44*, 1065-1072.

Linehan, M. (1993). *Cognitive-behavioral treatment of borderline personality disorder*. New York, NY: Guilford Press.

Lis, S., & Bohus, M. (2013). Social interaction in borderline personality disorder. *Current Psychiatry Reports*, *15*, 1-7.

Litz, B. T., Orsillo, S. M., Kaloupek, D., & Weathers, F. (2000). Emotional processing in posttraumatic stress disorder. *Journal of Abnormal Psychology*, *109*, 26-39.

Lloyd-Richardson, E. E., Perrine, N., Dierker, L., & Kelley, M. L. (2007). Characteristics and functions of non-suicidal self-injury in a community sample of adolescents. *Psychological Medicine, 37*, 1183-1192.

Lundqvist, L. & Dimberg, U. (1995). Facial expressions are contagious. *Journal of Psychophysiology, 9,* 203-211.

Lundqvist, D., Flykt, A., & Öhman, A. (1998). The Karolinska directed emotional faces - KDEF [CD ROM]. Stockholm, Sweden: Karolinska Institutet. Available from http://www.facialstimuli.com

Lydon, D. M., & Nixon, E. (2014). Facial mimicry interference affects reaction time but not accuracy on an emotion recognition task in children, adolescents and adults. *The Irish Journal of Psychology*, *35,* 106-120.

Lynch, T. R., Rosenthal, M. Z., Kosson, D. S., Cheavens, J. S., Lejuez, C. W., & Blair, R. J. (2006). Heightened sensitivity to facial expressions of emotion in borderline personality disorder. *Emotion, 6,* 647-655.

Maringer, M., Krumhuber, E. G., Fischer, A. H., & Niedenthal, P. M. (2011). Beyond smile dynamics: Mimicry and beliefs in judgments of smiles. *Emotion, 11*, 181-187.

Marsh, A. A., Adams Jr, R. B., & Kleck, R. E. (2005). Why do fear and anger look the way they do? Form and social function in facial expressions. *Personality and Social Psychology Bulletin*, *31*(1), 73-86.

Marsh, A. A., Kozak, M. N., & Ambady, N. (2007). Accurate identification of fear facial expressions predicts prosocial behavior. *Emotion, 7,* 239–251.

Mattes, R. M., Schneider, F., Heimann, H., & Birbaumer, N. (1995). Reduced emotional response of schizophrenic patients in remission during social interaction. *Schizophrenia Research*, *17*, 249-255.

Matzke, B., Herpertz, S. C., Berger, C., Fleischer, M., & Domes, G. (2014). Facial reactions during emotion recognition in borderline personality disorder: A facial electromyography study. *Psychopathology*, *47*, 101-110.

Mayer, J. D., Salovey, P., Caruso, D. R., & Sitarenios, G. (2001). Emotional intelligence as a standard intelligence. *Emotion, 3*, 232–242.

Meyer, B. R., Pilkonis, P. A., & Beevers, C. G. (2004). What's in a (neutral) face? Personality disorders, attachment styles, and the appraisal of ambiguous social cues. *Journal of Personality Disorders, 18*, 320–336.

Mitchell, A. E., Dickens, G. L., & Picchioni, M. M. (2014). Facial emotion processing in borderline personality disorder: A systematic review and meta-analysis. *Neuropsychology Review*, *24,* 166-184.

Mitchell, D. A. (2015). *Use of Multi-Informants in Predicting Adolescent Treatment Dropout.* (Doctoral Dissertation). Retreived from Loma Linda University Electronic Theses & Dissertations. (Order No, 272)

Moody, E. J., McIntosh, D. N., Mann, L. J., & Weisser, K. R. (2007). More than mere mimicry? The influence of emotion on rapid facial reactions to faces. *Emotion, 7*, 447-457.

Moran, P., Coffey, C., Romaniuk, H., Olsson, C., Borschmann, R., Carlin, J. B., & Patton, G. C. (2012). The natural history of self-harm from adolescence to young adulthood: A population-based cohort study. *The Lancet, 279*, 236-243.

Muehlenkamp, J. J. (2005). Self-injurious behaviour as a separate clinical syndrome. *American Journal of Orthopsychiatry*, *75,* 324-333.

Muehlenkamp, J. J., Claes, L., Havertape, L., & Plener, P. L. (2012). International prevalence of adolescent non-suicidal self-injury and deliberate self-harm. *Child and Adolescent Psychiatry and Mental Health, 6,* 10.

Muehlenkamp, J. J., Gutierrez, P. M. (2004). An investigation of differences between self-injurious behavior and suicide attempts in a sample of adolescents. *Suicide and Life-Threatening Behavior, 34*, 12-23.

Niedenthal, P. M., Mermillod, M., Maringer, M., & Hess, U. (2010). The simulation of smiles (SIMS) model: Embodied simulation and the meaning of facial expression. *Behavioural and Brain Sciences, 33*, 417-480.

Nijman, H. L., Dautzenberg, M., Merckelbach, H. L., Jung, P., Wessel, I., & del Campo, J. A. (1999). Self-mutilating behaviour of psychiatric inpatients. *European Psychiatry, 14*, 4-10.

Nixon, M. K., & Heath, N. (2009). Introduction to non-suicidal self-injury in adolescents. In M.K. Nixon & N. Heath (Eds.), *Self-injury in youth the essential guide to assessment and intervention,* (pp. 1-6). New York, NY: Routledge.

Nock, M. K. (2008). Actions speak louder than words: An elaborated theoretical model of the social functions of self-injury and other harmful behaviors. *Applied & Preventive Psychology, 12*(4), 159–168.

Nock, M. K. (2009). Why do people hurt themselves? New insights into the nature and functions of self-injury. *Current Directions in Psychological Science, 18*, 78-83.

Nock, M. K. (2010). Self-injury. *Annual Review of Clinical Psychology, 6*, 339-363.

Nock, M. K., & Favazza, A. (2009). Nonsuicidal self-injury: Definition and classification. In M. Nock (Ed.), *Understanding non-suicidal self-injury: Origins, assessment, and treatment,* (pp. 9-18). Washington, DC: American Psychological Association.

Nock, M. K., Joiner, T. E., Jr., Gordon, K. H., Lloyd-Richardson, E., & Prinstein, M. J. (2006). Non-suicidal self-injury among adolescents: Diagnostic correlates and relation to suicide attempts. *Psychiatry Research, 144*, 65-72.

Nock, M. K., & Mendes, W. B. (2008). Physiological arousal, distress tolerance, and social problem-solving deficits among adolescent self-injurers. *Journal of Consulting and Clinical Psychology, 76*, 28–38.

Oberman, L. M., Winkielman, P., & Ramachandran, V. S. (2007). Face to face: Blocking facial mimicry can selectively impair recognition of emotional expressions. *Social Neuroscience, 2*, 167-178.

Pattison, E. M., & Kahan, J. (1983). The deliberate self-harm syndrome. *American Journal of Psychiatry*, *140,* 867-872.

Plener, P. L., & Fegert, J. M. (2012). Non-suicidal self-injury: state of the art perspective of a proposed new syndrome for DSM V. *Child and Adolescent Psychiatry and Mental Health, 6,* 9-10.

Plener, P. L., Kaess, M., Schmahl, C., Pollak, S., Fegert, J. M., & Brown, R. C. (2018). Nonsuicidal self-injury in adolescents. *Deutsches Ärzteblatt International*, *115*(3), 23.

Renneberg, B., Heyn, K., Gebhard, R., & Bachmann, S. (2005). Facial expression of emotions in borderline personality disorder and depression. *Journal of Behaviour Therapy and Experimental Psychiatry*, *36*, 183-196.

Robertson, C. D., Miskey, H., Mitchell, J., & Nelson- Gray, R. (2013). Variety of self-injury: Is

the number of different methods of non- suicidal self- injury related to personality, psychopathology, or functions of self- injury? *Archives of Suicide Research, 17*(1), 33–40.

Robin, M., Pham-Scottez, A., Curt, F., Dugre-Le Bigre, C., Speranza, M., Sapinho, D., Corcos, M., Berthoz, S., & Kedia, G. (2012). Decreased sensitivity to facial emotions in adolescents with borderline personality disorder. *Psychiatry Research*, *200,* 417-421.

Rosenthal, M. Z., Gratz, K. L., Kosson, D. S., Cheavens, J. S., Lejuez, C. W., & Lynch, T. R. (2008). Borderline personality disorder and emotional responding: A review of the research literature. *Clinical Psychology Review*, *28*(1), 75-91

Rosenthal, R., & Rosnow, R. L. (1985). *Contrast analysis: Focused comparisons in the analysis of variance*. New York, NY: Cambridge University Press.

Rottenberg, J., Gross, J. J., & Gotlib, I. H. (2005). Emotion context insensitivity in major depressive disorder. *Journal of Abnormal Psychology*, *114*, 627-639.

Rozga, A., King, T. Z., Vuduc, R. W., & Robins, D. L. (2013). Undifferentiated facial electromyography responses to dynamic, audio-visual emotion displays in individuals with autism spectrum disorders. *Developmental Science*, *16*, 499-514.

Rymarczyk, K., Biele, C., Grabowska, A., & Majczynski, H. (2011). EMG activity in response to static and dynamic facial expressions. *International Journal of Psychophysiology, 79*, 330–333.

Schneider, K. G., Hempel, R. J., & Lynch, T. R. (2013). That “poker face” just might lose you the game! The impact of expressive suppression and mimicry on sensitivity to facial expressions of emotion. *Emotion*, *13*(5), 852.

Sel, A., Calvo-Merino, B., Tuettenberg, S., & Forster, B. (2015). When you smile, the world smiles at you: ERP evidence for self-expression effects on face processing. *Social Cognitive and Affective Neuroscience*, *10*(10), 1316-1322.

Selby, E. A., Bender, T. W., Gordon, K. H., Nock, M. K., & Joiner Jr, T. E. (2012). Non-suicidal self-injury (NSSI) disorder: A preliminary study. *Personality Disorders: Theory, Research, and Treatment*, *3,* 167.

Seymour, K. E., Jones, R. N., Cushman, G. K., Galvan, T., Puzia, M. E., Kim, K. L., Spirito, A., & Dickstein, D. P. (2016). Emotional face recognition in adolescent suicide attempters and adolescents engaging in non-suicidal self-injury. *European Child & Adolescent Psychiatry*, *25,* 247-259.

Silverman, M. M., Berman, A. L., Sanddal, N. D., O'Carroll, P. W., & Joiner, T. E. (2007). Rebuilding the tower of Babel: A revised nomenclature for the study of suicide and suicidal behaviours. Part 1: Background, rationale, and methodology. *Suicide and Life Threatening Behaviour, 37*, 248-263.

Soussignan, R., Jiang, T., Rigaud, D., Royet, J. P., & Schaal, B. (2010). Subliminal fear priming potentiates negative facial reactions to food pictures in women with anorexia nervosa. *Psychological Medicine*, *40*, 503-514.

Staebler, K., Renneberg, B., Stopsack, M., Fiedler, P., Weiler, M., & Roepke, S. (2011). Facial emotional expression in reaction to social exclusion in borderline personality disorder. *Psychological Medicine*, *41*, 1929-1938.

Stiglmayr, C. E., Grathwol, T., Linehan, M. M., Ihorst, G., Fahrenberg, J., & Bohus, M. (2005). Aversive tension in patients with borderline personality disorder: A computer-based controlled field study. *Acta Psychiatrica Scandinavica, 111*, 372-379.

Swannell, S. V., Martin, G. E., Page, A., Hasking, P., & St John, N. J. (2014). Prevalence of nonsuicidal self-injury in nonclinical samples: Systematic review, meta-analysis and meta-regression. *Suicide and Life-Threatening Behaviour*, *44,* 273-303.

Tang, J., Yu, Y., Wu, Y., Du, Y., Ma, Y., Zhu, H., … Liu, Z. (2011). Association between non-suicidal self- injuries and suicide attempts in Chinese adolescents and college students: A cross- section study. *PLoS ONE, 6*(4).

Tanner, A., Hasking, P., & Martin, G. (2016). Co- occurring non- suicidal self- injury and firesetting among at- risk adolescents: Experiences of negative life events, mental health problems, substance use, and suicidality. *Archives of Suicide Research, 20*, 233– 249.

Taylor, P. J., Jomar, K., Dhingra, K., Forrester, R., Shahmalak, U., & Dickson, J. M. (2018). A meta-analysis of the prevalence of different functions of non-suicidal self-injury. *Journal of Affective Disorders*, *227*, 759-769.

Turner, B. J., Wakefield, M. A., Gratz, K. L., & Chapman, A. L. (2017). Characterizing interpersonal difficulties among young adults who engage in nonsuicidal self-injury using a daily diary. *Behavior Therapy*, *48*(3), 366-379.

Turner, B. J., Yiu, A., Claes, L., Muehlenkamp, J. J., & Chapman, A. L. (2016). Occurrence and co- occurrence of nonsuicidal self- injury and disordered eating in a daily diary study: Which behavior, when? *Psychiatry Research*, *246*, 39– 47.

Van der Schalk, J., Fischer, A., Doosje, B., Wigboldus, D., Hawk, S. T., Rotteveel, M., & Hess, U. (2011). Convergent and divergent responses to emotional displays of ingroup and outgroup. *Emotion, 11*, 286-298.

Van Kleef, G. A. (2009). How emotions regulate social life: The emotions as social information (EASI) model. *Current Directions in Psychological Science, 18*, 184-188.

Von Ceumern-Lindenstjerna, I. A., Brunner, R., Parzer, P., Frey, M., Fiedler, P., & Resch, F. (2007). Wahrnehmung und Bewertung von emotionalen Gesichtsausdrücken bei weiblichen Jugendlichen mit einer borderline-persönlichkeitsstörung. *Zeitschrift für Kinder-und Jugendpsychiatrie und Psychotherapie, 35*, 333–340.

Vonderlin, E., Haffner, J., Behrend, B., Brunner, R., Parzer, P., & Resch, F. (2011). Welche problem berichten jugendliche mit selbstverletzendem verhalten? Ergebnisse einer repräsentativen schülerbefragung. *Kindheit Entwicklung, 20*, 118.

Walker, E. F., Grimes, K. E., Davis, D. M., & Smith, A. J. (1993). Childhood precursors of schizophrenia: Facial expressions of emotion. *The American Journal of Psychiatry*, *150*, 1654-1660.

Wester, K. L., & Trepal, H. C. (2017). *Non-suicidal self-injury: Wellness perspectives on behaviors, symptoms, and diagnosis*. New York, NY: Routledge.

Whitlock, J. (2009). The cutting edge: Non-suicidal self-injury in adolescence. *Developmental Psychology*, *42*, 407-17.

Whitlock, J., Eckenrode, J., & Silverman D. (2006). Self-injurious behaviours in a college population. *Pediatrics, 117*, 1939-1948.

Whitlock, J., & Knox, K. L. (2007). The relationship between self- injurious behavior and suicide in a young adult population. *Archives of Pediatrics & Adolescent Medicine, 161*(7), 634–640.

Wilkinson, P., Kelvin, R., Roberts, C., Dubicka, B., & Goodyer, I. (2011). Clinical and psychosocial predictors of suicide attempts and nonsuicidal self-injury in the adolescent depression antidepressants and psychotherapy trial (ADAPT). *American Journal of Psychiatry, 168*, 495-501.

Yates, T. M. (2004). The developmental psychopathology of self-injurious behavior: Compensatory regulation in posttraumatic adaptation. *Clinical Psychology Review, 24*, 35–74.

Yoo, S. H., Matsumoto, D., & LeRoux, J. A. (2006). The influence of emotion recognition and emotion regulation on intercultural adjustment. *International Journal of Intercultural Relations*, *30,* 345-363.

Zajonc, R. B., Murphy, S. T., & Inglehart, M. (1989). Feeling and facial efference: Implications of the vascular theory of emotion. *Psychological Review*, *96*, 395-416.

Zetterqvist, M. (2015). The DSM-5 diagnosis of nonsuicidal self-injury disorder: A review of the empirical literature. *Child and Adolescent Psychiatry and Mental Health*, *9,* 31-43.

Ziebell, L., Collin, C. A., Weippert, M., & Sokolov, M. (2017). Categorization of Emotional Facial Expressions in Humans with a History of Non-suicidal Self-injury. *International Journal of Comparative Psychology*, *30,* 1-14.

Chapter 2

Study 1: Categorization of Emotional Facial Expressions in Humans with a History of Non-suicidal Self-injury

Study 1 was published in International Journal of Comparative Psychology in 2017 and is generally formatted in accordance with the requirements of that journal.

Ziebell, L., Collin, C. A., Weippert, M., & Sokolov, M. (2017). Categorization of emotional facial expressions in humans with a history of non-suicidal self-injury. *International Journal of Comparative Psychology*, *30,* 1-14.

2.1 Abstract

In social animals, such as humans, accurate emotion expression categorization is important for appropriate social functioning. Inaccuracy in emotion categorization can lead to inadequate social behaviour, commonly seen in various psychiatric disorders. Non-suicidal self-injury (NSSI) is a psychiatric symptom involving deliberate self-inflicted injury of one's body, without intent to die. NSSI has been regarded as a dysfunctional coping strategy for managing intensely difficult feelings. Difficulties in social interactions have been reported by individuals who engage in NSSI, which may be related to their emotion categorization performance. Participants (17-25 yrs) with a history of NSSI and healthy controls viewed videos of faces changing over 10 s from neutral to a prototypical expression of sadness, disgust, surprise, fear, anger or happiness. They were instructed to stop each video as soon as they felt they recognized the emotion presented, thus indicating the minimum intensity of expression needed for categorization. They were then asked to categorize the expression. Minimum facial expression intensity, accuracy of categorization, and reaction time were the behavioural dependent variables of interest. NSSI participants showed significant advantages compared to controls in their ability to categorize negative emotion expressions, specifically fear, anger, disgust, and sadness. They also were able to recognize the ambiguous emotion of surprise at a lower stimulus intensity. To date, treatments for NSSI have high drop-out rates. Results from this research could be used to inform further development of therapies for the alleviation or prevention of NSSI.

2.2 Introduction

In social animals such as humans, accurate categorization of facial expressions of emotion is essential for appropriate social functioning, because recognizing the internal states of others from external cues can help to establish empathy, trust, and prosocial behavior. Moreover,

the accurate decoding of others' facial expressions is of great importance for guiding one's own behavior and regulating or managing one's own emotional state in various social contexts (Marsh, Kozak, & Ambady, 2007; Mayer, Salovey, Caruso, & Sitarenios, 2001). If facial expressions of emotion are not recognized, or recognized incorrectly, this can affect an individual's emotion regulation (Yoo, Matsumoto, & LeRoux, 2006). Emotion regulation is described as the processes by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions (Gross, 1998). For example, the ability to control the behavioral expression of one's negative emotions evoked during times of conflict or stress can be adaptive in many social contexts.

Inaccurate recognition and categorization of emotion expression can lead to emotion dysregulation and in turn can result in emotional disturbances, inadequate social behavior, poor social skills, less adaptive social problem-solving skills, and impaired social functioning, as seen in a variety of psychiatric disorders (Claes, Houben, Vandereycken, Bijttebier, & Muehlenkamp, 2010; Daros, 2012; Daros, Zakzanis, & Ruocco, 2013; Nock & Mendes, 2008). Indeed, emotion dysregulation appears to be involved in many psychiatric disorders. Examples include the failed regulation of anxiety in anxiety disorders (Cole, Michel, & Teti, 1994) or severe emotional dysregulation resulting in significant fear of abandonment and pervasive interpersonal problems in Borderline Personality Disorder (BPD; Lieb, Zanarini, Schmahl, Linehan, & Bohus, 2004). Additionally, evidence for inaccurate emotion categorization has also been found for BPD, Social Anxiety Disorder, Major Depressive Disorder and Eating Disorders (Aldinger et al., 2013; Daros et al., 2013; Fenske et al., 2015; Foa, Gilboa-Schechtman, Amir, & Freshman, 2000; Harrison, Sullivan, Tchanturia, & Treasure, 2009, 2010; Kucharska-Pietura, Nikolaou, Masiak, & Treasure, 2004). Depending on the disorder, research has found either impairments in emotion

recognition or sensitivities to facial expressions of emotion. Emotion regulation deficits in these populations are frequently thought to be central to the development and maintenance of psychological problems, and profoundly linked to emotion recognition capabilities.

Non-suicidal Self-injury

Non-suicidal Self-injury (NSSI) is intentional, self-inflicted damage to the surface of one's body without suicidal intent; it does not include forms of socially sanctioned self-injury, such as tattoos, ritual scarification, or piercings (American Psychiatric Association, 2013; Lloyd-Richardson, Perrine, Dierker, & Kelley, 2007). NSSI is a significant problem worldwide with lifetime prevalence estimates at 17.2% among adolescents, 13.4% among young adults (mean age 18 and 24 years) and 5.5% among adults (mean age over 25 years; Swannell, Martin, Page, Hasking, & St. John, 2014). NSSI behaviors include, but are not limited to, cutting, scratching, burning, stabbing, and/or self-hitting without suicidal intent. In past issues of the Diagnostic and Statistical Manual of Mental Disorders (DSM), NSSI has been limited to a symptom of Borderline Personality Disorder (BPD; American Psychiatric Association, 1994). However, suggestions have been made that NSSI should be considered a separate syndrome (Favazza & Rosenthal, 1990, 1993; Herpertz, 1995; Kahan & Pattison, 1984; Muehlenkamp, 2005; Pattison & Kahan, 1983), and recent research demonstrates that NSSI frequently occurs in individuals who do not meet diagnostic criteria for BPD (Selby, Bender, Gordon, Nock, & Joiner, 2012). This supports the idea that there is utility in understanding NSSI as its own diagnostic category. As such, Non-suicidal self-injury disorder now appears in the DSM-5 criteria as a condition for further study. Indeed, considerable research supports the classification of NSSI as a distinct entity that can occur independently of BPD and suicide, yet carries clinical significance (Glenn & Klonsky, 2013; Muehlenkamp, 2005; Nock, Joiner, Gordon, Lloyd-Richardson, & Prinstein,

2006; Zetterqvist, 2015). The focus of the present research study was to examine the emotion categorization capabilities of individuals with a history of NSSI, but no diagnosis of BPD.

NSSI and Emotion Recognition

The role of emotion dysregulation in NSSI behaviors is centrally linked to Linehan's (1993) biosocial theory. According to Linehan's theory, individuals engaging in NSSI behavior have significant difficulty with emotion regulation due to a biological predisposition for high emotional reactivity, as well as a social learning history of emotional invalidation from their families. An emotionally invalidating environment occurs when an individual's emotional experiences are not responded to appropriately or consistently (Linehan, 1993; In-Albon, Bürli, Ruf, & Schmid, 2013). This type of environment does not allow an individual to learn how to adaptively regulate intense emotions. Thus, these individuals rely on impulsive, short-term strategies, such as NSSI, to regulate emotions (In-Albon et al., 2013). Anger, anxiety, and frustration often precede engagement in NSSI, followed by temporary relief and calm, but ultimately result in sadness, guilt, anger, disgust and anxiety in the long term (Klonsky, 2007).

Emotion regulation is intricately linked with emotion perception (Gross, 2013, 2015). If facial expressions of emotion are not recognized correctly, emotion regulation and subsequent emotion recognition can be influenced. Several studies examining patients who engage in NSSI have found that these individuals are not able to perceive their own feelings at all, or sometimes the opposite, they perceive their feeling too strongly and aversively (Stiglmayr et al., 2005; Nock & Mendes, 2008). According to the biosocial theory (Linehan, 1993), greater sensitivity to emotion stimuli is a direct consequence of the emotion dysregulation characterized by NSSI. Thus, we would expect individuals with a history of NSSI to be more sensitive to emotion signals, especially those of a negative nature.

In individuals with BPD (of which NSSI is a frequent symptom), emotion dysregulation has been linked to dysregulation across cognitive processes, neurochemistry and physiology, facial and muscle reactions, and emotion-linked actions (Crowell, Beauchaine, & Linehan, 2009). These individuals display greater emotional sensitivity, greater emotional reactivity, and longer duration of emotional responses (Jovev et al., 2011). However, studies on emotion recognition in adolescents and adults with BPD have shown inconsistent results. A study conducted by Jovev and colleagues (2011) predicted increased emotion sensitivity in adolescents with BPD based on Linehan's (1993) theoretical framework by hypothesizing earlier response times to an emotion recognition task and more accurate recognition responses on the task compared to controls (Jovev et al., 2011). Contrary to their predictions, the BPD group exhibited somewhat longer response latencies for the recognition of fear and disgust. They also observed that the BPD group rated disgust and happiness as less positive than the control group, suggesting a possible negative bias in appraising social cues (Meyer, Pilkonis, & Beevers, 2004). Robin et al. (2012), who also investigated adolescents with BPD, found that they were less sensitive to facial expressions of anger and happiness (i.e., they required more intense facial expressions to correctly identify these emotions than control participants), and that they showed impairments when recognizing fully expressed emotions. In adults with BPD, Lynch et al. (2006) reported a heightened sensitivity to facial expressions, whereas Domes et al. (2008) reported a comparable emotion detection threshold in BPD and non-clinical controls. A recent review of 25 studies of emotion recognition in BPD concluded that despite differences in methodology, there were no significant recognition impairments for any negative emotions between BPD and healthy controls; however, there was consistent evidence supporting a negative response bias to neutral and ambiguous facial expressions (Mitchell, Dickens, & Picchioni, 2014).

To date, there are two studies examining facial emotion recognition capabilities in individuals exhibiting NSSI, both in an adolescent inpatient population. In-Albon, Ruf, and Schmid (2015) hypothesized that female adolescents engaging in NSSI would have more difficulty recognizing facial expressions, as measured by the intensity of expression at which they could accurately identify an emotion. They also predicted a decline in emotion recognition, mean emotion intensity before first correct response, and accuracy following a sad mood induction compared to a neutral mood. Contrary to their predictions, adolescents engaging in NSSI showed no general deficits accurately recognizing facial expressions of emotion, and no significant differences in intensity of emotion required for accurate identification between adolescents with NSSI disorder, clinical controls without NSSI, and nonclinical controls. All groups correctly recognized emotions at similar stages of emotional expressivity, and mood induction did not affect recognition or accuracy. However, adolescents with NSSI disorder did rate the valence and arousal of emotions as significantly more unpleasant for neutral and happy expression and significantly more arousing for angry, sad, and happy expressions compared to the non-clinical control group.

Most recently, Seymour et al. (2016) examined facial emotion expression recognition in three groups: (1) inpatient adolescents engaging in NSSI, (2) inpatient adolescents who attempted suicide, and (3) typically developing controls. Facial emotion recognition ability was assessed using DANVA-2, a computer-based behavioral task in which participants are asked to identify 2-second static photographs of child and adult faces expressing happiness, sadness, anger, or fear at high and low intensities. Their results showed that adolescents with NSSI made more errors on child fearful and adult sad face recognition compared to the typically developing controls. They concluded that adolescent inpatients engaged in NSSI showed greater deficits in

facial emotion expression recognition compared to controls, but not when compared to inpatient adolescents who attempted suicide.

In summary, there is a divergence between the predictions derived from Linehan's biosocial theory of the etiology of BPD and the findings in the literature; the former predicts greater sensitivity to emotion and thus better performance in categorizing facial expressions, but the latter has generally shown this not to be the case. It is thus unclear what to expect with individuals who have a history of NSSI in the absence of BPD. Based on Linehan's theory, one is led to hypothesize that individuals with a history of NSSI will show superior performance at emotion categorization. Conversely, based on comparisons with the literature on the related condition of BPD and NSSI, one is led to expect the opposite, or perhaps no difference between groups.

One reason why previous literature might have failed to find differences in emotion categorization performance between participants with BPD and controls is that the former may be more impulsive (Jovev et al., 2011). This would lead them to have higher rates of error across all emotion categories as responses are given too quickly. That is, their greater sensitivity might have been cancelled out by their poorer impulse control. For this reason, in the present study we used a measure of emotion categorization ability that allowed us to detect impulsivity effects. Specifically, we presented participants with stimuli consisting of videos of faces that gradually varied (morphed) over 10 seconds from a neutral to an emotional expression and asked them to press a button to stop the video as soon as they felt they could recognize the emotion. They were then to immediately categorize the emotion as happy, sad, angry, fearful, disgusted or surprised. Participants who are more impulsive would be expected to stop the video too soon, yielding a lower emotion intensity but higher error rates. Subjects that are genuinely more effective at

categorizing emotions should demonstrate either: (1) Lower required emotion intensity without reduced accuracy, (2) Superior accuracy without a higher required emotion intensity, or (3) Superior accuracy and a lower required emotion intensity. For instance, if participants with a history of NSSI are more impulsive, then they would tend to choose an emotion intensity that is too low for them to make an accurate assessment. Conversely, if such individuals can make equally accurate categorizations at lower intensity levels than controls, then this would provide evidence compatible with the idea that Linehan's biosocial model is correct with regards to the etiology of NSSI.

Given the small amount of previous literature on NSSI, and the divergent results in studies on BPD, we have chosen to base our hypotheses on Linehan's biosocial theory. We therefore predict that a community sample of individuals with a history of NSSI will be more sensitive to emotion signals than controls, and that they will exhibit superior performance in emotion categorization. To guard against confounds due to impulsive responses we assess emotion categorization ability in terms of both the minimum facial expression intensity required to perform the categorization and the accuracy of categorization. In addition, we examine the reaction time for choosing a category label, and the frequency of use of the various category labels in order to probe for any other response biases that might account for our results.

2.3 Method

Participants. The study sample is composed of young adults recruited through an undergraduate subject pool at the University of Ottawa. Participants were drawn from a pool of students enrolled in the introductory psychology courses. The University of Ottawa Ethics Review Board approved this research study. After the purpose and procedure of the study were explained to participants, informed written consent was obtained. A total of 38 participants with

a history of engaging in NSSI and 48 control participants were recruited through this method. All NSSI participants reported having engaged in intentional self-inflicted injury to the surface their body at least 5 times or more within their lifetime. The majority of participants self-injured over 6 months ago, 50% (*n* = 19). However, within the last 6 months, 44.7% (*n* = 17) reported thinking about self-injuring 1 to 5 times and 36% (*n* = 14) engaged in the behavior, while 15.8% (*n* = 6) reported thinking about self-injuring monthly or weekly 13.2% (*n* = 5), and 13.2% (*n* = 5) engaged in the behavior. Demographic data regarding our sample are shown in Table 1.

Table 1
Participant Demographics

Variable	HNSSI group (*n* = 38)	Control group (*n* = 48)
Age: years	18.68 ± 1.33	18.75± 1.12
Sex: male	8% (3)	6% (3)
Ethnicity: Caucasian	68% (26)	62% (30)
Comorbid Diagnosis:		
Depression	21% (8)	-
Generalized Anxiety Disorder	28% (11)	-
PTSD	5% (2)	-
OCD	3% (1)	-
Other	8% (3)	-
None	57% (22)	100% (48)

Inclusion/Exclusion Criteria. Eligible participants were between 17 to 24 years of age. For inclusion in the NSSI group, a participant had to report having engaged in intentional self-inflicted injury to the surface of his or her body at least 5 times within their lifetime, with the expectation that the injury would lead to only minor or moderate physical harm (i.e., no suicidal intent). These participants were identified through subject pool pre-screening questions. The pre-screening question read, “Have you ever intentionally self-inflicted damage to the surface of your body to cause bleeding, bruising, or pain (e.g., cutting, burning, stabbing, and/or hitting),

without the intent to kill yourself? Please note that this does not include ear piercing, tattooing, circumcision, or cultural healing rituals." Potential responses included Never; Once; 2-4 times; 5 or more times. Only individuals who responded "Never" or "5 or more times" were screened in to participate as controls or NSSI respectively. Exclusion criteria for both the NSSI and control groups included a self-reported diagnosis of Borderline Personality Disorder. The pre-screening question read, "Have you ever been diagnosed with Borderline Personality Disorder? Yes/No." Additionally, individuals who reported to have engaged in NSSI "5 or more times" on the pre-screening question but failed to report NSSI behavior in either of the administered NSSI questionnaires were also excluded from the study. Refer to Table 1 for demographic characteristics of the sample by group.

2.4 Measures

Socio-Demographic Questionnaire. This demographic questionnaire collected standard participant information such as age, gender, primary language, ethnicity, education, and current or past mental health diagnoses. This information was used to describe the demographics of the NSSI and control groups.

The Ottawa Self Injury Inventory (OSI - Functions 1.1). This questionnaire assessed self-injurious behaviors and their functions. The OSI - Functions 1.1 is a 33-item self-report measure designed to identify the psychosocial functions of NSSI. It addresses cognitive, affective, behavioral, and environmental aspects of self-injury and requires approximately 20 minutes to complete. Example questions include "why do you think you started and if you continue, why do you still self-injure?" and example responses include "to release unbearable tension" or "to punish myself." Answers were provided on a 5-point scale (0 = never a reason, 2 = sometimes a reason, 4 = always a reason). This scale provided cumulative scores for the

subscales of internal emotional regulation (0 to 32), external emotional regulation (0 to 12), social influence (0 to 36), and sensation seeking (0 to 12). Test–retest reliability has previously been demonstrated over a two-week time span for this scale (*r* between 0.52 - 0.74 across domains; Cloutier & Nixon, 2003).

The Inventory of Statements About Self-Injury (ISAS). Section II of this questionnaire was administered. It is a 39-item self-report measure that assessed an individual's reasons for engaging in self-injurious behaviors on a scale from 0 ("not relevant") to 2 ("very relevant"). Based on previous research (Klonsky & Glenn, 2009), 13 functions of NSSI have been identified. The questionnaire states "when I self-harm, I am…" and example responses include "causing pain so I will stop feeling numb" or "creating a physical sign that I feel awful." The score on these 13 functions can be summed (ranging from 0 to 6) to create separate factors that index interpersonal functions of NSSI (i.e., autonomy, interpersonal boundaries, interpersonal influence, peer-bonding, self-care, revenge, sensation seeking, toughness; Cronbach's alpha = 0.94) and Intrapersonal Functions of NSSI (i.e., affect-regulation, anti-dissociation, anti-suicide, marking distress, self-punishment; Cronbach's alpha = 0.84). The interpersonal functions and intrapersonal functions factors correlated moderately (*r* = 0.40).

2.5 Procedure

Study participation included a computer-based task (emotion recognition) at the Integrated Neurocognitive and Social Psychophysiology Interdisciplinary Research Environment (INSPIRE) lab at the University of Ottawa. Prior to the computerized tasks, and after having the study described to them verbally, participants signed an informed consent document. All participants completed the socio-demographic questionnaire**.** Two additional questionnaires, the Ottawa Self Injury Inventory (OSI) and the Inventory of Statements About Self-Injury (ISAS),

were completed by individuals in the NSSI group. Participants that reported suicidal ideation or severe harm on the OSI underwent a suicide protocol that assessed their level of risk.

Emotion recognition task. This task involved identifying the emotion expressions of a series of morphing facial images presented on a computer screen. On each trial, a 10-second video was presented wherein a face image changed smoothly from a neutral expression until 100% expression intensity was reached (see Figure 1). By pressing a button, participants signaled at what point along the morphing progression they were able to identify the emotion expression. This provided an index of the minimum emotion intensity subjects felt they needed in order to categorize the expression shown. Immediately following the button press, participants were provided a forced-choice task to identify the emotion presented; each of the six basic emotions described by Ekman (1993; happiness, sadness, anger, fear, disgust and surprise) was presented across 24 identities (equal numbers of Caucasian male (12) and female (12) color images). Thus, a total of 144 trials (24 identities x 6 emotions) were presented. These were shown in random order. On each trial, image number and response time were electronically recorded, providing an index of the emotion intensity threshold.

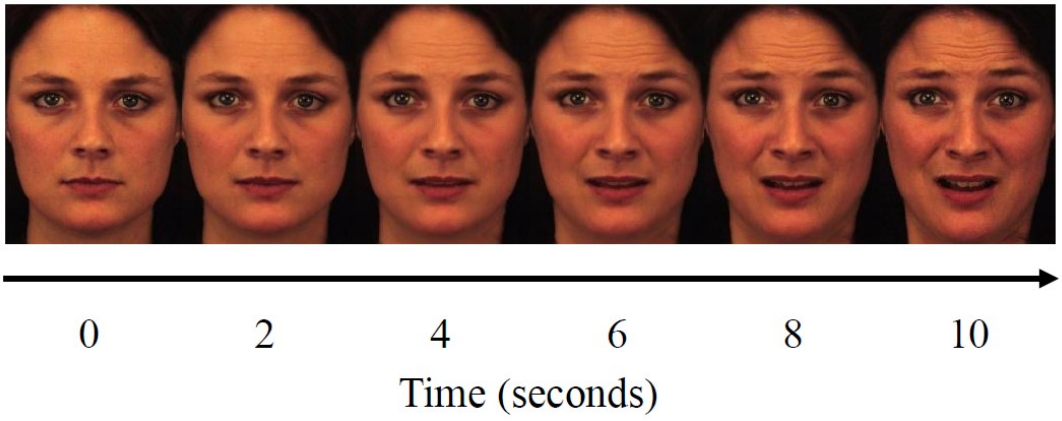


Figure 1. An example of the stimuli presented for the emotion of fear. Images were presented in succession as 10-second video wherein the face image transformed smoothly from a neutral expression to 100% expression intensity.

The morphing stimuli were created using Morpheus Photo Morpher® v3.17 (Morpheus Software, LLC) such that 150 images were created to produce a video of an emotion expression seamlessly progressing from 0 (neutral) to 100% (prototypic expression) in 10 seconds. Face images were obtained from the Karolinska Directed Emotional Faces (Lundqvist, Flykt, & Öhman, 1998) database. This image database includes 70 individuals (35 females and 35 males) each displaying 7 different emotion expressions (including a neutral facial expression). Images are of amateur actors aged 20 to 30 years old with no beards, mustaches, earrings, or eyeglasses, and no visible makeup. A total of 48 individuals were selected for the study based on image quality. Stimuli were pre-processed by MATLAB image processing toolbox to have equal overall lightness and color composition.

2.6 Results

Mean accuracy results for each emotion category are shown in Figure 2. To analyze between-groups differences in performance, we conducted a series of planned contrasts (Rosenthal & Rosnow, 1985). The error term for these analyses was taken from a mixed 2 x 6

ANOVA (see the Appendix for the ANOVA table). These analyses showed that participants with a history of NSSI are generally equally accurate in categorizing emotion expressions when compared to control participants. However, with regards to the expression of fear, we found that the NSSI group was significantly superior to control participants, $F(1, 84) = 4.75$, $p = 0.03$. There was no difference between groups in accuracy for categorizing happy face stimuli, however these may be subject to a ceiling effect.

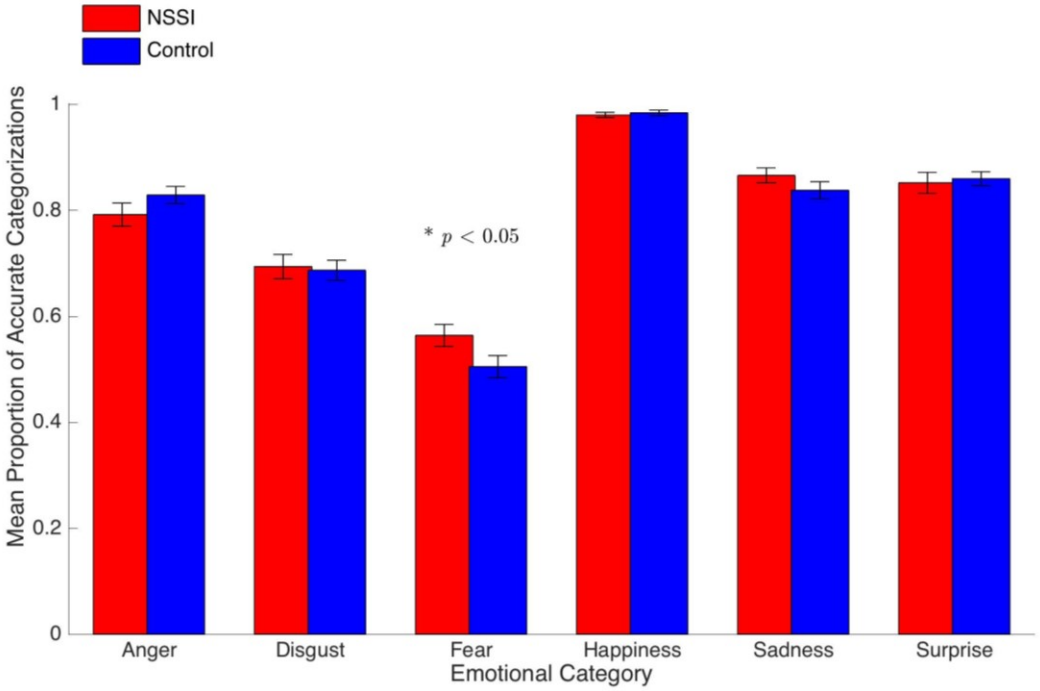


Figure 2. Mean proportion of accurate categorization for each emotion category. Participants with a history of NSSI were significantly more accurate in recognizing fear. Error bars represent one standard error of the mean.

Mean emotion intensity data for each emotion category are shown in Figure 3. We again conducted a series of planned contrasts to assess whether there were any group differences in this measure (see Appendix for mixed factorial ANOVA results). These analyses showed that

participants with a history of NSSI were superior at recognizing the emotion of disgust, in that they could recognize it at a lower emotion intensity, $F(1, 84) = 23.3$, $p < 0.01$, despite showing no differences in accuracy. Similarly, the analyses revealed that the NSSI group was able to recognize angry, $F(1, 84) = 5.8$, $p = 0.01$, and sad expressions, $F(1, 84) = 6.7$, $p = 0.01$, at a lower intensity levels than controls. As with disgust, this was not simply a speed-accuracy trade-off, as there was no difference in accuracy between the groups. The lack of difference between groups in terms of the intensity of fear expressions likewise supports the idea that the accuracy difference shown in Figure 2 is a genuine difference in behavioral performance. Thus, for four negative emotions—anger, disgust, fear and sadness—there is evidence of superior sensitivity in individuals with a history of NSSI. This finding is compatible with Linehan's model suggesting a greater sensitivity to negative emotions in the related condition of BPD. This is the first evidence of such differences in a population defined by a history of NSSI in the absence of a diagnosis of BPD.

Finally, analyses also revealed that the NSSI group was able to recognize surprise expressions at a lower intensity level, $F(1, 84) = 16.8$, $p < 0.01$, than controls. Surprise has ambiguous valence, in that it can be both negative and positive, so this finding does not clearly fit with the prediction of superior sensitivity to negative emotions.

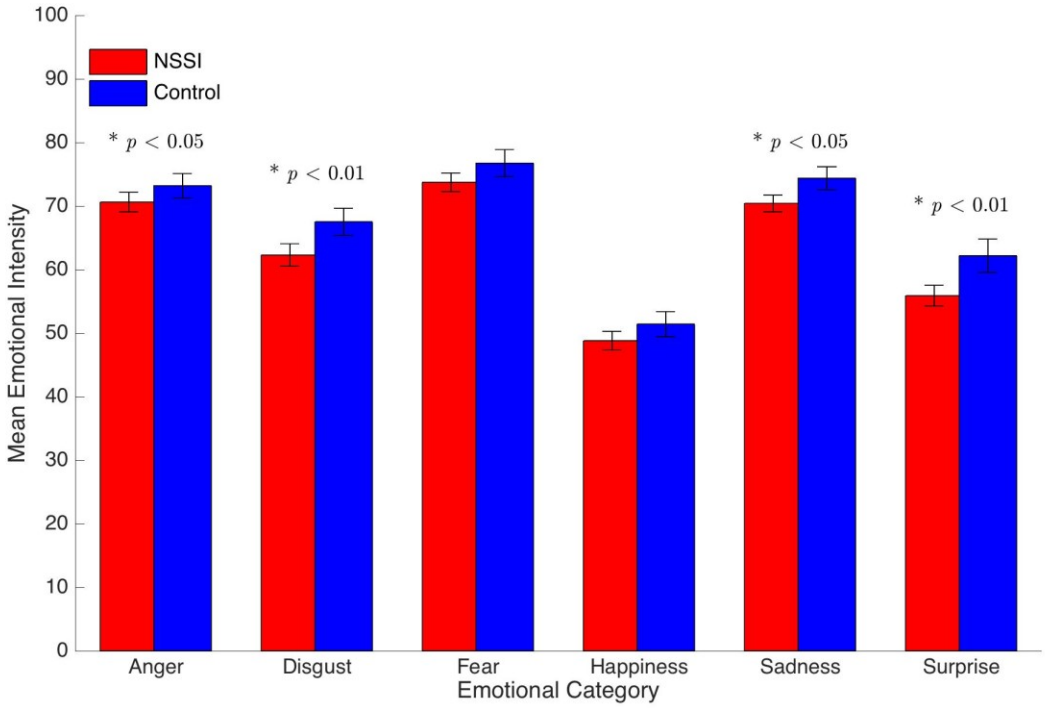


Figure 3. **Mean emotion intensity percentage**. Zero indicates a neutral facial expression, and 100 indicates a full-intensity expression. Participants with a history of NSSI were able to recognize disgust, sadness and surprise at a significantly lower emotion intensity. Error bars represent one standard error of the mean.

In addition to analyzing accuracy and emotion intensity data, we also examined reaction times. That is, we examined the amount of time it took participants to categorize the stimulus's emotion after they had stopped the morph video to indicate that they recognized it. Differences in reaction times might cast doubt on the interpretability of differences in accuracy or emotion intensity, suggesting that they are due to speed-accuracy trade-offs. To check for this, a series of planned comparison *t*-tests were carried out. None of these showed any significant inter-group differences.

Finally, we examined another potential confounding factor in our results, which is response bias. That is, participants with a history of NSSI may have achieved superior performance in certain emotion categories by using particular responses more often. To test for this, we conducted a series of planned comparison *t*-tests, one for each emotion category. These found no differences between groups in response frequency for any of the emotion categories.

2.7 Discussion

This study sought to determine whether individuals with a history of NSSI exhibit enhanced sensitivity to negative facial expressions as compared to controls. This was assessed via three behavioral measures: Accuracy of categorization, minimum expression intensity at which categorization could be made, and reaction time to choose an emotion category. Our data show a pattern of differences supporting the hypothesis that individuals with a history of NSSI exhibit superior performance at emotion categorization for negative emotions. Specifically, they demonstrated superior accuracy when categorizing fear, and were able to categorize anger, disgust and sad expressions at a lower intensity. Reaction time data showed no differences between groups, assuaging concerns about possible speed-accuracy trade-offs. This latter point is especially important in this population, as they may be prone to impulsivity (Hamza, Willoughby, & Heffer, 2015). For this reason, the present study used the measures of accuracy and reaction time for emotion categorization to allow us to detect impulsivity effects. One would expect that greater impulsivity would lead to lower emotion intensity, but also higher error rates. Additionally, if the participants with a history of NSSI were indeed more impulsive, this would result in higher error rates across all emotion categories, as responses for all emotions would be given too quickly. This was not found in the current study. Furthermore, our data also showed no evidence of a bias towards either group using any response categories more than the other.

Participants with a history of NSSI also showed an ability to categorize surprise at a lower intensity level. In this study, surprise had an ambiguous valence, in that participants could interpret it as either positive or negative. This finding does not clearly fit with our prediction; however, it may reflect a more general sensitivity to emotions that are potentially negative. Compatible with this is the fact that we found no suggestions of inter-group differences in the categorization of happy faces on any of our measures. This result from the history of NSSI population may correspond with the evidence found in BPD by Daros et al. (2013) and Mitchell et al. (2014), supporting a negative response bias to neutral and ambiguous facial expressions. The emotion of surprise can have any valence such as neutral, pleasant, unpleasant, positive, or negative. Whether participants with a history of NSSI interpreted the surprise emotion presented in this study as negative is a question that requires further investigation.

Our findings are compatible with Linehan's biosocial theory of the etiology of NSSI, which suggests that this behavior arises from poor emotion regulation. These results fit a model in which individuals with NSSI are hypersensitive to others' emotions, especially negative ones, and therefore experience poorer emotional interactions and poorer social outcomes. While higher sensitivity apparently led to better performance in our task, this does not mean that it is an asset in real-world interactions. According to Linehan's model, one reason for this is that individuals with high sensitivity also exhibit high reactivity. That is, they over-react to others' emotions, interpreting them as higher in valence than they are. If this were the case, we would expect individuals with a history of NSSI to exhibit a greater degree of physiological response to emotive faces. Subsequent research should focus on investigating the bio-behavioral correlates of emotion face processing including any differences in physiological responses to emotions.

Comparing our results regarding NSSI to the previous literature on BPD suggests a divergence between these two conditions. Most studies on individuals with BPD have found no evidence that they have superior emotion sensitivity, and some have even found evidence suggesting poorer sensitivity in this population as compared to controls. In contrast, we find evidence of superior performance on several negative emotions. This may provide further evidence that NSSI and BPD are separate clinical entities, with different underlying emotional processes, etiologies and symptomatologies, as others have previously argued (Favazza & Rosenthal, 1990, 1993; Herpertz, 1995; Kahan & Pattison, 1984; Muehlenkamp, 2005; Pattison & Kahan, 1983; Selby et al., 2012).

Unlike the study conducted by Seymour et al. (2016), where inpatient adolescents engaged in NSSI made more recognition errors for child fearful faces and adult sad faces compared to controls, our sample of NSSI participants drawn from a non-psychiatric population were found to be superior at recognizing these emotions compared to typically developing controls. It is likely that their sample was composed of participants with more severe cases of NSSI as compared to our sample, as demonstrated by their need for hospitalization, and as suggested by the authors, may have been subject to Berkson's bias. Additionally, the design of Seymour et al.'s study permitted participants to view a static, 2-second image of a facial emotion instead of viewing a morphing progression. Interestingly, when assessing NSSI participants with a similar morphing paradigm to the current study, In-Albon et al. (2015) found no general deficits in accurately recognizing facial expressions of emotion. However, compatible with the present findings, they did show that the NSSI group, relative to controls, rated neutral and happy expressions as more unpleasant, whereas angry, sad, and happy expressions were rated as more arousing.

The fact that we find superior performance in the NSSI participants only for negative facial expressions suggests that this group is mainly hyper-sensitive to emotions that may signal social rejection or threat. Unlike Von Ceumern-Lindenstjerna et al.'s (2007) findings in individuals with BPD, we find no suggestion that those with a history of NSSI view happy faces more negatively. Neither minimum expression intensity nor accuracy differed between groups in our study when happy expressions were being judged. This may again suggest a distinction between BPD and NSSI. If an individual who engages in NSSI is hyper-sensitive to the social the cues of those around them, particularly fearful, angry, sad or disgusted faces as our data suggest, they may overreact in their own emotional responses to those around them, leading to rejection or isolation. This could serve to maintain a perpetuating cycle of NSSI behaviors. Additionally, since theoretical models of NSSI have postulated that individuals engage in this behavior as a means of gaining attention or influencing others' behavior, it is possible that individuals engaged in NSSI might be extremely attentive to negative social cues signaling lack of belonging.

Limitations. There are a few limitations that must be taken into account when interpreting the results of the present study. First, we relied on participants to self-report a diagnosis of borderline personality disorder, which does not yield as reliable results as implementing a scale to assess borderline characteristics. Future studies should employ a scale such as the Personality Assessment Inventory to better assess for characteristics of borderline personality disorder. This would allow for a continuous measure of borderline characteristics rather than relying on a simple dichotomous self-reported diagnosis. Additionally, administration of all questionnaires occurred approximately 40 minutes prior to the test administration and every attempt was made by the researchers to discuss only neutral topics with participants while

preparing for the emotion recognition task to avoid priming. However, is it possible that completing questionnaires about self-injury induced more negative emotions for the history of NSSI participants compared to the control participants. A possible increased emotional state could have influenced the performance of the history of NSSI group on in the emotion categorization task and may provide an alternative explanation for our pattern of findings. However, the finding that there were no differences in the frequency of responses between groups somewhat assuages this concern.

Conclusions. Results from this study show that individuals with a history of NSSI exhibited a pattern of differences that suggest superior performance of emotion categorization for negative emotions. They performed slightly better than controls when accurately categorizing fear, and they required a lower stimulus intensity to correctly categorize anger, disgust, sad and surprise expressions. The history of NSSI participants were able to categorize these emotions without displaying different reaction times compared to controls, thus decreasing concerns regarding speed-accuracy trade-offs.

Our findings add to the limited research on NSSI and point to the need for more studies on this condition. There is currently very little guidance for clinicians treating NSSI because it is considered a symptom of other disorders such as BPD, rather than as a distinct condition. Moreover, the drop-out rates for therapies aimed at NSSI are quite high (Burns, Dudley, Hazell, & Patton, 2005; Mitchell, 2015; Wester & Trepal, 2016). Our data support the contention that NSSI is distinct from BPD, suggesting that therapies should be tailored specifically for it. This may lead to more effective interventions with higher retention rates. Further research is needed to verify our findings, and to examine whether the apparent greater sensitivity of those with a history of NSSI is in fact linked to greater emotional reactivity and poorer outcomes.

2.8 References

Aldinger, M., Stopsack, M., Barnow, S., Rambau, S., Spitzer, C., Schnell, K., & Ulrich, I. (2013). The association between depressive symptoms and emotion recognition is moderated by emotion regulation. *Psychiatry Research*, *205,* 59–66.

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Publishing.

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Burns, J., Dudley, M., Hazell, P., & Patton, G. (2005). Clinical management of deliberate self-harm in young people: the need for evidence-based approaches to reduce repetition. *Australia and New Zealand Journal of Psychiatry, 39,* 121–128.

Claes, L., Houben, A., Vandereycken, W., Bijttebier, P., & Muehlenkamp, J. (2010). Brief report: The association between non-suicidal self-injury, self-concept and acquaintance with self-injurious peers in a sample of adolescents. *Journal of Adolescence*, *33,* 775–778.

Cloutier, P. F., & Nixon, M. K. (2003). The Ottawa self-injury inventory: A preliminary evaluation. Abstracts to the 12th International Congress European Society for Child and Adolescent Psychiatry. *European Child & Adolescent Psychiatry*, *12*(Suppl. 1), 1–94.

Cole, P. M., Michel, M. K., & Teti, L. O. D. (1994). The development of emotion regulation and dysregulation: A clinical perspective. *Monographs of the Society for Research in Child Development*, *59*, 73–102.

Crowell, S. E., Beauchaine, T. P., & Linehan, M. M. (2009). A biosocial developmental model of borderline personality: Elaborating and extending Linehan's theory. *Psychological Bulletin*, *135,* 495–510.

Daros, A. (2012). *Emotion perception in borderline personality disorder* (Accession Order No. AAT MR92890) [Master's thesis, University of Toronto]. ProQuest Dissertation and Theses Global.

Daros, A. R., Zakzanis, K. K., & Ruocco, A. C. (2013). Facial emotion recognition in borderline personality disorder. *Psychological Medicine*, *43,* 1953–1963.

Domes, G., Czieschnek, D., Weidler, F., Berger, C., Fast, K., & Herpertz, S. C. (2008). Recognition of facial affect in Borderline Personality Disorder. *Journal of Personality Disorders, 22,* 135–147.

Ekman, P. (1993). Facial expression and emotion. *American Psychologist, 48*, 384–392.

Favazza, A. R., & Rosenthal, R. J. (1990). Varieties of pathological self-mutilation. *Behavioral Neurology*, *3,* 77–85.

Favazza, A. R., & Rosenthal, R. J. (1993). Diagnostic issues in self-mutilation. *Psychiatric Services*, *44,* 134–140.

Fenske, S., Lis, S., Liebke, L., Niedtfeld, I., Kirsch, P., & Mier, D. (2015). Emotion recognition in borderline personality disorder: effects of emotional information on negative bias. *Borderline Personality Disorder and Emotion Dysregulation*, *2,* 1–12.

Foa, E. B., Gilboa-Schechtman, E., Amir, N., & Freshman, M. (2000). Memory bias in generalized social phobia: remembering negative emotional expressions. *Journal of Anxiety Disorders, 14*, 501–519.

Glenn, C. R., & Klonsky, E. D. (2013). Nonsuicidal self-injury disorder: An empirical investigation in adolescent psychiatric patients. *Journal of Clinical Child & Adolescent Psychology, 42*, 496–507.

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology*, *2*, 271–299.

Gross, J. J. (2013). Emotion regulation: Taking stock and moving forward. *Emotion*, *13,* 359–365.

Gross, J. J. (2015). Emotion regulation: Current status and future prospects. *Psychological Inquiry, 26*, 1–26.

Hamza, C. A., Willoughby, T., & Heffer, T. (2015). Impulsivity and nonsuicidal self-injury: A review and meta-analysis. *Clinical Psychology Review*, *38*, 13–24.

Harrison, A., Sullivan, S., Tchanturia, K., & Treasure, J. (2009). Emotion recognition and regulation in anorexia nervosa. *Clinical Psychology & Psychotherapy*, *16,* 348–356.

Harrison, A., Sullivan, S., Tchanturia, K., & Treasure, J. (2010). Emotional functioning in eating disorders: attentional bias, emotion recognition and emotion regulation. *Psychological Medicine, 40,* 1887–1897.

Herpertz, S. (1995). Self-injurious behavior Psychopathological and nosological characteristics in subtypes of self-injurers. *Acta Psychiatrica Scandinavica*, *91,* 57–68.

In-Albon, T., Bürli, M., Ruf, C., & Schmid, M. (2013). Non-suicidal self-injury and emotion regulation: a review on facial emotion recognition and facial mimicry. *Child and Adolescent Psychiatry and Mental Health*, *7,* 1-11.

In-Albon, T., Ruf, C., & Schmid, M. (2015). Facial emotion recognition in adolescents with nonsuicidal self-injury. *Psychiatry Research*, *228,* 332–339.

Jovev, M., Chanen, A., Green, M., Cotton, S., Proffitt, T., Coltheart, M., & Jackson, H. (2011). Emotional sensitivity in youth with borderline personality pathology. *Psychiatry Research, 187*, 234–240.

Kahan, J., & Pattison, E. M. (1984). Proposal for a distinctive diagnosis: The Deliberate Self-Harm syndrome (DSH). *Suicide and Life-Threatening Behavior*, *14,* 17–35.

Klonsky, E. D. (2007). The functions of deliberate self-injury: A review of the evidence. *Clinical Psychology Review*, *27,* 226–239.

Klonsky, E. D., & Glenn, C. R. (2009). Assessing the functions of non-suicidal self-injury: Psychometric properties of the Inventory of Statements About Self-injury (ISAS). *Journal of Psychopathology and Behavioral Assessment*, *31*, 215-219.

Kucharska-Pietura, K., Nikolaou, V., Masiak, M., & Treasure, J. (2004). The recognition of emotion in the faces and voice of anorexia nervosa. *International Journal of Eating Disorders, 35,* 42–47.

Lieb, K., Zanarini, M. C., Schmahl, C., Linehan, M. M., & Bohus, M. (2004). Borderline personality disorder. *Lancet, 364,* 453–461.

Linehan, M. (1993). *Cognitive-behavioral treatment of borderline personality disorder*. New York, NY: Guilford Press.

Lloyd-Richardson, E. E., Perrine, N., Dierker, L., & Kelley, M. L. (2007). Characteristics and functions of non-suicidal self-injury in a community sample of adolescents. *Psychological Medicine, 37,* 1183–1192.

Lundqvist, D., Flykt, A., & Öhman, A. (1998). The Karolinska directed emotional faces - KDEF [CD ROM]. Stockholm, Sweden: Karolinska Institutet. Available from http://www.facialstimuli.com

Lynch, T. R., Rosenthal, M. Z., Kosson, D. S., Cheavens, J. S., Lejuez, C. W., & Blair, R. J. (2006). Heightened sensitivity to facial expressions of emotion in borderline personality disorder. *Emotion, 6,* 647–655.

Marsh, A. A., Kozak, M. N., & Ambady, N. (2007). Accurate identification of fear facial expressions predicts prosocial behavior. *Emotion, 7,* 239–251.

Mayer, J. D., Salovey, P., Caruso, D. R., & Sitarenios, G. (2001). Emotional intelligence as a standard intelligence. *Emotion, 3*, 232–242.

Meyer, B. R., Pilkonis, P. A., & Beevers, C. G., (2004). What's in a (neutral) face? Personality disorders, attachment styles, and the appraisal of ambiguous social cues. *Journal of Personality Disorders, 18*, 320–336.

Mitchell, A. E., Dickens, G. L., & Picchioni, M. M. (2014). Facial emotion processing in borderline personality disorder: A systematic review and meta-analysis. *Neuropsychology Review*, *24,* 166—184.

Mitchell, D. A. (2015). *Use of Multi-Informants in Predicting Adolescent Treatment Dropout.* (Doctoral Dissertation). Retreived from Loma Linda University Electronic Theses & Dissertations. (Order No, 272)

Muehlenkamp, J. J. (2005). Self-injurious behavior as a separate clinical syndrome. *American Journal of Orthopsychiatry*, *75,* 324–333.

Nock, M. K., Joiner, T. E., Gordon, K. H., Lloyd-Richardson, E., & Prinstein, M. J. (2006). Nonsuicidal self-injury among adolescents: Diagnostic correlates and relation to suicide attempts. *Psychiatry Research, 144*, 65–72.

Nock, M. K., & Mendes, W. B. (2008). Physiological arousal, distress tolerance, and social problem-solving deficits among adolescent self-injurers. *Journal of Consulting and Clinical Psychology*, *76,* 28–38.

Pattison, E. M., & Kahan, J. (1983). The deliberate self-harm syndrome. *American Journal of Psychiatry*, *140,* 867–872.

Robin, M., Pham-Scottez, A., Curt, F., Dugre-Le Bigre, C., Speranza, M., Sapinho, D., Corcos, M., Berthoz, S., & Kedia, G. (2012). Decreased sensitivity to facial emotions in adolescents with Borderline Personality Disorder. *Psychiatry Research*, *200,* 417–421.

Rosenthal, R., & Rosnow, R. L. (1985). *Contrast analysis: Focused comparisons in the analysis of variance*. New York, NY: Cambridge University Press.

Selby, E. A., Bender, T. W., Gordon, K. H., Nock, M. K., & Joiner Jr, T. E. (2012). Non-suicidal self-injury (NSSI) disorder: a preliminary study. *Personality Disorders: Theory, Research, and Treatment*, *3,* 167–175.

Seymour, K. E., Jones, R. N., Cushman, G. K., Galvan, T., Puzia, M. E., Kim, K. L., Spirito, A., & Dickstein, D. P. (2016). Emotional face recognition in adolescent suicide attempters and adolescents engaging in non-suicidal self-injury. *European Child & Adolescent Psychiatry*, *25,* 247–259.

Stiglmayr, C. E., Grathwol, T., Linehan, M. M., Ihorst, G., Fahrenberg, J., & Bohus, M. (2005). Aversive tension in patients with borderline personality disorder: A computer-based controlled field study. *Acta Psychiatrica Scandinavica, 111*, 372–379.

Swannell, S. V., Martin, G. E., Page, A., Hasking, P., & St John, N. J. (2014). Prevalence of nonsuicidal self-injury in nonclinical samples: Systematic review, meta-analysis and meta-regression. *Suicide and Life-Threatening Behavior*, *44,* 273–303.

Von Ceumern-Lindenstjerna, I. A., Brunner, R., Parzer, P., Frey, M., Fiedler, P., & Resch, F. (2007). Wahrnehmung und Bewertung von emotionalen Gesichtsausdrücken bei weiblichen Jugendlichen mit einer Borderline-Persönlichkeitsstörung. *Zeitschrift fur Kinder und Jugendpsychiatrie und Psychotherapie, 35*, 333–340.

Wester, K. L., & Trepal, H. C. (2017). *Non-suicidal self-injury: Wellness perspectives on behaviors, symptoms, and diagnosis*. New York, NY: Routledge.

Yoo, S. H., Matsumoto, D., & LeRoux, J. A. (2006). The influence of emotion recognition and emotion regulation on intercultural adjustment. *International Journal of Intercultural Relations*, *30,* 345–363.

Zetterqvist, M. (2015). The DSM-5 diagnosis of nonsuicidal self-injury disorder: a review of the empirical literature. *Child and Adolescent Psychiatry and Mental Health*, *9,* 31-43

2.9 Appendix

Power Analysis. According to a study examining emotional sensitivity in youth with BPD that employed a similar emotion recognition task for morphing facial expressions (Jovev et al., 2011), a range of Cohen's d effect sizes (between 0.1–0.6) were reported for emotion sensitivity among the six emotions examined (anger, disgusts, fear, happiness, sadness, surprise). An average of these reported effect sizes produced a Cohen's d of 0.36 (Effect size f = 0.18). For this study, assuming a Cohen's d of 0.36, power of 0.8 with α of 0.05, an ANOVA: Repeated-Measures, within-between interaction calculation for sample size was performed with GPower 3.1.9.2 for a 2 (NSSI and Control) X 6 (happy, sad, anger, fear, disgust, and surprise) design. The power analysis yielded an estimated total sample size of 36 participants (18 control and 18 NSSI). Hence, the total collected sample size of 86 (38 NSSI and 48 Controls) is likely adequate for the interpretation of a non-significant finding.

ANOVA Calculations. In order to obtain the error terms for our planned comparisons (Rosenthal & Rosnow, 1985), we conducted separate 2 (Group: NSSI or Control) × 6 (Emotion: sadness, disgust, surprise, fear, anger or happiness) mixed factorial ANOVAs on accuracy and emotion intensity data. For accuracy, Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(14) = 80.43$, $p < 0.001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.83$).

Table 2
Results of Mixed Factorial ANOVA for Accuracy

Source	*df*	*MS*	*F*	η^2_p	*p*
Group	1	0.008	.551	0.007	0.460
Error	84	0.014			
Emotion	4.13	2.49	163.54	0.661	<0.001
Emotion x Group	4.13	0.027	1.79	0.021	0.128
Error	346.7	0.015			

For emotion intensity, Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(14) = 95.80$, $p < 0.001$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.70$).

Table 3
Results of Mixed Factorial ANOVA for Emotion Intensity

Source	*df*	*MS*	*F*	η^2_p	*P*
Group	1	1990.42	2.47	0.029	0.120
Error	84	806.42			
Emotion	3.48	11281.51	226.12	0.729	<0.001
Emotion x Group	3.48	70.93	1.42	0.017	0.232
Error	292.12	49.89			

Chapter 3

Study 2: Using an Ideal Observer analysis to investigate the visual perceptual efficiency of individuals with a history of NSSI when identifying emotional expressions

Study 2 was published in PLoS ONE in 2019 and is generally formatted in accordance with the requirements of that journal.

Ziebell, L., Collin, C., Rainville, S., Mazalu, M., Weippert, M. (2020). Using an ideal observer analysis to investigate the visual perceptual efficiency of individuals with a history of non-suicidal self-injury when identifying emotional expressions. *PLoS ONE, 15*(2), e0227019.

3.1 Abstract

Individuals who engage in non-suicidal self-injury (NSSI) often report significant interpersonal difficulties, with studies lending support to the idea of impaired social interactions. Perceptual processing deficits of facial expressions have also been associated with interpersonal difficulties, yet little research has assessed how individuals with a history of NSSI (HNSSI) process facial emotions. This study used an ideal observer analysis to assess emotion processing capabilities of these individuals. A total of 30 HNSSI and 31 controls were presented with static images of various facial expressions (fear, anger, disgust, happiness, sadness, surprise) at three intensity levels (50%, 75% and 100% emotion expressivity). Recognition of emotions were measured by signal-proportion thresholds, efficiency scores, and unbiased hit rate. Error responses were also recorded to investigate errors biases made by each group. No significant differences between HNSSI and controls were found in signal-proportion thresholds or efficiency scores. Decreased accuracy of HNSSI participants for recognizing fearful expressions was observed. An increased likelihood of mistaking angry for happy expressions and a decreased likelihood of mistaking sad for surprised expressions were recorded for the HNSSI group compared to controls. These findings provide support to the literature reporting deficits in accurate emotion identification for those engaged in NSSI behaviours.

3.2 Introduction

Non-suicidal self-injury (NSSI) has been defined as the deliberate, self-inflicted injury to tissues of the body without suicidal intent [1, 2]. It has become a prevalent and clinically significant behaviour observed with increasing frequency over the past few decades among adolescents and young adults [3]. Furthermore, NSSI has been recognized as a significant public health concern with estimates of lifetime prevalence rates between 5.5% in adults to 17.2% in

adolescents [4], and 21–45% in clinical inpatient samples [5-7]. Since a clear association has been identified between NSSI and suicidal behavior [8-10], it is critical to understand factors that contribute to and predispose individuals to engage in this type of behaviour, with the hope of ultimately informing treatment and prevention strategies.

One of the most frequently reported functions for engaging in NSSI is related to emotion regulation [11-13]. Broadly defined, emotion regulation is the implicit and explicit effort to recognize, understand and manage one's own emotions and emotional expression [14-17]. An additional function reported for NSSI behaviours is related to efforts to attenuate, regulate or avoid negative emotional and cognitive states arising from challenging interpersonal interactions, as individuals who engage in NSSI often report significant interpersonal and social difficulties [18]. Those engaged in NSSI may do so as a means to communicate with others, particularly when less extreme attempts at communication fail to produce the desired results [19]. This is relevant to understanding the social functions that perpetuate NSSI because adolescents engaging in this behaviour have also been found to exhibit greater difficulty evaluating interpersonal situations [20] and display reduced vigilance to positive social information [21].

From an emotional intelligence framework, Yoo et al. [22] have examined the link between recognition and regulation of emotion and concluded that emotion recognition may in fact be a precursor to emotion regulation. For instance, facial emotion perception is a central component to maintaining adequate social functioning, and if emotional facial expressions are not recognized accurately, then the ability to employ appropriate emotion regulation will ultimately be influenced. In this sense, accurate emotion recognition is critical, both within the self and in other people, to appropriately regulate emotional responses. Recent research has also linked engaging in NSSI with Alexithymia, an impairment in introspection about emotion that

often co-occurs with poor emotion recognition in self and others [23] and poor non-verbal expressiveness [24]. In particular, individuals who have difficulty perceiving and understanding their own emotions may have difficulty navigating emotionally charged situations, especially when social interactions require the interpretation of non-verbal or subtle emotional cues. Hence, the ability to accurately infer facial emotions is essential for guiding one's own behaviours and regulating emotional states in various social situations. Supporting these concepts, recent research has also suggested that impaired ability to understand internal emotions may be linked to an impairment in emotion identification when faces are presented quickly or with visual degradation [23;25-29]

Results from our previous research [30] showed advantages in an emotion recognition task for a history of non-suicidal-self-injury (HNSSI) group, such as lower emotion intensity recognition thresholds and increased accuracy categorizing negative and ambiguous emotions, as compared to controls. Drawing from these results and the aforementioned studies, it is therefore of interest to further examine the emotional expression recognition capabilities of individuals with a HNSSI using a more psychophysical approach to this same question.

While Ziebell et al. [30] examined sensitivity in HNSSI in terms of emotional expression intensity, there are other dimensions along which sensitivity might vary. One of these dimensions is a simple perception signal-to-noise ratio. That is, subjects with high sensitivity to emotion expression might be expected to correctly categorize such expressions despite a high level of visual noise degrading the image. This type of sensitivity has been examined in a number of related contexts, including face detection in prosopagnosia [31] but to our knowledge, it has not been used to examine facial expression recognition. Understanding whether participants with HNSSI exhibit greater noise tolerance is useful in understanding this condition,

as it will enable us to determine at what stage in visual processing differences in emotion recognition arise. While Ziebell et al. [30] showed that there was an advantage in negative emotion recognition for HNSSI participants in terms of the minimum level of emotion intensity needed to identify an expression, this leaves open the question of whether this occurs due to an advantage in early visual processing, or by an advantage at some later higher-order stage of analysis.

This study therefore sought to investigate whether HNSSI participants exhibit an advantage in the signal-proportion threshold required for accurate emotion categorization, as compared to control participants. This was accomplished by presenting participants with images of emotionally expressive faces embedded in variable quantities of fractal luminance noise. Fractal luminance noise is defined as random variations in luminance wherein the contrast energy of the noise at each spatial frequency is equivalent to that in natural images. Put another way, the function of contrast energy by spatial frequency is defined by $E = 1/f^n$, where E is energy, f is frequency and n is an exponent, typically between 1 and 2.2. As such, the energy in the noise is proportional to that in the signal (i.e., the images of faces), with more energy at low spatial frequencies and less at higher ones. Measurement of the noise thresholds provides a means for assessing participants' sensitivity to emotional expression: The noisier the image with which they can correctly perform the emotion categorization task, the more sensitive they are to the information in the image of the emotion expression. The facial image and fractal noise are added together linearly to compose the final stimulus, and the amount of signal relative to the noise is expressed as a signal proportion. The addition of variable amounts of noise brings the amount of information available for a participant to use when identifying the emotion presented under exact experimental control. Importantly, the mixture of signal and noise was also varied

such that overall image contrast always remained fixed: an increase in signal resulted in a decrease in noise and vice versa – a technique known as "titration" in the psychophysical literature. By design, the titration technique forces the signal and noise to covary in opposite directions, resulting in a ratio of signal energy to overall image energy – or "signal proportion" – bounded between 0.0 and 1.0. The more conventional metric in the literature of signal-to-noise ratio (SNR) is unbounded and typical of situations in which either signal or noise is fixed. Both metrics, signal-proportion and SNR, are related and can be mathematically re-expressed in terms of each other, so the choice of metric is simply dependent upon convenience. Titration is an elegant method that, in this particular case, also guards against any possibility that image contrast could somehow be a confounding variable associated with facial emotion.

As in our earlier experiment [30], our approach was designed to determine if NSSI participants show superior performance on this type of emotion recognition task compared to controls. Furthermore, because differences between NSSI and controls were observed at low expression intensities in our previous study, group differences in accuracy and errors will be investigated as a function of both emotion category and intensity.

In addition to measuring noise thresholds, the performance of participants will be subjected to an ideal observer analysis. This kind of analysis provides an informative approach to understanding the visual recognition of facial emotions by humans. The central concept of an ideal observer analysis is the “ideal observer algorithm” (IO), which is a computer program that performs a given visual task, like emotion recognition, in a mathematically optimal fashion given the available information, and within specified constraints [32]. This is not to say that the ideal observer will perform without error, but rather that it will perform at the physical limit of what is possible given the available information in the facial emotion stimulus [32]. When an ideal

observer makes an error, it is generally due to the complexity and uncertainty in the visual environment, such as inherent noise in light or the signal used by the ideal observer [32]. The ideal observer algorithm first determines its own performance on the emotion recognition task, which is then applied as a baseline against which to compare the performance of human participants. The ratio of human performance to ideal performance, known as "efficiency," factors out the effects of variation in information content, and yields a pure measure of a human observer's relative ability to make use of the information available [33]. This provides a means by which to determine which emotions are objectively easier to detect and which are more difficult, clarifying interpretation of human performance data. Note that ideal observers are only ideal within the narrow scope for which they are designed. For instance, the ideal observer in this experiment operates purely on the pixel-by-pixel correspondence between the stimulus and the set of stored noiseless templates; however, absolute ideal performance is not the goal. The goal here is that an ideal observer is simply a model that captures important information about a stimulus set and allows one to evaluate human performance in the context of task difficulty, or in this particular case, by taking into account the possibility that some emotions may be intrinsically more difficult to detect than others regardless of who is doing the detecting.

Expanding on the results of Ziebell et al., [30], it is expected that individuals with a HNSSI will be more sensitive to negative emotions. In particular, it is anticipated that they will have lower signal-proportion detection thresholds and higher efficiency scores for the emotions of fear, anger, disgust and sadness at all emotion intensities compared to controls. It is also expected that the discrepancy between signal-proportion detection thresholds for the HNSSI and controls will be most pronounced at the lowest (50%) emotion intensity, as emotion identification is more challenging at this intensity level, and the HNSSI group's greater

identification sensitivity may become more evident. More generally, comparing human performance to the ideal observer performance for detecting various facial expressions will help elucidate if differences in the ease of detection are the result of differences inherent to the stimuli, or if they are attributable to variations in human higher-order processing of emotions. For example, if detecting happy faces is fundamentally easier due to information in the stimuli and unrelated to characteristics of the observer, calculating an efficiency score will eliminate enhanced detection of happiness and theoretically equate its detection threshold with all other emotion-detection thresholds.

It is also expected that the HNSSI participants will display greater accuracy in emotion identification for negative emotions, as assessed by the *unbiased hit rate* [34]. Calculating a simple hit rate is valid for measuring overall accuracy when considering all emotions combined. However, when measuring the accuracy of specific emotions, the hit rate does not consider "false alarms", or biases in the use of one or more response categories [34]. In other words, in order to measure recognition accuracy by a participant for a given emotion, the number of misses (i.e., mislabelling disgust as anger), as well as the number of false alarms (i.e., incorrectly labeling another emotion as anger) should be taken into account. Failure to do so could lead to less precise calculations of accuracy rates. Thus, in the present study the unbiased hit rate was primarily used as a measure of accuracy.

Finally, error patterns will be compared between the HNSSI and control groups to determine if biases in error patterns are evident. Any differences may further highlight emotion categorization differences between the HNSSI and control groups.

3.3 Materials and methods

Participants. The study sample is composed of young adults (between 17 to 24 years of

age) recruited from an undergraduate subject pool at the University of Ottawa. The University of Ottawa Ethics Review Board approved this research study. Approval was also granted by the Research Ethics Committee to include minors (participants under age 18) in the study without parental or guardian consent. A total of 61 participants (30 HNSSI and 31 control) were recruited. Refer to Table 1 for demographic characteristics of the sample by group. No differences were found between HNSSI and the control groups for age, sex or ethnicity. Not surprisingly, the HNSSI group had higher rates of comorbid depression, anxiety and other past diagnoses compared to the control group.

Table 1. Participant demographics.

Variable	HNSSI group (n = 30)	Control group (n = 31)	p (d.f.)
Age: years	19.00 ± 1.84	19.23± 1.56	0.61 (59)
Sex: male	10% (3)	19% (6)	0.31 (59)
Ethnicity: White	73% (22)	58% (18)	0.99 (59)
Past Diagnosis:			
Depression	37% (11)	6% (2)	<0.01 (59)
GAD	27% (8)	7% (2)	0.03 (59)
PTSD	3% (1)	3% (1)	0.99 (59)
OCD	7% (2)	0% (0)	-
Other	13% (5)	3% (1)	0.04 (59)
None	43% (13)	84% (26)	<0.01 (59)

Eligibility criteria. Pre-screening questions, administered through the recruitment website, were used to identify a subset of the population who had a HNSSI, but reported no history of a Borderline Personality Disorder (BPD) diagnosis. For inclusion in the HNSSI group, a participant had to have engaged in intentional self-inflicted injury to the surface of his or her body at least 5 times in their lifetime, with the expectation that the injury would lead to only minor or moderate physical harm (i.e., no suicidal intent). The pre-screening question read, "Have you ever intentionally self-inflicted damage to the surface of your body to cause bleeding,

bruising, or pain (e.g., cutting, burning, stabbing, and/or hitting), without the intent to kill yourself? Please note that this does not include ear piercing, tattooing, circumcision, or cultural healing rituals." Potential responses included Never; Once; 2-4 times; 5 or more times. Only individuals who responded "Never" or "5 or more times" were screened in to participate as controls or HNSSI respectively. Exclusion criteria for both the NSSI and control groups included a self-reported diagnosis of Borderline Personality Disorder. The pre-screening question read, "Have you ever been diagnosed with Borderline Personality Disorder? Yes/No." Additionally, individuals who reported to have engaged in NSSI "5 or more times" on the pre-screening question but failed to report NSSI behavior in either of the administered NSSI questionnaires (see measures below) were also excluded from the study. Furthermore, administered questionnaires were only validated for research purposes in English, therefore, participants were excluded if they are unable to read and understand English.

All HNSSI participants reported having engaged in intentional self-inflicted injury to the surface their body at least 5 times or more within their lifetime. The majority of HNSSI reported thinking about self-injuring within the past month 60% (n = 18), and 17% (n = 5) had actually engaged in the behavior within the month. Additionally, 70% (n = 21) of the HNSSI participants reported thinking about self-injuring within the past 6 months and half the sample reported actually engaging in self-injuring within that timeframe 50% (n = 15).

3.4 Measures

Socio-demographic questionnaire. This demographic questionnaire collected standard participant information such as age, gender, primary language, ethnicity, education, and current or past mental health diagnosis. This information was used to descriptive compute statistics of the NSSI and control groups.

The Ottawa Self Injury Inventory. This questionnaire (OSI - Functions 1.1) assessed self-injurious behaviours and their functions. This scale provided cumulative scores for the subscales of internal emotional regulation, external emotional regulation, social influence, and sensation seeking [35].

The Inventory of Statements About Self-Injury. This questionnaire (ISAS - Section II) assessed an individual's reasons for engaging in self-injurious behaviours. This scale provided a cumulative score for subscales of interpersonal functions of NSSI (i.e., autonomy, interpersonal boundaries, interpersonal influence, peer-bonding, self-care, revenge, sensation seeking, and toughness) and Intrapersonal Functions (i.e., affect-regulation, anti-dissociation, anti-suicide, marking distress, self-punishment) of NSSI [36].

3.5 Procedure

Consent. Prior to the task, and after having the study described to them verbally, participants read and signed an informed consent form.

Questionnaires. All participants completed the socio-demographic questionnaire. Two additional questionnaires, the Ottawa Self Injury Inventory (OSI) and the Inventory of Statements About Self-Injury (ISAS), were completed by the HNSSI group only. If any HNSSI participants reported suicidal ideation or severe harm, by endorsing Q3, Q4, Q5, or Q6 on the OSI, a suicide protocol was implemented. Additionally, the NSSI participants were all given a list of resources in the event they wished to seek further psychological support. Questionnaires were administered prior to starting the experiment to identify any participants actively engaged in suicidal ideation, and to administer the appropriate suicidal assessment protocol to these vulnerable participants. Moreover, approximately 20 minutes elapsed between completion of the questionnaires and the beginning of study administration to mitigate any emotional arousal

arising from completing the questionnaires that might otherwise have affected participant performance on the study.

Stimuli. Participants were presented with static grey scale images of faces expressing one of six emotions (happiness, sadness, anger, fear, disgust or surprise) at varying degrees of emotion intensity (50%, 75% or 100%). Stimuli were masked with varying degrees of fractal luminance noise. The energy vs. spatial frequency function of the fractal noise matched that of the face image. The amount of fractal noise, added to the otherwise noiseless stimuli, effectively controlled the difficulty of the task (i.e., “signal-to-noise ratio”), such that more noise destroyed available information or, equivalently, corrupted the signal and increased the difficulty of emotion detection. As previously mentioned, the contrast of the image (root mean square) was kept constant regardless of how the proportion of signal and noise energy was titrated.

Although signal proportion (i.e., the relative amount of signal and noise contributing to the stimulus) varied from trial to trial, the signal and noise components always had identical so-called pink – or "fractal" – spectral profiles where contrast energy is concentrated at lower spatial frequencies on a per-frequency basis, but distributed equally across constant-octave frequency bands. A total of 58 identities (29 male and 29 female) from the Karolinska Directed Emotional Faces [37] database were used for this task; however, each participant was only tested with a single identity. This was done to avoid interactions with facial identification. An oval window was created around each face to best approximate its contours. The window was then smoothed and window edges were slightly blurred by applying a low-pass filter to produce a gradual transition between the face image and the gray background (Fig 1). There were 58 identities x 6 emotions x 3 emotional intensities for a total of 1044 face images.

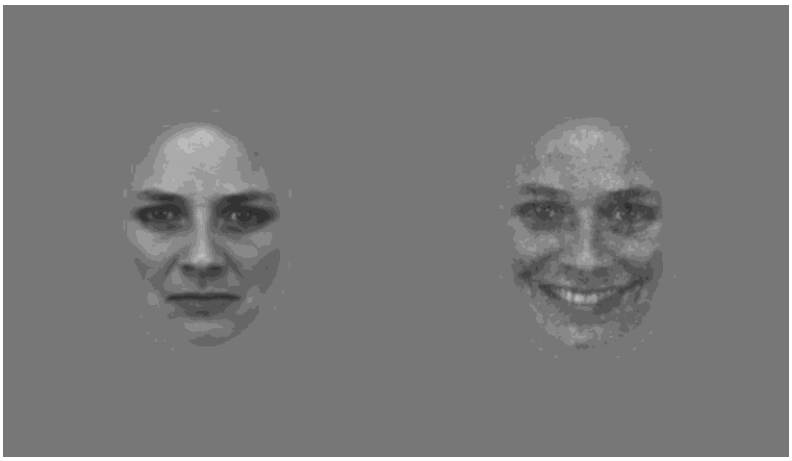


Fig 1. Two examples of stimulus used for emotion categorization task. The first image is an example of a disgusted face at 50% intensity without any fractal noise. The second image is an example of a happy face at 100% intensity embedded in fractal noise intended to partially mask the image. These images were modified from the Karolinska Directed Emotional Faces database, with "AF01DIS" and "AF01HAS" displayed. Reprinted from Lundqvist, D., Flykt, A., & Öhman, A. under a CC BY license, with permission from the Karolinska Institutet original copyright (1998).

To introduce noise into the image, the face and the fractal noise were added linearly to create the final stimulus. The amount of signal (face image) relative to the noise is expressed as a signal proportion, or Var(Signal)/(Var(Signal) + Var(Noise)) that varied between 0 (noise only) to 1 (signal only). Note that the alternative metric for signal-to-noise ratio (SNR) previously referred to is simply Var(Signal)/Var(Noise), but signal proportion was favoured largely as a matter of convenience. The signal proportion was expressed in *Log2* units because human performance tends to be linear with respect to the logarithm of signal proportion. This means that a signal-only stimulus (no noise) has a signal-proportion of *Log2* (1) = 0, an equal mixture of signal and noise has a signal-proportion of *Log2* (0.5) = -1, and a noise-only stimulus would have a proportion of *Log2* (0) = -∞. However, a noise only stimulus is uninformative for this

task, as there is no face information for the participant to detect and was not used as a stimulus.

Human performance of emotion recognition task. Participants began the computer task with practice trials in which they were asked to identify each of the six basic emotions described by Ekman [38] (happiness, sadness, anger, fear, disgust and surprise) through a computer-based 6-alternative forced-choice (6AFC) procedure. A total of six practice trials were presented, one for each of the six emotions presented during the experiment. These practice images were presented at full emotion intensity and without fractal noise to facilitate learning of the corresponding keyboard responses. These practice trials not only helped the participant associate the emotions with the correct keyboard responses, but also helped to familiarize them with the various emotion expressions of their selected stimulus identity.

Once the practice trials were completed, participants began the experimental trials. On each trial, a participant was presented with a face image. The identity of the model presented in the image did not change for a given subject. That is, each subject was tested on a single individual model. The image varied in emotion intensity (50%, 75%, or 100%), emotion category (sad, happy, angry, afraid, surprised or disgusted), and degree of fractal noise. The design matrix of the experiment included 6 emotions X 3 intensities X 50 repetitions for a total of 900 trials. Eighteen randomly interleaved staircases, one for each emotion x intensity, ran in parallel such that each staircase updated the stimulus' signal-proportion on each trial to converge toward a threshold in a one-up-one-down fashion. For example, if a participant correctly categorized the stimulus "75% sadness" at a given signal-proportion, then the degree of fractal noise obscuring the image was increased in the next presentation of that stimulus; conversely, if they misidentified the emotion, the degree of fractal noise obscuring the image decreased during the next presentation of that stimulus (ie, a one-up one-down procedure). By definition, the one-

up one-down procedure converges on the 50% correct point and clusters observations sufficiently near the more theoretically informative performance level in a 6AFC task, 58.3% which is halfway between chance (1/6 = 16.7%) and ceiling (100%). Once data were gathered, a separate psychometric function was fitted to each unique combination of emotion and intensity, whereby signal-proportion thresholds were computed corresponding to 58.3% performance.

Ideal observer performance of emotion recognition task. In addition to gathering data from human observers, an Ideal Observer Algorithm also performed the task. This was a computer program that performed the same task as human observers but did so by making ideal use of the visual information available in the images. Specifically, the Ideal Observer program worked as follows: For each trial, the algorithm searched through the database of all the images used in the experiment to find the best match with the image presented in the trial. The best match was determined by calculating the correlation between pixel values in the presented stimulus image and pixel values in each image in the database. In noiseless conditions, where the pixel values in the image presented for a trial are identical to the pixel values in the image from the database yield a perfect correlation ($r = 1$, i.e. the two images are identical) and lower r values for all other database images, thus performing the task perfectly with 100% accuracy.

The next step was to add noise to the images. In a similar fashion to what was done with human observers, variable amounts of fractal noise were added to the images, until the ideal observer's performance fell to the 58.3% accuracy threshold. The amount of stimulus signal needed to do this was the variable of interest and was labeled the signal proportion threshold. In theory, this threshold represents the minimum amount of signal (or, equivalently, the maximum amount of noise) that any perceptual system could tolerate in doing the task. However, it should be noted that an Ideal Observer is only an ideal *observer,* not an ideal thinker or performer. That

is, the IO makes perfect use of all the information in the stimulus, but nothing else. It has no knowledge, for instance, of shape-from-shading, or average facial structure, or 3D shape. Thus, it was possible for a human to outperform the ideal observer if the human's higher-order knowledge allowed them to use more than simply perceptual information.

3.6 Data Analysis

Power analysis. In order to ensure sufficient power, a priori power analysis was used to determine the sample size required per group. In a study that examined sensitivity to facial expressions of emotion in BPD using static pictures of facial affect [39], a large Cohen's d effect size of 0.8 (Effect size f = 0.4) was reported for greater sensitivity across the six emotions examined (anger, disgusts, fear, happiness, sadness, surprise) [40]. However, there is little to no available literature to guide an estimate of effect size for thresholds or efficiency scores in a comparable population. Our efficiency scores are a ratio calculation, and thus prone to greater error, so a more conservative estimate of effect size was selected as a prudent measure. Assuming a small effect size f = 0.10 (Cohen's d of 0.2), power of 0.8 with α of 0.05 to compute sample size using GPower 3.1.9.2 for an ANOVA Repeated-Measures, within-between interaction of a 2 (NSSI and Control) X 6 (happy, sad, anger, fear, disgust, and surprise) X 3 (50%, 75%, 100%) design, the estimated total sample size is 56 participants. Hence, the total collected sample size of 61 (30 NSSI and 31 Control) is likely adequate for the interpretation of any non-significant findings.

3.7 Results

Threshold and efficiency. Threshold and efficiency scores were analyzed using planned contrasts [41] to test the above stated hypotheses. In order to obtain the error terms for the planned contrasts [41], the data were subjected to mixed factorial ANOVAs, with group (NSSI

and control) as the between-subjects factor, and stimulus emotion (sad, disgusted, surprised, fearful, angry and happy faces) and intensity (50% intensity, 75% intensity and 100% intensity) as the within-subjects factors (Table A and Table B in S1 File).

Due to the nature of participants' responses and the minimum number of trials presented per emotion, calculating a threshold and efficiency score for all participants was not possible, resulting in an 8.4% loss of data for both variables. The chi-squared statistic referred to as Little's MCAR test was used to test whether values were missing completely at random [42]. The MCAR test used for the missing threshold values resulted in χ^2 (462, N = 61) = 507.72, p = .070, and χ^2 (462, N = 61) = 498.50, p = .117 for the missing efficiency values, indicating that data were indeed missing at random (i.e., no identifiable pattern existed in the missing values). This finding means that our data meet the assumptions for the application of imputation methods to fill in missing data.

To maximize available data, the method of data imputation known as Multiple Imputation (MI) was selected as an appropriate technique for addressing the missing values in this circumstance. MI is superior to a single imputation because it makes repeated draws from a model of the distribution of variables that have missing values to create several complete datasets. These datasets can then be analyzed in parallel. Variations in outcome between the datasets reflect uncertainty from the imputation process itself [43]. As suggested by White, Royston, and Wood [44], the number of imputations should be greater than or equal to the percentage of missing observations to ensure an adequate level of reproducibility. Since the dataset had 8.4% missing data for both variables, 9 imputations were selected to produce a total of 9 imputed datasets for each variable in accordance with this suggestion. The MI procedure was carried out with IBM SPSS Statistics 24. Prior to imputation, the dataset was assessed for

univariate outliers. Due to the ambiguity of the sample size created by using the multiple imputation procedure, a standard z-score cut-off of above 2.5 *SD*, was used to identify outliers, which were winsorized by having their scores changed to the closest non-outlying score [45,46]. Overall, 3.01% of threshold scores and 2.28% of efficiency scores were considered univariate outliers and winsorized.

Typically, multiple imputation combines output across all imputed datasets, and the results are pooled for interpretation, which also produces confidence intervals. However, because no explicit rules have been defined for pooling *F*-tests of (repeated-measures) analysis of variance [47] and this function is not available for an ANOVA calculation in IBM SPSS Statistics 24, the data for the median error term of the 9 imputed datasets was used to obtain the mean squared value for the contrast calculations. These calculations were also repeated with the lowest and highest mean squared value produced by the multiply imputed datasets to create an upper and lower bound for the analysis, and to act as a confidence interval.

Considering a relatively large number of planned contrasts (18), and to account for the increased probability of making a type I error, the alpha level was adjusted by using a *Bonferroni approach* as suggested by Rosenthal and Rosnow [41] at $\alpha = 0.05/18 = 0.003$. Given that group sample sizes differed slightly, the harmonic mean between sample sizes across both groups was used in all contrast analyses [41]. Effect sizes for the contrasts were also measured and reported as *r* [41]. Values of *r* ranging from 0.10, 0.30 and 0.5 are considered small, medium and large effect sizes respectively [41]. The results of the contrast analyses are reported here and the ANOVA tables are presented in the Appendix.

Emotion detection scores for threshold and efficiency. Results from the planned contrasts showed no consistent evidence of group differences for threshold scores between the

HNSSI and control group (see Table 2). This result remained consistent when testing contrasts at the upper and lower bound of the mean squared value obtained for the 9 imputed datasets. That is, regardless of whether a strict or liberal criterion was applied to our contrast analyses, the two groups displayed comparable threshold scores for each emotion and across all intensities presented. We note that this same result is obtained whether one applies the Bonferroni correction or not, showing that it is not the result of overly conservative statistical procedures.

Table 2. Results of planned comparisons for threshold.

Emotion	*Intensity*	*NSSI (Mean ± SE)*	*Control (Mean ± SE)*	*Effect Size (r)*	*P*
Fear	50%	0.443 ± 0.045	0.382 ± 0.034	0.098	0.111
	75%	0.321 ± 0.039	0.287 ± 0.022	0.062	0.313
	100%	0.286 ± 0.037	0.239 ± 0.020	0.088	0.156
Anger	50%	0.241 ± 0.019	0.243 ± 0.019	0.003	0.961
	75%	0.188 ± 0.015	0.203 ± 0.017	0.028	0.645
	100%	0.167 ± 0.016	0.193 ± 0.027	0.048	0.441
Disgust	50%	0.360 ± 0.037	0.406 ± 0.035	0.075	0.227
	75%	0.302 ± 0.037	0.352 ± 0.040	0.093	0.133
	100%	0.260 ± 0.035	0.310 ± 0.039	0.091	0.138
Happy	50%	0.148 ± 0.011	0.173 ± 0.011	0.040	0.513
	75%	0.099 ± 0.004	0.106 ± 0.007	0.012	0.849
	100%	0.075 ± 0.006	0.085 ± 0.006	0.019	0.763
Sad	50%	0.225 ± 0.019	0.201 ± 0.016	0.038	0.536
	75%	0.174 ± 0.012	0.172 ± 0.012	0.003	0.960
	100%	0.166 ± 0.013	0.165 ± 0.010	0.002	0.965
Surprise	50%	0.364 ± 0.042	0.325 ± 0.038	0.063	0.308
	75%	0.236 ± 0.023	0.176 ± 0.015	0.111	0.071
	100%	0.168 ± 0.016	0.136 ± 0.013	0.059	0.338

Note. Mean and SE are calculated based on the average of the 9 imputed datasets. Effect size and p-values are calculated using the median mean square error and df of the 9 imputed datasets.

Results from the planned contrasts for efficiency also showed no consistent evidence of group differences between the HNSSI and control group (see Table 3). While there were differences at the 0.05 level for 75% happy and 50% sad stimuli, the effect sizes were small and these effects were not consistent across intensities, nor across negative emotions. Moreover, the Bonferroni correction resulting in an adjusted α level of $p < 0.003$ made it such that these results are in fact non-significant. Again, the same pattern of results remained consistent when testing contrasts at the upper bound of the mean squared value for the 9 imputed datasets, and the lower bound also did not reach a significance level of $p < 0.003$.

Table 3. Results of planned comparisons for efficiency.

Emotion	*Intensity*	*NSSI(Mean ± SE)*	*Control(Mean ± SE)*	*Effect Size (r)*	*P*
Fear	50%	0.473 ± 0.072	0.586 ± 0.066	0.064	0.190
	75%	0.464 ± 0.056	0.436 ± 0.065	0.016	0.742
	100%	0.389 ± 0.052	0.357 ± 0.045	0.007	0.924
Anger	50%	0.753 ± 0.112	0.687 ± 0.097	0.038	0.445
	75%	0.578 ± 0.062	0.617 ± 0.075	0.022	0.646
	100%	0.635 ± 0.135	0.471 ± 0.053	0.040	0.625
Disgust	50%	0.603 ± 0.080	0.477 ± 0.041	0.071	0.149
	75%	0.451 ± 0.042	0.443 ± 0.038	0.004	0.928
	100%	0.397 ± 0.034	0.344 ± 0.042	0.013	0.873
Happy	50%	1.048 ± 0.095	0.995 ± 0.099	0.030	0.541
	75%	0.830 ± 0.057	1.007 ± 0.079	0.099	0.042
	100%	0.914 ± 0.081	0.970 ± 0.096	0.013	0.868
Sad	50%	0.971 ± 0.092	1.213 ± 0.124	0.136	0.005
	75%	0.731 ± 0.067	0.719 ± 0.063	0.007	0.888
	100%	0.533 ± 0.049	0.525 ± 0.046	0.002	0.981
Surprise	50%	0.490 ± 0.083	0.494 ± 0.058	0.002	0.961

75%	0.465 ± 0.070	0.469 ± 0.057	0.002	0.967
100%	0.422 ± 0.055	0.544 ± 0.095	0.030	0.718

Note. Mean and SE are calculated based on the average of the 9 imputed datasets. Effect size and p-values are calculated using the median mean square error and df of the 9 imputed datasets.

Emotion recognition accuracy at various intensities. Participants' accuracies for recognizing emotions at 50%, 75% and 100% intensities are reported in Table 4. The unbiased hit rate [34] was calculated for each of the six emotion expressions to measure recognition accuracy. This index was selected because it is a more appropriate measure than hit rate, due to the fact that it accounts for participants' non-uniform use of other emotion categories and thus mitigates response bias. The datasets were screened for assumptions and assessed for univariate outliers. Since no missing data were present in the accuracy scores, and a full dataset was analyzed, an outlier was defined as having a z-score above 2.43 *SD* in accordance with the Van Selst and Jolicoeur [48] recommendations for the above stated sample size, and outliers were winsorized by having their scores changed to the closest non-outlying score [45-46]. Overall, 1.3% of the NSSI data and 3.2% of the control data were considered univariate outliers and winsorized. Normality was assessed using Shapiro-Wilk's test (p <.05), and skewness and kurtosis scores fell within a ±2 criterion range [49-50]. In the NSSI group, non-normality was detected for fear and disgust at 50%, 75% and 100% intensity. In the control group, non-normality was detected for fear at 50%, 75% and 100% and anger and disgust at 50%. Applying an Arcsine transformation did not improve the distribution and we therefore opted to continue with the analysis using the non-transformed data.

Table 4. Unbiased hit rate for recognition of facial expressions presented at 50%, 75% and 100% intensity.

Emotion	*Intensity*	*NSSI (Mean ± SE)*	*Control (Mean ± SE)*	*Effect Size (r)*	*p*
Fear	50%	0.151 ± 0.023	0.189 ± 0.022	0.115	0.037

	75%	0.194 ± 0.024	0.265 ± 0.023	0.211	< 0.001*
	100%	0.212 ± 0.023	0.273 ± 0.023	0.182	< 0.001*
Anger	50%	0.272 ± 0.012	0.253 ± 0.014	0.058	0.295
	75%	0.281 ± 0.011	0.264 ± 0.018	0.052	0.349
	100%	0.286 ± 0.010	0.274 ± 0.017	0.036	0.506
Disgust	50%	0.250 ± 0.025	0.263 ± 0.020	0.039	0.473
	75%	0.251 ± 0.023	0.244 ± 0.023	0.021	0.699
	100%	0.257 ± 0.020	0.252 ± 0.025	0.015	0.783
Happy	50%	0.361 ± 0.012	0.367 ± 0.015	0.018	0.741
	75%	0.356 ± 0.013	0.356 ± 0.013	0.000	1.000
	100%	0.362 ± 0.012	0.363 ± 0.013	0.003	0.956
Sad	50%	0.215 ± 0.012	0.244 ± 0.014	0.088	0.110
	75%	0.255 ± 0.014	0.288 ± 0.013	0.100	0.069
	100%	0.290 ± 0.015	0.297 ± 0.015	0.021	0.699
Surprise	50%	0.313 ± 0.024	0.293 ± 0.019	0.024	0.659
	75%	0.340 ± 0.021	0.332 ± 0.019	0.019	0.776
	100%	0.346 ± 0.020	0.335 ± 0.017	0.033	0.544

* Significant at the $p < 0.003$ level

In order to obtain the error terms for the planned contrasts [41] the data were subjected to mixed factorial ANOVAs, with group (history of non-suicidal self-injury group and control group) as the between-subjects factor, and stimuli type (sad, disgusted, surprised, fearful, angry and happy faces) and intensity (50%, 75%, and 100%) as the within subject factors (S7 Table).

As with our previous analyses, a relatively large number of planned contrasts (18), were performed, so to decrease the probability of making a type I error, the alpha level was again adjusted with the *Bonferroni approach* as suggested by Rosenthal & Rosnow [41] at $\alpha = 0.05/18 = 0.003$. Effect sizes for the contrasts were also measured and reported as *r* [41]. Results from

these planned contrasts for unbiased hit rate show that the HNSSI group were less accurate at identifying fear at the 75% and 100% intensity level. This trend was also observed in the fear accuracy scores at 50% intensity. Accuracy scores obtained through hit rate were also calculated and compared between groups, which showed the same pattern of results consistent with those obtained from the unbiased (S4 and S5 Tables). There were no other consistent or significant results observed for other emotions or across other intensity levels.

Group differences in error patterns. The next analysis was intended to further examine the nature of group differences by assessing the types of errors made by each group when misidentifying an emotion. Accordingly, a confusion matrix analysis with the number of errors was performed to determine if participants were mistaking one emotion for another as each emotion was presented at the three intensities.

Data were first assessed by the Shapiro-Wilk test, which is most appropriate for smaller sample sizes, to assess normality (S6 Table). Although many of the error responses appeared non-normally distributed according to this conservative statistic, the majority of data fell within a ±2 criterion range for skewness and kurtosis (S7 Table) and were thus considered normally distributed [49-50]. Visual inspection of the distributions revealed that responses were similarly slightly skewed in a positive direction. Additionally, data were assessed for outliers as defined by having a z-score above 2.43 *SD* in accordance with the sample size [48]. For each of the emotions presented, 3.1% of the NSSI data and 4.3% of the control data were considered univariate outliers for fear; 2.9% of the NSSI data and 3.2% of the control data for anger; 4% of the NSSI data and 3.7% of the control data for disgust; 2.2% of the NSSI data and 2.6% of the control data for happy; 2.4% of the NSSI data and 2.6% of the control data for sad; and 3.1% of the NSSI data and 1.5% of the control data for surprised were considered univariate outliers.

These outliers were winsorized by having their scores changed to the closest non-outlying score [45-46].

Error analysis at 50%, 75% and 100% emotion intensity. Error pattern analysis for each of the six emotions across intensities showed occasional significant results, however, few consistent patterns were observed. Of note, the HNSSI group was significantly less likely to confuse sad expressions with the emotion of surprise at 50% and 75% intensity compared to the control group, a statistically significant difference of $t(59) = -2.24$, $p = .019$, $d = 0.62$, and $t(59) = -2.67$, $p = .009$, $d = 0.69$ respectively. When surprise was presented at 100% intensity, the reverse was true, as the HNSSI group was significantly less likely to mistake surprise with the emotion of sadness compared to controls, a statistically significant difference of $t(59) = -2.43$, $p = .018$, $d = 0.62$.

Additionally, a pattern was noted between the emotions of anger and happiness, with the HNSSI group being significantly more likely to mistake angry expressions at 50% intensity for expressions of happiness compared to controls, a significant difference of $t(49.82) = 2.20$, $p = .033$, $d = 0.57$. The HNSSI group was also more likely to mistake happy expressions at 100% intensity for the emotion of anger compared to controls, a significant difference of $t(59) = 2.19$, $p = .033$, $d = 0.56$. When collapsed across emotion intensity, some of these patterns remained. For example, the HNSSI group was significantly less likely to confuse sad expressions with the emotion of surprise and significantly more likely to confuse angry expressions with the emotion of happiness, a statistically significant difference of $t(59) = -2.31$, $p = .024$, $d = 0.56$ and $t(59) = 2.18$, $p = .033$, $d = 0.59$ respectively. Refer to the Supplemental Information for a full error analysis summary (S1-S9 Figures).

3.8 Discussion

The present study investigated if HNSSI participants showed advantages in the signal-proportion threshold required for accurate emotion categorization compared to control participants. Furthermore, participants' performance was subjected to an Ideal Observer analysis to determine their efficiency ratio, which factors out variation in information content to yield a pure measure of an observer's performance. This model used a simple algorithm to calculate the dot product of the stimulus image with each potential available image to identify the maximally likely match, thus optimizing the available image information. Results from this study revealed no differences between HNSSI and control participants for signal-proportion detection threshold or efficiency ratios for any of the emotions presented at all three intensities. These results were obtained despite adequate samples sizes determined by a priori power analyses, sufficient power, and focused statistical analyses. No observed differences between groups may imply that, for a lower level of visual analysis, a history of engaging in NSSI behaviour has no effect on emotion detection thresholds. Likewise, having engaged in NSSI behaviours does not appear to relate to a greater efficiency in detecting emotional faces, as calculated through ideal observer analysis. These results are in contrast to the results obtained by Ziebell et al., [30], who found advantages for a HNSSI group on an emotion recognition task, such as lower emotion intensity thresholds for negative emotions. One could argue that these advantages may be the result of the more dynamic and richer stimuli (moving, coloured) used, which more realistically mimicked in vivo social interactions compared to the static, grey-scale images distorted by fractal noise, which were used in the current study. These contradicting results may also suggest that differences exist at a higher order level of visual and cognitive processes (such as prior knowledge or memory) on this perceptual task.

To date, two studies have examined facial emotion recognition capabilities in individuals exhibiting NSSI behaviours. An analogous study that used a morphing emotion paradigm also found no group differences in the intensity of emotion required for correct participant categorization of happy, sad, angry, disgusted, fearful, or neutral facial expressions, nor did they see any group differences in the accuracy of emotion recognition [51]. However, this study also used sad and neutral mood induction to evoke specific mood states before presenting the stimuli, which was not the case for the current research or the Ziebell et al., [30] study. Seymour et al. [52], who also used static images for their experiment, found that adolescents engaging in NSSI made more errors on child fearful and adult sad face recognition compared to the typically developing controls.

According to Linehan's biosocial theory [53], the emotion dysregulation observed in individuals with Borderline Personality Disorder (BPD) is hypothesized to be a consequence of their greater emotional sensitivity. Although NSSI is frequently a symptom of BPD, NSSI and BPD can also occur separately and be conceptualized along a continuum with some phenomenological overlap [54-56]. The research findings on emotion recognition capabilities in adolescents with BPD are inconsistent and range from no differences [57-58], to decreased sensitivity to some facial emotions [59]. Studies examining adult participants with BPD are likewise inconsistent, with greater sensitivity to facial expressions reported [39] in addition to no differences [60]. Mitchell et al.'s [40] review of emotion recognition in BPD concluded no significant recognition impairments in BPD compared to controls for any negative emotions, despite the various methodological differences between studies. However, only a minority of individuals engaging in NSSI behavior meet the criteria for BPD [51, 61, 62]. These divergent results within and between BPD and NSSI studies, as well as differences in the studied

populations, make it unclear as to what would be expected regarding emotion recognition capabilities from individuals who have a history of engaging in NSSI in the absence of BPD.

In the current study, differences in accuracy scores were observed, as assessed through the unbiased hit rate, which showed decreased accuracy for the HNSSI group in response to correctly categorizing fearful faces at 75% and 100% intensity. This trend was also observed at the lowest intensity of fear at 50%, which came out slightly above the conservatively adjusted p-value to accommodate for the multiple comparisons. These results appear in line with the observations made by Seymour et al., [52] who found that inpatient adolescents engaged in NSSI made more emotional face recognition errors for child fearful faces compared to typically developing controls. Among other reasons, theoretical models of NSSI postulate that engaging in NSSI may be used by individuals as a means for social communication to gain attention or influence other's behavior [63-64]. Moreover, other empirical studies have found that individuals who engage in NSSI display social communication skills deficits such as impaired social problem-solving, poor verbal skills, and alexithymia [11,19, 65]. Hence it is possible that individuals who have engaged in NSSI may indeed display deficits in the critical social communication skill of accurate emotional face recognition. Deficits in emotional face identification could also contribute to the mechanism by which feelings of social isolation develop and perpetuate the cycle of self-harm. If an individual who has engaged in NSSI misinterprets their surrounding social cues, such as fearful faces as our data suggests, then they may attribute incorrect emotional responses to those around them, leading to further social isolation and emotional activation. Research conducted by Marsh et al. [66] has indicated that the ability to recognize fearful facial expressions can predict prosocial behavior. Hence, a misinterpretation of fearful faces is likely to contribute to the emotional disturbances, inadequate

social behavior, and less adaptive social problem-solving skills often observed in adolescents who engage in NSSI behavior [67, 65]. Of course, further empirical investigation is needed to help develop and validate this theory. A discrepancy in emotion identification abilities of HNSSI individuals may also exist between their perceptions of dynamic images versus the static images presented in the current study. Moreover, the current study was conducted with individuals who reported a history of engaging in NSSI and were not necessarily actively engaged in self-injury at the time of study. Examining this population, although unique and previously unstudied, may also provide weaker results compared to the results of the aforementioned studies that investigated adolescents actively engaged in self-injury.

While an error pattern analysis across the six emotions provided some occasional significant results, few consistent patterns were clearly observed. Interesting observations were noted in errors made between sad and surprised expressions. In particular, HNSSI participants appeared significantly less likely to confuse sad facial emotions with surprise compared to control, particularly when errors were collapsed across the three emotion intensities. However, the clinical relevance of this finding and how it relates to HNSSI emotion perception remains somewhat unclear. A more easily interpreted finding is the HNSSI group's tendency to confuse angry expressions at low intensities with the emotion of happy, and happy expressions at a high intensity with the emotion of anger compared to controls. After collapsing across emotion intensity, the HNSSI group was significantly more likely to mistake angry faces for happy expressions. Confusion between positive and negative emotions, particularly happy and angry expressions, could easily lead to inappropriate responses in social situations. When social exchanges require the interpretation of subtle emotional cues, individuals who mistakenly perceive the valence of emotions may be particularly taxed when required to navigate

emotionally charged situations. Work by Demers et al., [21], shows results consistent with the idea that adolescents engaged in NSSI show reduced vigilance to positive social information. This result, in combination with our study results, lends further support to the notion that individuals who have engaged in NSSI experience difficulty evaluating interpersonal situations [20].

In summary, this study found no significant group differences between HNSSI and controls participants regarding signal-proportion thresholds or efficiency scores. Results did, however, find decreased accuracy of HNSSI participants for recognizing fearful expressions and an increased likelihood of mistaking angry faces for happy expressions compared to controls. These findings provide further support for the literature that proposes deficits in accurate emotion perception of static images by individuals who have engaged in NSSI behaviours.

3.9 References

1. Klonsky, E. D., Muehlenkamp, J., Lewis, S. P., & Walsh, B. Nonsuicidal self-injury advances in psychotherapy evidence-based practice. Toronto, ON: Hogrefe Publishing; 2011
2. Nock, M. K. Self-injury. Annual Review of Clinical Psychology. 2010; 6, 339-363. doi: 10.1146/annurev.clinpsy.121208.131258
3. Hawton, K., Saunders, K. E., & O'Connor, R. C. Self-harm and suicide in adolescents. The Lancet. 2012; 379(9834), 2373-2382. doi:10.1016/S0140-6736(12)60322-5
4. Swannell, S. V., Martin, G. E., Page, A., Hasking, P., & St John, N. J. Prevalence of nonsuicidal self-injury in nonclinical samples: Systematic review, meta-analysis and meta-regression. Suicide and Life-Threatening Behaviour. 2014. 44, 273-303. doi: 10.1111/sltb.12070
5. Briere, J., & Gil, E. Self-mutilation in clinical and general population samples: Prevalence, correlates, and functions. American Journal of Orthopsychiatry. 1998; 68(4), 609-620.
6. Cloutier, O.F., Martin, J., Kennedy, A., Nixon, M. K., & Muehlenkamp, J. J. (2010). Characteristics and co-occurrence of adolescent non-suicidal self-injury and suicidal behaviours in pediatric emergency crisis services. Journal of Youth and Adolescence, 39(3), 259-269. doi: 10.1007/s10964-009-9465-1
7. Darche, M. A. Psychological factors differentiating self-mutilation and non-self-mutilation adolescent inpatient females. Psychiatric Hospital, 1990; 21(1), 31– 35.
8. Hamza, C. A., Stewart, S. L., & Willoughby, T. Examining the link between nonsuicidal self-injury and suicidal behavior: A review of the literature and an integrated model. Clinical Psychology Review. 2012; 32(6), 482-495. doi: 10.1016/j.cpr.2012.05.003
9. Klonsky, E. D., May, A. M., & Glenn, C. R. The relationship between non-suicidal self-injury and attempted suicide: Converging evidence from four samples. Journal of Abnormal Psychology. 2013; 122(1), 231. doi: 10.1037/a0030278
10. Tuisku, V., Kiviruusu, O., Pelkonen, M., Karlsson, L., Strandholm, T., & Marttunen, M. Depressed adolescents as young adults–predictors of suicide attempt and non-suicidal self-injury during an 8-year follow-up. Journal of Affective Disorders, 2014; 152, 313-319. doi: 10.1016/j.jad.2013.09.031
11. Jacobson, C. M., & Gould, M. The epidemiology and phenomenology of non-suicidal self-injurious behavior among adolescents: A critical review of the literature. Archives of Suicide Research, 2007; 11(2), 129-147. doi: 10.1080/13811110701247602
12. Klonsky, E. D. The functions of deliberate self-injury: A review of the evidence. Clinical Psychology Review, 27(2), 226-239. 2007; doi: 10.1016/j.cpr.2006.08.002
13. Klonsky, E. D. The functions of self-injury in young adults who cut themselves: Clarifying the evidence for affect-regulation. Psychiatry Research, 2009; 166(2-3), 260-268. doi: 10.1016/j.psychres.2008.02.008
14. Gratz, K. L., & Roemer, L. Multidimensional assessment of emotion regulation and dysregulation: Development, factor structure, and initial validation of the difficulties in

emotion regulation scale. Journal of Psychopathology and Behavioral Assessment, 2004; 26(1), 41-54. doi: 10.1007/s10862-008-9102-4.
15. Gross, J. J. Emotion regulation: Affective, cognitive, and social consequences. Psychophysiology, 2002; 39(3), 281-291. doi: 10.1017.S0048577201393198
16. Mennin, D. S., Holaway, R. M., Fresco, D. M., Moore, M. T., & Heimberg, R. G. Delineating components of emotion and its dysregulation in anxiety and mood psychopathology. Behavior Therapy, 2007; 38(3), 284-302. doi: 10.1016/j.beth.2006.09.001
17. Thompson, R. A. Emotion regulation: A theme in search of definition. Monographs of the Society for Research in Child Development, 1994; 59(2-3), 25-52. doi: 10.2307/1166137
18. Bentley, K. H., Nock, M. K., & Barlow, D. H. The four-function model of nonsuicidal self-injury: Key directions for future research. Clinical Psychological Science, 2014; 2(5), 638-656. doi: 10.1177/2167702613514563
19. Nock, M. K. Actions speak louder than words: An elaborated theoretical model of the social functions of self-injury and other harmful behaviors. Applied and Preventive Psychology, 2008; 12(4), 159-168. doi: 10.1016/j.appsy.2008.05.002
20. Tatnell, R., Hasking, P., Newman, L., Taffe, J., & Martin, G. Attachment, emotion regulation, childhood abuse and assault: examining predictors of NSSI among adolescents. Archives of Suicide Research, 2017; 21(4), 610-620. doi: 10.1080/13811118.2016.1246267
21. Demers, L. A., Schreiner, M. W., Hunt, R. H., Mueller, B. A., Klimes-Dougan, B., Thomas, K. M., & Cullen, K. R.. Alexithymia is associated with neural reactivity to masked emotional faces in adolescents who self-harm. Journal of Affective Disorders, 2019; 249, 253-261.doi: 10.1016/j.jad.2019.02.038
22. Yoo, S. H., Matsumoto, D., & LeRoux, J. A. The influence of emotion recognition and emotion regulation on intercultural adjustment. International Journal of Intercultural Relations, 2006; 30(3), 345-363. doi: 10.1016/j.ijintrel.2005.08.006
23. Grynberg, D., Chang, B., Corneille, O., Maurage, P., Vermeulen, N., Berthoz, S., & Luminet, O. Alexithymia and the processing of emotional facial expressions (EFEs): systematic review, unanswered questions and further perspectives. PloS ONE, 2012; 7(8), e42429. doi: 10.1371/journal.pone.0042429
24. Troisi, A., Delle Chiaie, R., Russo, F., Russo, M. A., Mosco, C., & Pasini, A. Nonverbal behavior and alexithymic traits in normal subjects: Individual differences in encoding emotions. Journal of Nervous and Mental Disease, 1996; *184*(9), 561-566.
25. Cook, R., Brewer, R., Shah, P., & Bird, G. Alexithymia, not autism, predicts poor recognition of emotional facial expressions. Psychological Science, 2013; 24(5), 723-732. doi: 10.1177/0956797612463582
26. Kätsyri, J., Saalasti, S., Tiippana, K., von Wendt, L., & Sams, M. Impaired recognition of facial emotions from low-spatial frequencies in Asperger syndrome. Neuropsychologia, 2008; 46(7), 1888-1897. doi: 10.1016/j.neuropsychologia.2008.01.005

27. Parker, P. D., Prkachin, K. M., & Prkachin, G. C. Processing of facial expressions of negative emotion in alexithymia: the influence of temporal constraint. Journal of Personality, 2005; 73(4), 1087-1107. doi: 10.1111/j.1467-6494.2005.00339.x
28. Prkachin, G. C., Casey, C., & Prkachin, K. M. Alexithymia and perception of facial expressions of emotion. Personality and Individual Differences, 2009; 46(4), 412-417. doi: 10.1016/j.paid.2008.11.010
29. Swart, M., Kortekaas, R., & Aleman, A. Dealing with feelings: characterization of trait alexithymia on emotion regulation strategies and cognitive-emotional processing. PLoS ONE, 2009; 4(6), e5751. doi: 10.1371/journal.pone.0005751
30. Ziebell, L., Collin, C. A., Weippert, M., & Sokolov, M. Categorization of Emotional Facial Expressions in Humans with a History of Non-suicidal Self-injury. International Journal of Comparative Psychology, 2017; 30, 1-14. doi: uclapsych_ijcp_32935
31. Xu, X., & Biederman, I. Neural correlates of face detection. Cerebral Cortex, 2014; 24(6), 1555-1564. doi: 10.1093/cercor/bht005
32. Geisler, W. S. Ideal observer analysis. In J.S. Werner & L.M. Chalupa (Eds.), The Visual Neurosciences, (pp. 825–837). Cambridge: MIT Press; 2004
33. Geisler, W. S. Contributions of ideal observer theory to vision research. Vision Research, 2011; 51, 771-781. doi: 10.1016/j.visres.2010.09.027
34. Wagner, H. L. On measuring performance in category judgment studies of nonverbal behavior. Journal of Nonverbal Behavior, 1993; 17, 3-28. doi: 10.1007/BF00987006
35. Cloutier, P. F., & Nixon, M. K. The Ottawa self-injury inventory: A preliminary evaluation. Abstracts to the 12th International Congress European Society for Child and Adolescent Psychiatry. European Child & Adolescent Psychiatry. 2003; 12(Suppl. 1), 1–94.
36. Klonsky, E. D., & Glenn, C. R. Assessing the functions of non-suicidal self-injury: Psychometric properties of the Inventory of Statements about Self-Injury (ISAS). Journal of Psychopathology and Behavioural Assessment, 2009 31, 215-219.doi: 10.1007/s10862-008-9107-z
37. Lundqvist, D., Flykt, A., & Öhman, A. The Karolinska directed emotional faces - KDEF [CD ROM]. Stockholm, Sweden: Karolinska Institutet. (1998).
38. Ekman, P. Facial expression and emotion. American Psychologist, 1993; 48(4), 384. doi: 10.1037/0003-066X.48.4.384
39. Lynch, T. R., Rosenthal, M. Z., Kosson, D. S., Cheavens, J. S., Lejuez, C. W., & Blair, R. J. Heightened sensitivity to facial expressions of emotion in borderline personality disorder. Emotion, 2006; 6, 647-655. doi: 10.1037/1528-3542.6.4.647
40. Mitchell, A. E., Dickens, G. L., & Picchioni, M. M. Facial emotion processing in borderline personality disorder: a systematic review and meta-analysis. Neuropsychology Review, 2014; 24(2), 166-184. doi: 10.1007/s11065-014-9254-9
41. Rosenthal, R., & Rosnow, R. L. Contrast analysis: Focused comparisons in the analysis of variance. New York, NY: Cambridge University Press; 1985
42. Hill, M. A. SPSS Missing Value Analysis 7.5 [Computer program manual]. Chicago: SPSS Inc.; 1985

43. Mackinnon, A. The use and reporting of multiple imputation in medical research–a review. Journal of Internal Medicine, 2010; 268(6), 586-593. doi: 10.1111/j.1365-2796.2010.02274.x
44. White, I. R., Royston, P., & Wood, A. M. Multiple imputation using chained equations: issues and guidance for practice. Statistics in Medicine, 2011; 30(4), 377-399. doi: 10.1002/sim.4067
45. Hogg, R. V. Statistical robustness: One view of its use in applications today. The American Statistician, 33 (3), 1979; 108–115. doi: 10.1080/00031305.1979.10482673
46. Huber, P. J. Robust statistics. Hoboken, NJ: John Wiley & Sons; 2011
47. van Ginkel, J. R., & Kroonenberg, P. M. Analysis of variance of multiply imputed data. Multivariate Behavioral Research, 2014; 49(1), 78-91. doi: 10.1080/00273171.2013.855890
48. Van Selst, M. V., & Jolicoeur, P. A solution to the effect of sample size on outlier elimination. The Quarterly Journal of Experimental Psychology, 1994; 47(3), 631-650. doi: 10.1080/14640749408401131
49. Gravetter, F. J., & Wallnau, L. B. Statistics for the behavioral sciences (10th ed.). Belmont, California: Wadsworth Publishing; 2016
50. Trochim, W., & Donnelly, J.The research knowledge methods base. Cincinatti, OH: Atomic Dog Publishing; 2006
51. In-Albon, T., Ruf, C., & Schmid, M. Facial emotion recognition in adolescents with nonsuicidal self-injury. Psychiatry Research, 2015; 228(3), 332-339. doi: 10.1016/j.psychres.2015.05.089
52. Seymour, K. E., Jones, R. N., Cushman, G. K., Galvan, T., Puzia, M. E., Kim, K. L., Spirito, A., & Dickstein, D. P. Emotional face recognition in adolescent suicide attempters and adolescents engaging in non-suicidal self-injury. European Child & Adolescent Psychiatry, 2016; 25(3), 247-259. doi: 10.1007/s00787-015-0733-1
53. Linehan, M. Cognitive-behavioral treatment of borderline personality disorder. New York, NY: Guilford Press; 1993
54. Bracken-Minor, K. L., & McDevitt-Murphy, M. E. Differences in features of non-suicidal self-injury according to borderline personality disorder screening status. Archives of Suicide Research, 2014; 18(1), 88-103.doi: 10.1080/13811118.2013.809040
55. Muehlenkamp, J. J., Ertelt, T. W., Miller, A. L., & Claes, L.Borderline personality symptoms differentiate non-suicidal and suicidal self-injury in ethnically diverse adolescent outpatients. Journal of Child Psychology and Psychiatry, 2011; 52(2), 148-155. doi: 10.1111/j.1469-7610.2010.02305.x
56. Pérez, S., Marco, J. H., & García-Alandete, J. Comparison of clinical and demographic characteristics among borderline personality disorder patients with and without suicidal attempts and non-suicidal self-injury behaviors. Psychiatry Research, 2014; 220(3), 935-940. doi: 10.1016/j.psychres.2014.09.001
57. Jovev, M., Chanen, A., Green, M., Cotton, S., Proffitt, T., Coltheart, M., & Jackson, H. Emotional sensitivity in youth with borderline personality pathology. Psychiatry Research, 2011; 187, 234–240. doi: 10.1016/j.psychres.2010.12.019

58. Von Ceumern-Lindenstjerna, I. A., Brunner, R., Parzer, P., Frey, M., Fiedler, P., & Resch, F. Wahrnehmung und Bewertung von emotionalen Gesichtsausdrücken bei weiblichen Jugendlichen mit einer Borderline-Persönlichkeitsstörung. Zeitschrift fur Kinder und Jugendpsychiatrie und Psychotherapie, 2007; 35, 333–340. doi: 10.1024 / 1422-4917.35.5.333
59. Robin, M., Pham-Scottez, A., Curt, F., Dugre-Le Bigre, C., Speranza, M., Sapinho, D., Corcos, M., Berthoz, S., & Kedia, G. Decreased sensitivity to facial emotions in adolescents with Borderline Personality Disorder. Psychiatry Research, 2012; 200(2-3), 417-421. doi: 10.1016/j.psychres.2012.03.032
60. Domes, G., Czieschnek, D., Weidler, F., Berger, C., Fast, K., Herpertz, S.C., Recognition of facial affect in borderline personality disorder. Journal of Personality Disorders, 2008; 22, 135-147. doi: 10.1521/pedi.2008.22.2.135.
61. In-Albon, T., Bürli, M., Ruf, C., & Schmid, M. Non-suicidal self-injury and emotion regulation: a review on facial emotion recognition and facial mimicry. Child and Adolescent Psychiatry and Mental Health, 2013; 7(1), 5. doi: 10.1186/1753-2000-7-5
62. Selby, E. A., Bender, T. W., Gordon, K. H., Nock, M. K., & Joiner Jr, T. E. Non-suicidal self-injury (NSSI) disorder: a preliminary study. Personality Disorders: Theory, Research, and Treatment, 2012; 3(2), 167. doi: 10.1037/a0024405
63. Nock, M. K., & Prinstein, M. J. A functional approach to the assessment of self-mutilative behavior. Journal of Consulting and Clinical Psychology, 2004; 72(5), 885. doi: 10.1037/0022-006X.72.5.885
64. Nock, M. K., & Prinstein, M. J. Contextual features and behavioral functions of self-mutilation among adolescents. Journal of Abnormal Psychology, 2005; 114(1), 140. doi: 10.1037/0021-843X.114.1.140
65. Nock, M. K., & Mendes, W. B. Physiological arousal, distress tolerance, and social problem-solving deficits among adolescent self-injurers. Journal of Consulting and Clinical Psychology, 2008; 76(1), 28. doi: 10.1037/0022-006X.76.1.28
66. Marsh, A. A., Kozak, M. N., & Ambady, N. Accurate identification of fear facial expressions predicts prosocial behavior. Emotion, 2007; 7(2), 239. doi: 10.1037/1528-3542.7.2.239
67. Claes, L., Houben, A., Vandereycken, W., Bijttebier, P., & Muehlenkamp, J. Brief report: The association between non-suicidal self-injury, self-concept and acquaintance with self-injurious peers in a sample of adolescents. Journal of Adolescence, 2010; 33(5), 775-778. doi: 10.1016/j.adolescence.2009.10.012

3.10 Supporting Information

S1 File. Supporting Data and Error Analysis Summary. This supporting file contains the results of the mixed factorial ANOVA for threshold (Table A), efficiency (Table B), unbiased hit rate (Table C), and hit rate accuracy (Table D). It also contains the hit rate accuracy for recognition of fearful facial expressions across intensities (Table E), the Shapiro-Wilk tests of normality (Table F), skewness and kurtosis of error responses to presented emotions (Table G), and a detailed error analysis summary.

In order to obtain the error term for our planned contrasts on signal proportion Threshold (Rosenthal & Rosnow, 1985), a 2 (Group: NSSI or Control) × 6 (Emotion: sadness, disgust, surprise, fear, anger or happiness) x 3 (50%, 75%, and 100% intensity) mixed factorial ANOVA using Threshold data was performed. Mauchly's test indicated that the assumption of sphericity had been violated, and therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon < 0.75$).

Table A. Results of mixed factorial ANOVA for threshold.

Source	*df*	*MS*	*F*	η^2_p	*p*
Group	1	0.003	0.035	0.001	0.853
Intensity	1.425	1.595	208.49	0.779	0.000
Intensity x Group	1.425	0.005	0.619	0.010	0.488
Error	84.093	0.008			
Emotion	3.073	2.341	35.879	0.378	0.000
Emotion x Group	3.073	0.107	1.637	0.027	0.181
Error	181.327	0.065			
Intensity x Emotion	4.456	0.121	7.16	0.108	0.000
Intensity x Emotion x Group	4.456	0.006	0.362	0.006	0.854
Error	262.915	0.017			

Note. The median error term of the 9 imputed datasets is displayed in this table.

Likewise, the error term for our planned comparisons on the Efficiency data was derived from a 2 (Group: NSSI or Control) × 6 (Emotion: sadness, disgust, surprise, fear, anger or happiness) x 3 (50%, 75%, and 100% intensity) mixed factorial ANOVA. Again, Mauchly's test indicated that the assumption of sphericity had been violated, thus the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon < 0.75$).

Table B. Results of mixed factorial ANOVA for efficiency.

Source	*df*	*MS*	*F*	η^2_p	*p*
Group	1	0.009	0.024	0.000	0.878
Intensity	1.986	2.595	36.67	0.383	0.000
Intensity x Group	1.986	0.103	1.271	0.021	0.284
Error	117.16	0.081			
Emotion	4.072	9.736	22.829	0.279	0.000
Emotion x Group	4.072	0.257	0.603	0.010	0.663
Error	240.229	0.426			
Intensity x Emotion	6.999	0.912	7.969	0.119	0.000
Intensity x Emotion x Group	6.999	0.212	1.849	0.030	0.077
Error	412.925	0.114			

Note. The median error term of the 9 imputed datasets is displayed in this table.

The error term for the planned comparisons using the Unbiased Hit Rate (Rosenthal & Rosnow, 1985), was derived from a 2 (Group: NSSI or Control) × 6 (Emotion: sadness, disgust, surprise, fear, anger or happiness) x 3 (50% intensity, 75% intensity and 100% intensity) mixed factorial ANOVA. Mauchly's test of sphericity indicated that the assumption of sphericity was violated, thus the degrees of freedom were once again corrected using the Greenhouse-Geisser estimates of sphericity ($\varepsilon < 0.75$).

Table C. Results of mixed factorial ANOVA for unbiased hit rate.

Source	*df*	*MS*	*F*	η^2_p	*P*
Group	1	0.021	0.521	0.009	0.473
Intensity	1.451	0.131	38.629	0.396	0.000
Intensity x Group	1.451	0.001	0.341	0.006	0.642
Error	85.583	0.003			
Emotion	3.987	0.644	23.991	0.289	0.000
Emotion x Group	3.987	0.042	1.578	0.026	0.181
Error	235.245	0.027			
Intensity x Emotion	5.592	0.034	6.269	0.096	0.000
Intensity x Emotion x Group	5.592	0.003	0.601	0.718	0.010
Error	329.946	0.005			

The error term for the planned comparisons using hit rate accuracy data (Rosenthal & Rosnow, 1985), was derived from a 2 (Group: NSSI or Control) × 6 (Emotion: sadness, disgust, surprise, fear, anger or happiness) x 3 (50% intensity, 75% intensity and 100% intensity) mixed factorial ANOVA. Mauchly's test of sphericity indicated that the assumption of sphericity was violated, thus the degrees of freedom were once again corrected using the Greenhouse-Geisser estimates of sphericity ($\varepsilon < 0.75$).

Table D. Results of mixed factorial ANOVA for hit rate accuracy data.

Source	*df*	*MS*	*F*	η^2_p	*P*
Group					
Intensity	1.367	451.352	43.706	0.426	0.000
Intensity x Group	1.367	4.101	0.397	0.007	0.102
Error	80.680	10.327			
Emotion	2.421	3918.857	23.493	0.285	0.000
Emotion x Group	2.421	251.602	1.508	0.025	0.221

Error	142.837	166.809			
Intensity x Emotion	3.521	106.766	4.343	0.069	0.003
Intensity x Emotion x Group	3.521	22.055	0.897	0.456	0.456
Error	207.750	24.582			

Results from these planned contrasts for accuracy data show that the HNSSI group were significantly less accurate at identifying fear at the 50%, 75% and 100% intensity level at the 0.05 level. No other significant results were observed for other emotions across intensity levels.

Table E. Hit rate accuracy for recognition of fearful facial expressions across intensities.

Emotion	*Intensity*	*NSSI (Mean ± SE)*	*Control (Mean ± SE)*	*Effect Size (r)*	*P*
Fear	50%	16.433 ± 2.027	19.000 ± 1.994	0.139	0.044*
	75%	18.867 ± 1.814	22.742 ± 1.785	0.207	0.003*
	100%	20.067 ± 1.812	23.290 ± 1.783	0.173	0.012*

* Significant at the $p < 0.05$ level

Table F. Shapiro-Wilk tests of normality for error responses to emotions.

			NSSI		*Control*	
Presented Emotion	*Intensity*	*Error Response*	*Statistic*	*p*	*Statistic*	*p*
Anger	50	Fear	.877	.002	.906	.010
	50	Disgust	.947	.140	.812	.000
	50	Happy	.935	.067	.904	.009
	50	Sad	.958	.276	.892	.005
	50	Surprised	.877	.002	.780	.000
	75	Fear	.858	.001	.829	.000
	75	Disgust	.954	.214	.906	.010
	75	Happy	.909	.014	.883	.003
	75	Sad	.954	.211	.948	.142
	75	Surprised	.842	.000	.855	.001
	100	Fear	.912	.016	.849	.000

	100	Disgust	.892	.005	.862	.001
	100	Happy	.914	.019	.941	.088
	100	Sad	.935	.067	.938	.074
	100	Surprised	.842	.000	.906	.010
Disgust	50	Fear	.784	.000	.860	.001
	50	Anger	.835	.000	.863	.001
	50	Happy	.819	.000	.862	.001
	50	Sad	.795	.000	.838	.000
	50	Surprised	.678	.000	.724	.000
	75	Fear	.806	.000	.825	.000
	75	Anger	.954	.214	.855	.001
	75	Happy	.901	.009	.886	.003
	75	Sad	.748	.000	.780	.000
	75	Surprised	.721	.000	.782	.000
	100	Fear	.796	.000	.868	.001
	100	Anger	.958	.268	.841	.000
	100	Happy	.839	.000	.898	.006
	100	Sad	.741	.000	.782	.000
	100	Surprised	.768	.000	.763	.000
Fear	50	Anger	.790	.000	.786	.000
	50	Disgust	.803	.000	.856	.001
	50	Happy	.870	.002	.739	.000
	50	Sad	.824	.000	.817	.000
	50	Surprised	.695	.000	.783	.000
	75	Anger	.790	.000	.814	.000
	75	Disgust	.666	.000	.847	.000
	75	Happy	.849	.001	.840	.000
	75	Sad	.846	.001	.790	.000

	75	Surprised	.823	.000	.760	.000
	100	Anger	.822	.000	.849	.000
	100	Disgust	.694	.000	.844	.000
	100	Happy	.864	.001	.879	.002
	100	Sad	.859	.001	.835	.000
	100	Surprised	.817	.000	.932	.050
Happy	50	Fear	.875	.002	.899	.007
	50	Anger	.926	.038	.924	.030
	50	Disgust	.929	.047	.953	.193
	50	Sad	.969	.504	.960	.287
	50	Surprised	.859	.001	.907	.011
	75	Fear	.881	.003	.869	.001
	75	Anger	.933	.060	.958	.254
	75	Disgust	.958	.270	.921	.026
	75	Sad	.947	.144	.936	.063
	75	Surprised	.882	.003	.815	.000
	100	Fear	.909	.014	.909	.012
	100	Anger	.967	.466	.914	.017
	100	Disgust	.938	.083	.951	.168
	100	Sad	.895	.006	.954	.207
	100	Surprised	.897	.007	.942	.096
Sad	50	Fear	.864	.001	.929	.040
	50	Anger	.935	.069	.942	.092
	50	Disgust	.941	.098	.928	.038
	50	Happy	.950	.165	.929	.042
	50	Surprised	.858	.001	.902	.008
	75	Fear	.895	.006	.942	.094
	75	Anger	.897	.007	.929	.042

	75	Disgust	.917	.022	.930	.045
	75	Happy	.946	.129	.936	.064
	75	Surprised	.798	.000	.923	.028
	100	Fear	.908	.014	.903	.008
	100	Anger	.915	.020	.943	.102
	100	Disgust	.932	.056	.914	.016
	100	Happy	.933	.058	.908	.011
	100	Surprised	.881	.003	.925	.032
Surprise	50	Fear	.910	.015	.864	.001
	50	Anger	.808	.000	.906	.010
	50	Disgust	.807	.000	.886	.003
	50	Happy	.838	.000	.842	.000
	50	Sad	.816	.000	.939	.077
	75	Fear	.933	.061	.891	.004
	75	Anger	.880	.003	.898	.007
	75	Disgust	.843	.000	.882	.003
	75	Happy	.860	.001	.896	.006
	75	Sad	.820	.000	.920	.023
	100	Fear	.922	.030	.899	.007
	100	Anger	.933	.060	.898	.006
	100	Disgust	.890	.005	.916	.018
	100	Happy	.913	.018	.910	.013
	100	Sad	.906	.012	.938	.075

Table G. Skewness and Kurtosis of error responses to presented emotions.

Presented Emotion	*Intensity*	*Error Response*	*NSSI*		*Control*	
			Skewness	*Kurtosis*	*Skewness*	*Kurtosis*
Anger	50	Fear	.923	-.052	.459	-.359
	50	Disgust	.267	-.911	1.778	3.479

	50	Happy	.715	-.150	.627	-.717
	50	Sad	-.070	-.969	1.166	1.170
	50	Surprised	.258	-.869	1.193	.286
	75	Fear	1.016	.287	1.371	1.421
	75	Disgust	.290	-.681	.776	-.228
	75	Happy	.847	.149	.450	-1.199
	75	Sad	.294	-.913	.530	-.304
	75	Surprised	.547	-1.139	.892	.002
	100	Fear	.330	-1.034	.898	-.287
	100	Disgust	1.014	1.200	.869	-.398
	100	Happy	.754	-.027	.385	-.825
	100	Sad	.469	-.406	.561	-.633
	100	Surprised	1.107	.421	.646	-.446
Disgust	50	Fear	.966	-.339	.887	-.157
	50	Anger	1.537	2.224	1.246	.938
	50	Happy	.881	-.414	1.062	.535
	50	Sad	1.190	.167	1.257	.714
	50	Surprised	1.245	.018	1.011	-.493
	75	Fear	.776	-.803	.889	-.385
	75	Anger	.582	.827	1.257	.950
	75	Happy	.738	-.437	.742	-.155
	75	Sad	1.321	.277	1.456	1.118
	75	Surprised	1.602	2.026	1.107	.120
	100	Fear	.846	-.706	.746	-.482
	100	Anger	.365	-.649	1.202	.648
	100	Happy	.819	-.712	.865	.055
	100	Sad	1.458	.766	1.512	1.435
	100	Surprised	1.559	2.513	1.231	.310

Fear	50	Anger	1.104	-.020	1.397	1.054
	50	Disgust	.895	-.454	1.029	.318
	50	Happy	.474	-.931	1.479	1.341
	50	Sad	1.296	.734	1.370	1.119
	50	Surprised	1.566	1.095	1.227	.073
	75	Anger	.957	-.562	1.101	-.012
	75	Disgust	2.067	3.532	1.094	.539
	75	Happy	.819	-.651	1.184	.503
	75	Sad	1.091	.156	1.424	.965
	75	Surprised	1.265	.581	1.801	2.654
	100	Anger	1.386	1.662	.967	-.062
	100	Disgust	1.781	2.098	.774	-.778
	100	Happy	.570	-.916	.993	.426
	100	Sad	1.044	.298	1.498	2.243
	100	Surprised	1.059	-.221	.105	-1.023
Happy	50	Fear	1.010	.330	.537	-.888
	50	Anger	.579	-.723	.586	-.686
	50	Disgust	.029	-1.290	.356	-.486
	50	Sad	.347	-.058	.517	-.096
	50	Surprised	1.237	1.381	.293	-1.216
	75	Fear	.824	-.168	.779	-.592
	75	Anger	.763	.529	.400	-.534
	75	Disgust	.499	-.536	.464	-.518
	75	Sad	.538	-.317	.585	-.074
	75	Surprised	.399	-1.170	1.249	.543
	100	Fear	.740	.069	.598	-.510
	100	Anger	.258	-.149	.701	-.118
	100	Disgust	.036	-1.206	.597	.052

	100	Sad	.516	-1.090	-.172	-.955
	100	Surprised	.725	-.171	.395	-.567
Sad	50	Fear	.984	-.093	.285	-1.104
	50	Anger	.740	.053	.628	-.082
	50	Disgust	.275	-.763	.915	.953
	50	Happy	.577	-.353	.462	-.521
	50	Surprised	.862	-.188	.315	-1.050
	75	Fear	.769	-.402	.389	-.368
	75	Anger	.933	.102	.400	-.365
	75	Disgust	.591	-.450	.220	-1.218
	75	Happy	.400	-.835	.369	-.947
	75	Surprised	1.242	.785	.757	.166
	100	Fear	.829	-.169	1.061	.946
	100	Anger	.699	-.457	.310	-.799
	100	Disgust	.109	-.899	.590	-.702
	100	Happy	.673	-.148	.836	.056
	100	Surprised	.892	-.145	.360	-.903
Surprise	50	Fear	.982	.657	1.248	1.181
	50	Anger	.808	-.642	.596	-.383
	50	Disgust	1.225	1.077	.604	-.728
	50	Happy	1.055	.079	.990	-.086
	50	Sad	1.522	1.827	-.087	-1.219
	75	Fear	.766	.114	.942	.020
	75	Anger	.784	-.370	.605	-.772
	75	Disgust	.940	.069	-.054	-1.349
	75	Happy	.098	-1.614	.630	-.832
	75	Sad	1.607	2.680	.765	.769
	100	Fear	.761	-.199	.821	-.384

100	Anger	.367	-.630	.843	.258
100	Disgust	.280	-.992	.757	.194
100	Happy	.833	-.004	.671	-.488
100	Sad	.188	-1.211	.628	-.346

Types of errors recognizing fear at 50%, 75% and 100%. Independent samples T-tests were conducted to assess error differences between the NSSI and control groups. No differences in error patterns were detected between the NSSI and control groups at 50% and 75% intensity. However, at 100% intensity, the NSSI group was significantly less likely to mistake fearful expressions for happy (2.1 ± 0.36) compared to the control group (3.5 ± 0.57), a statistically significant difference of -1.42 (95% CI, -2.79 to -0.04), $t(59) = -2.062$, $p = .044$, $d = 0.53$ (Figure S1).

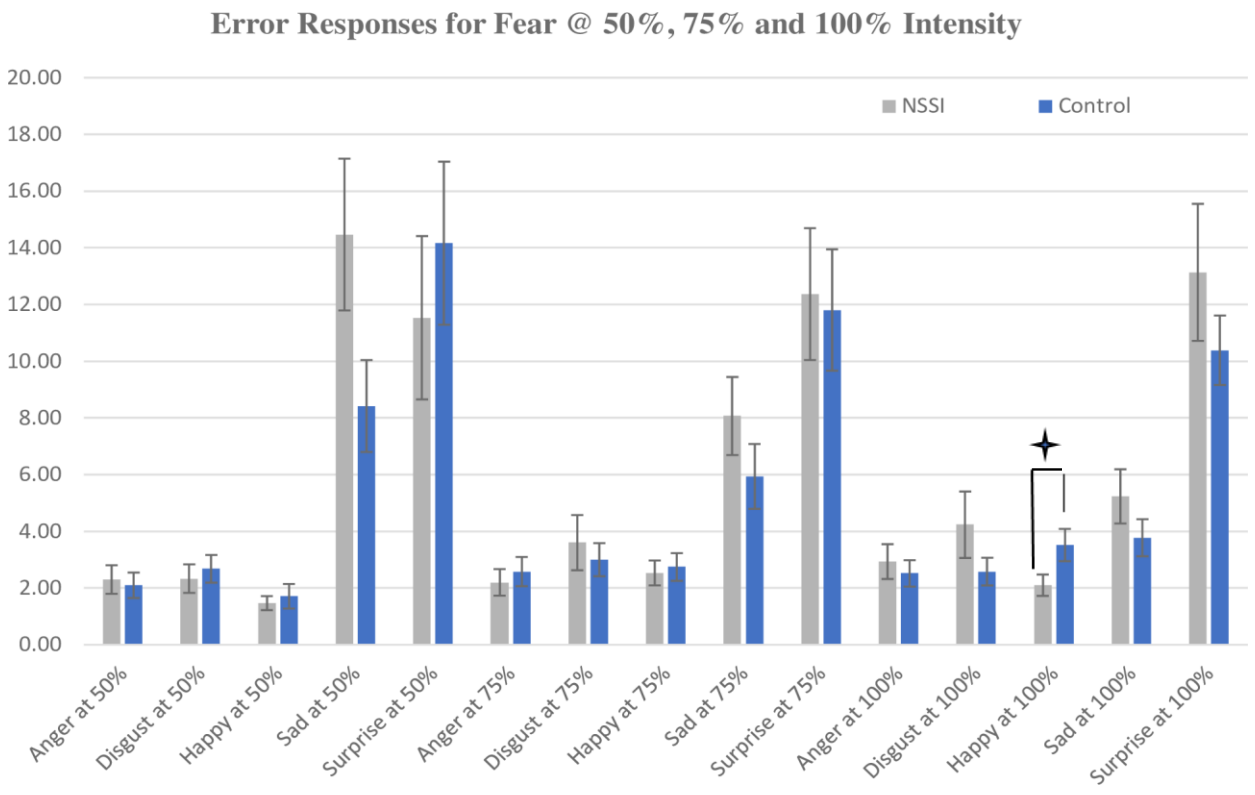


Figure S1. Group differences in errors made for fear at 3 emotion intensities.

Types of errors recognizing angry at 50%, 75% and 100%. Independent samples T-tests were conducted to assess differences in errors made identifying angry expressions between NSSI and control groups. At 50% intensity, the NSSI group was significantly less likely to mistake angry expressions for disgust (4.23 ± 0.50) compared to the control group (7.71 ± 1.40), a statistically significant difference of -3.47 (95% CI, -6.49 to -0.46), $t(37.46) = -2.33$, $p = .025$, $d = 0.59$, and were significantly more likely to mistake angry expressions for happy (4.23 ± 0.49) compared to controls (2.68 ± 0.38), a significant difference of 1.56 (95% CI, -0.14 to 2.97), $t(49.82) = 2.20$, $p = .033$, $d = 0.57$. However, no other differences in error patterns were detected between the NSSI and control groups at 75% and 100% intensity (Figure S2).

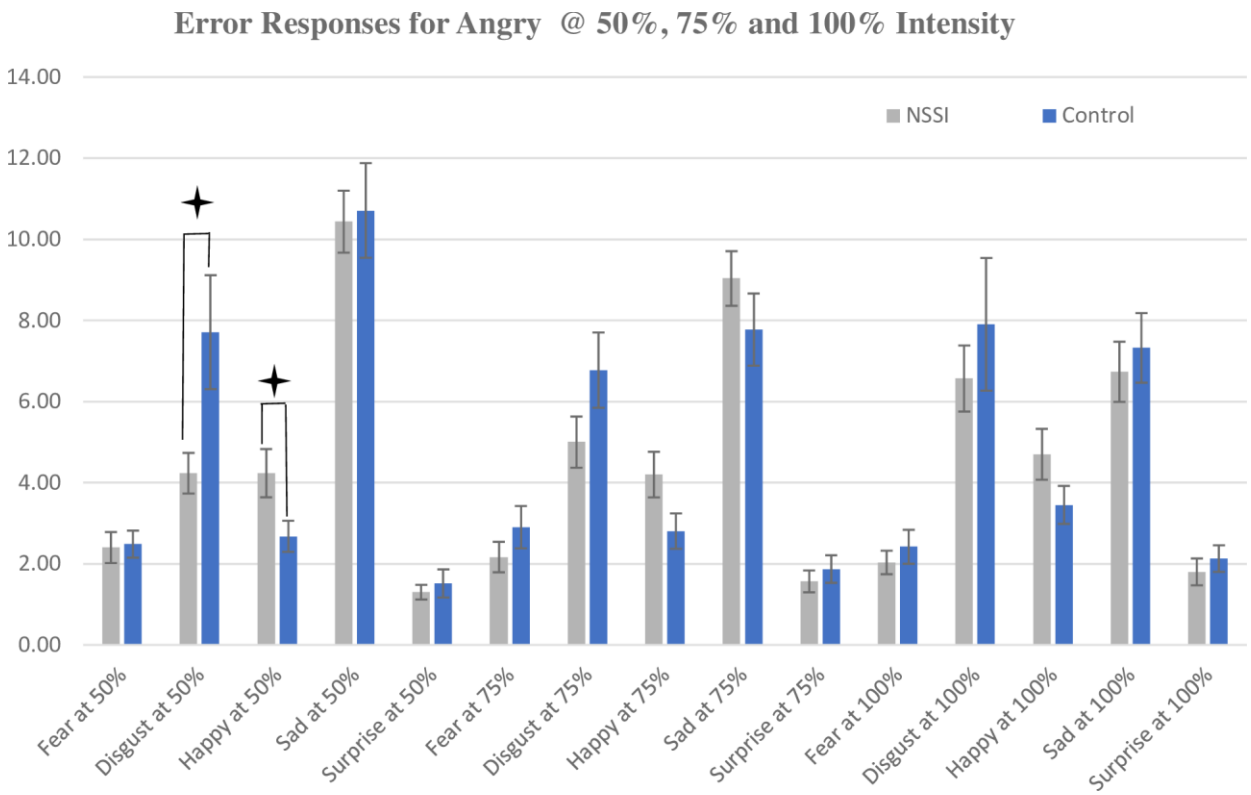


Figure S2. Group differences in errors made for anger at 3 emotion intensities.

Types of errors recognizing disgust at 50%, 75% and 100%. Independent samples T-tests were conducted to assess differences in errors made identifying disgust expressions between

NSSI and control groups. At 50% intensity, the NSSI group was significantly less likely to mistake disgusted expressions for fear (1.03 ± 0.23) compared to the control group (2.06 ± 0.39), a statistically significant difference of -1.03 (95% CI, -1.93 to -0.13), $t(38.47) = -2.31$, $p = .026$, $d = 0.59$. At 100% intensity, the NSSI group was significantly more likely to mistake disgusted expressions for sad (7.47 ± 1.48) compared to controls (3.68 ± 0.76), a significant difference of 3.79 (95% CI, 0.43 to 7.15), $t(43.39) = 2.27$, $p = .028$, $d = 0.60$. However, no other differences in error patterns were detected between the NSSI and control groups (Figure S3).

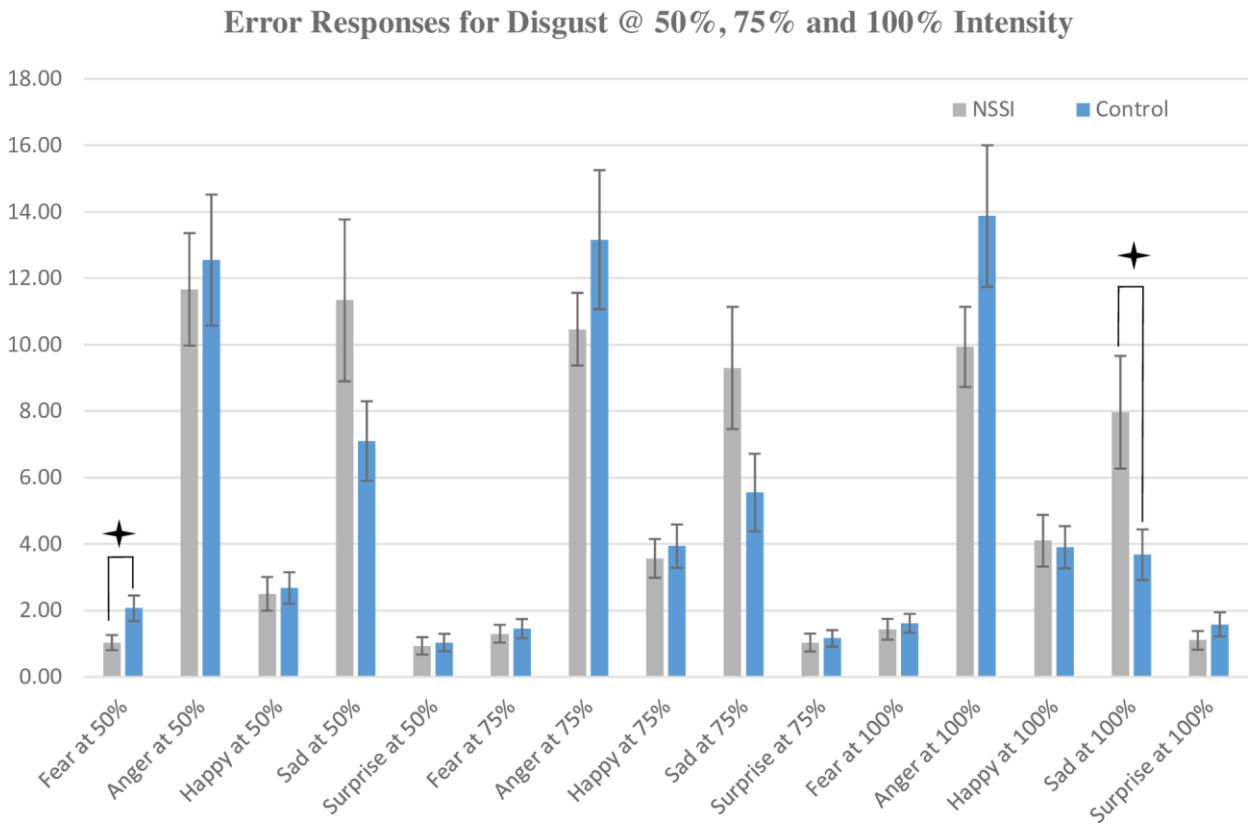


Figure S3. Group differences in errors made for disgust at 3 emotion intensities.

Types of errors recognizing happy at 50%, 75% and 100%. Independent samples T-tests were conducted to assess differences in errors made identifying happy expressions between NSSI and control groups. At 75% intensity, the NSSI group was significantly less likely to

mistake happy expressions for surprise (2.13 ± 0.33) compared to the control group (3.83 ± 0.55), a statistically significant difference of -1.71 (95% CI, -3.00 to -0.42), $t(48.80) = -2.67$, $p = .010$, $d = 0.68$. At 100% intensity, the NSSI group was significantly more likely to mistake happy expressions for anger (5.77 ± 0.45) compared to controls (4.32 ± 0.48), a significant difference of 1.44 (95% CI, 0.12 to 2.77), $t(59) = 2.19$, $p = .033$, $d = 0.56$. However, no other differences in error patterns were detected between the NSSI and control groups at any other intensities (Figure S4).

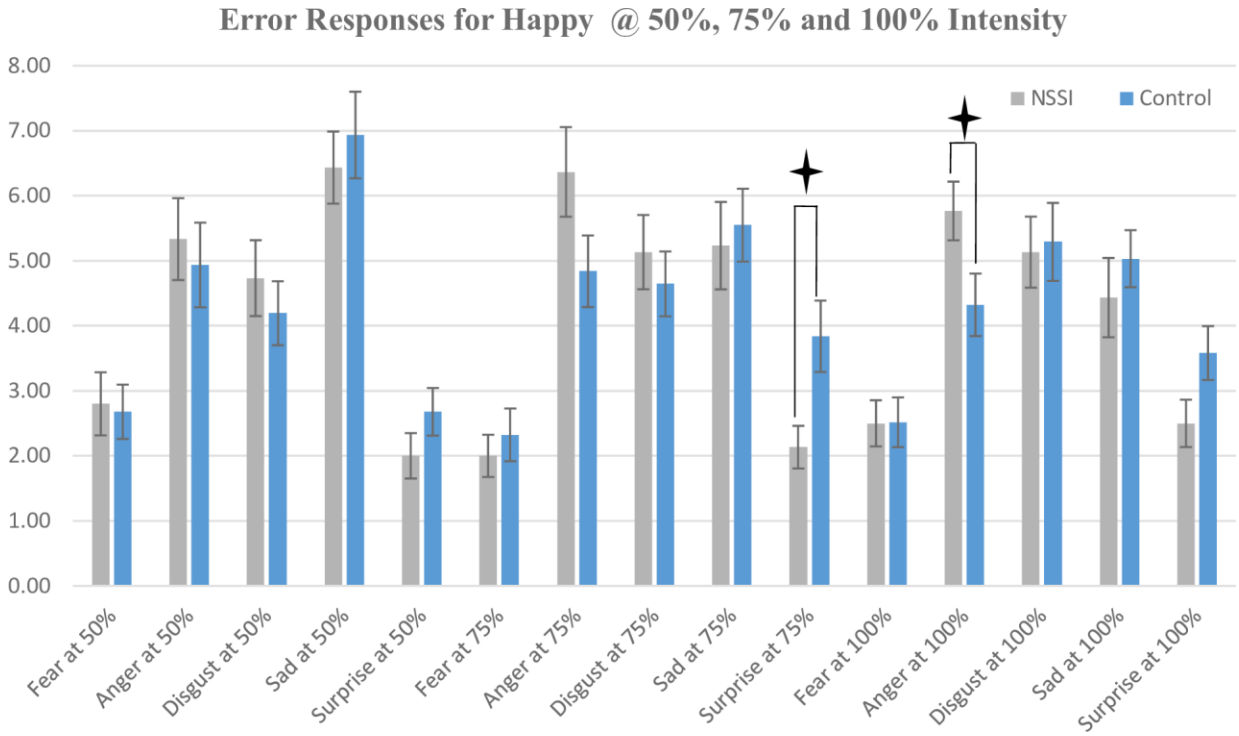


Figure S4. Group differences in errors made for happy at 3 intensities.

Types of errors recognizing sad at 50%, 75% and 100%. Independent samples T-tests were conducted to assess differences in errors made identifying happy expressions between NSSI and control groups. At 50% intensity, the NSSI group was significantly less likely to mistake sad expressions for surprise (1.63 ± 0.29) compared to the control group (2.58 ± 0.26), a statistically significant difference of -0.95 (95% CI, -1.73to -0.16), $t(59) = -2.24$, $p = .019$, $d = 0.62$. At 75% intensity, the NSSI group was again significantly less likely to mistake sad expressions for

surprise (1.60 ± 0.29) compared to controls (2.90 ± 0.39), a significant difference of -1.30 (95% CI, -2.27 to -0.34), $t(59) = -2.67$, $p = .009$, $d = 0.69$. However, no other differences in error patterns were detected between the NSSI and control groups at any other intensities (Figure S5).

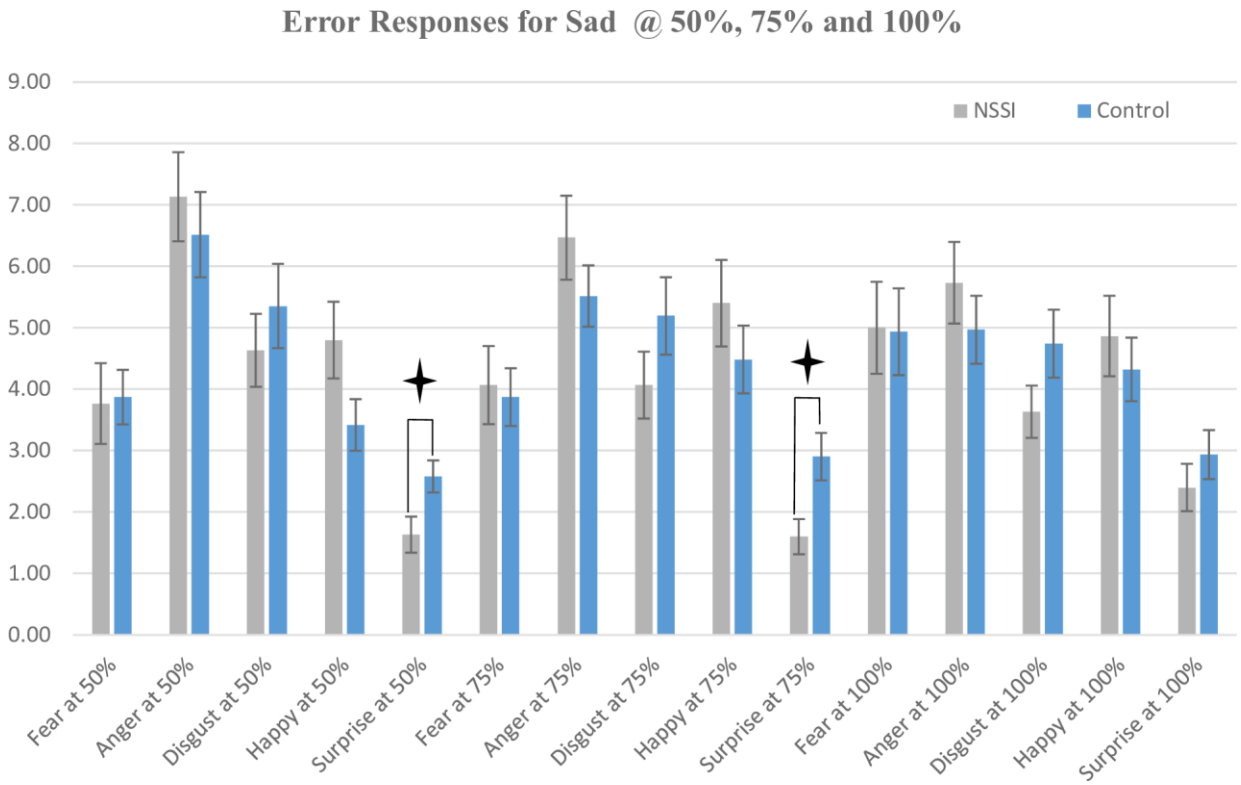


Figure S5. Group differences in errors made for sad at 3 intensities.

Types of errors recognizing surprised at 50%, 75% and 100%. Independent samples T-tests were conducted to assess differences in errors made identifying happy expressions between NSSI and control groups. At 100% intensity, the NSSI group was significantly less likely to mistake surprised expressions for sad (2.77 ± 0.39) compared to the control group (4.32 ± 0.51), a statistically significant difference of -1.56 (95% CI, -2.84 to -0.28), $t(59) = -2.43$, $p = .018$, $d = 0.62$. However, no other differences in error patterns were detected between the NSSI and control groups at any other intensities (Figure S6).

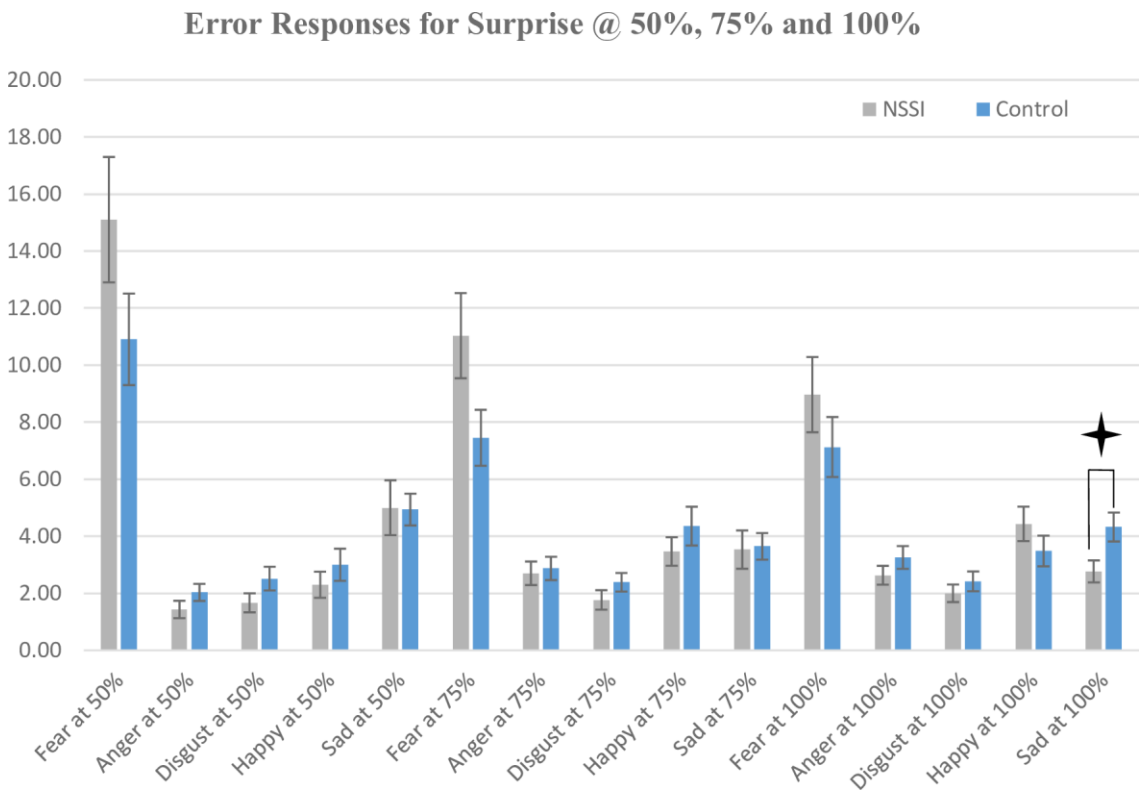


Figure S6. Group differences in errors made for surprise at 3 intensities.

Types of errors for all emotions collapsed across intensities. Independent samples T-tests were conducted to assess differences in errors made when identifying the emotion expressions collapsed across intensities between NSSI and control groups. The NSSI group was significantly more likely to mistake angry expressions for the emotion of happy (4.38 ± 0.50) compared to the control group (2.98 ± 0.35), a statistically significant difference of -1.40 (95% CI, -2.61 to -0.18), $t(59) = -2.31$, $p = .024$, $d = 0.59$. The NSSI group was also significantly less likely to mistake happy (2.24 ± 0.29) and sad (1.92 ± 0.28) expression for the emotion of surprise compared to the control group (3.37 ± 0.40 and 2.81 ± 0.29), statistically significant differences of 1.12 (95% CI, -2.12 to 0.12), $t(59) = 2.24$, $p = .029$, $d = 0.57$ and 0.88 (95% CI, 1.70 to 0.07), $t(59) = 2.18$, $p = .033$, $d = 0.56$. However, no other differences in error patterns were detected between the NSSI and control groups for any other emotions (Figures S7-S9).

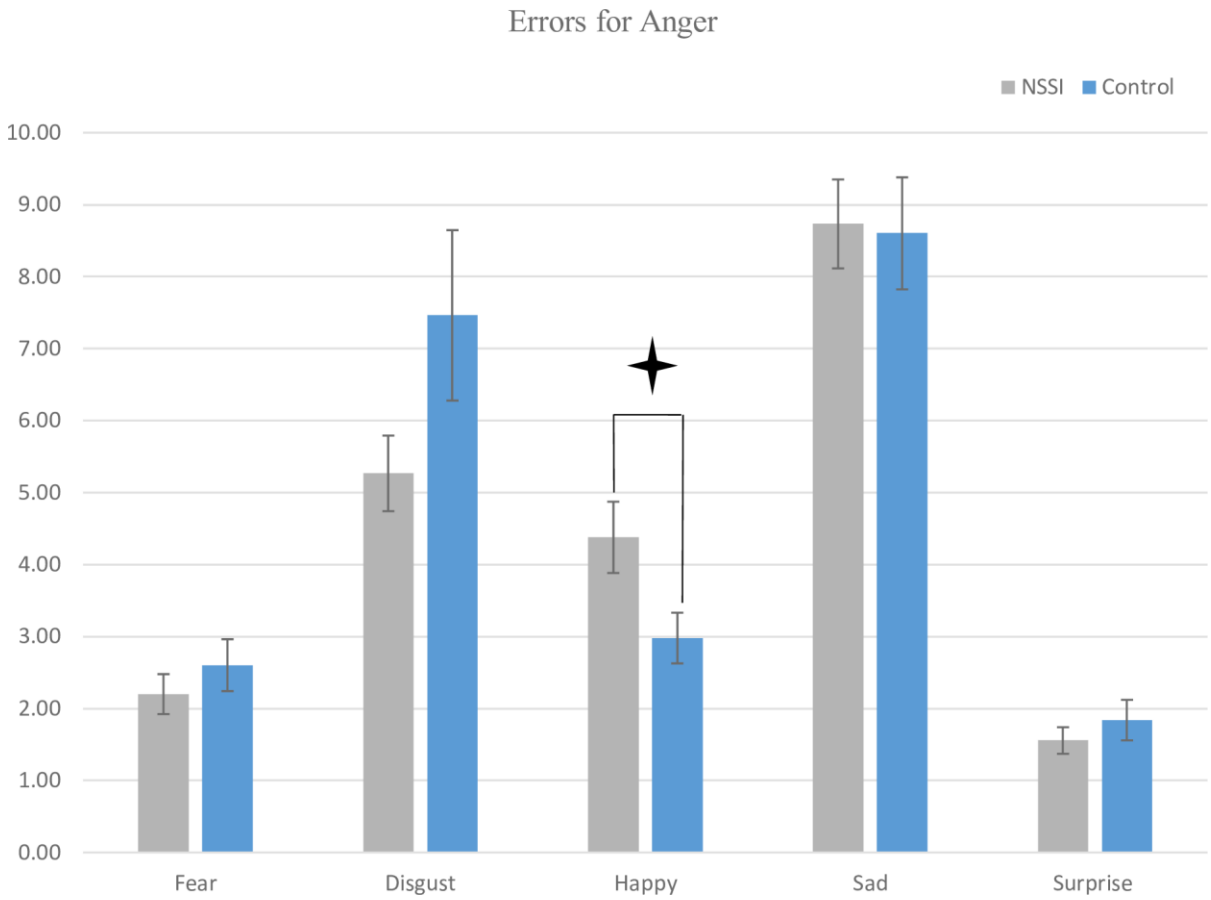


Figure S7. Group differences in errors made for anger collapsed across intensities.

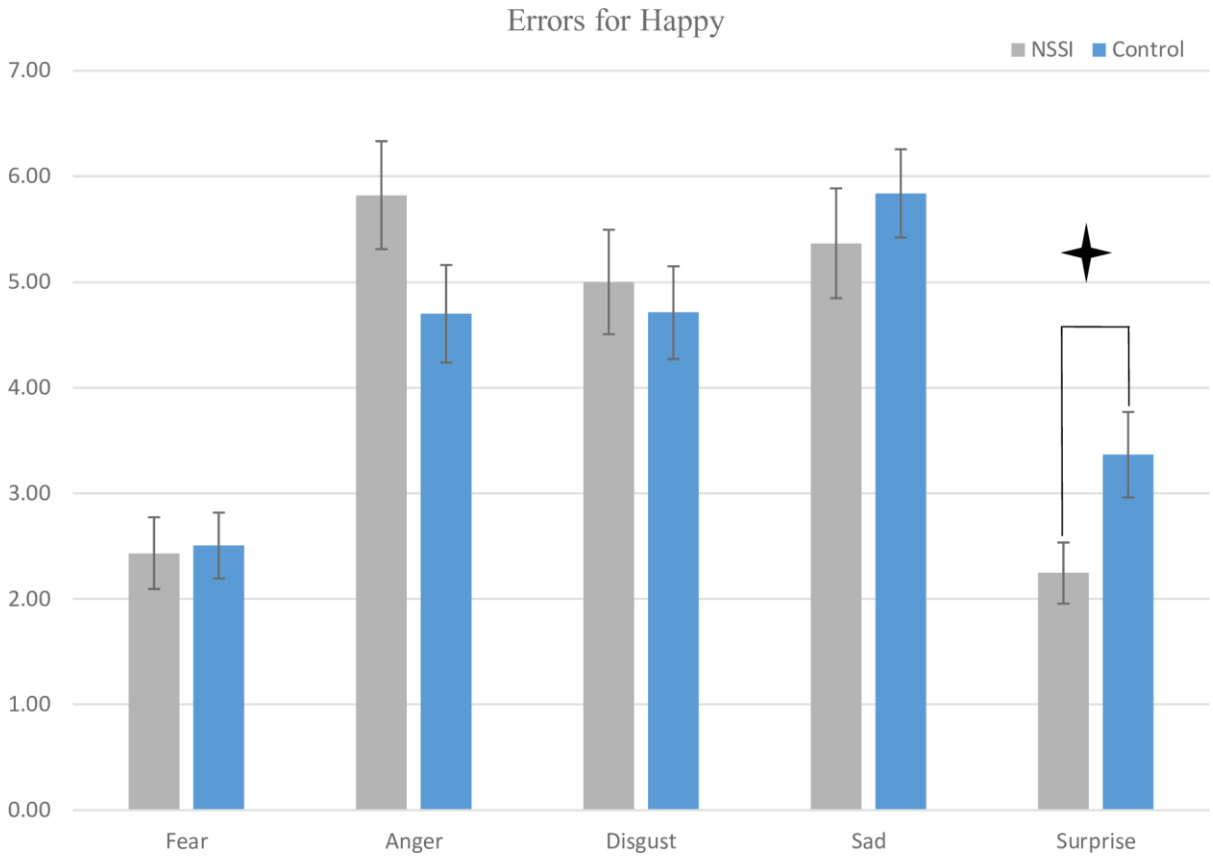


Figure S8. Group differences in errors made for happy collapsed across intensities.

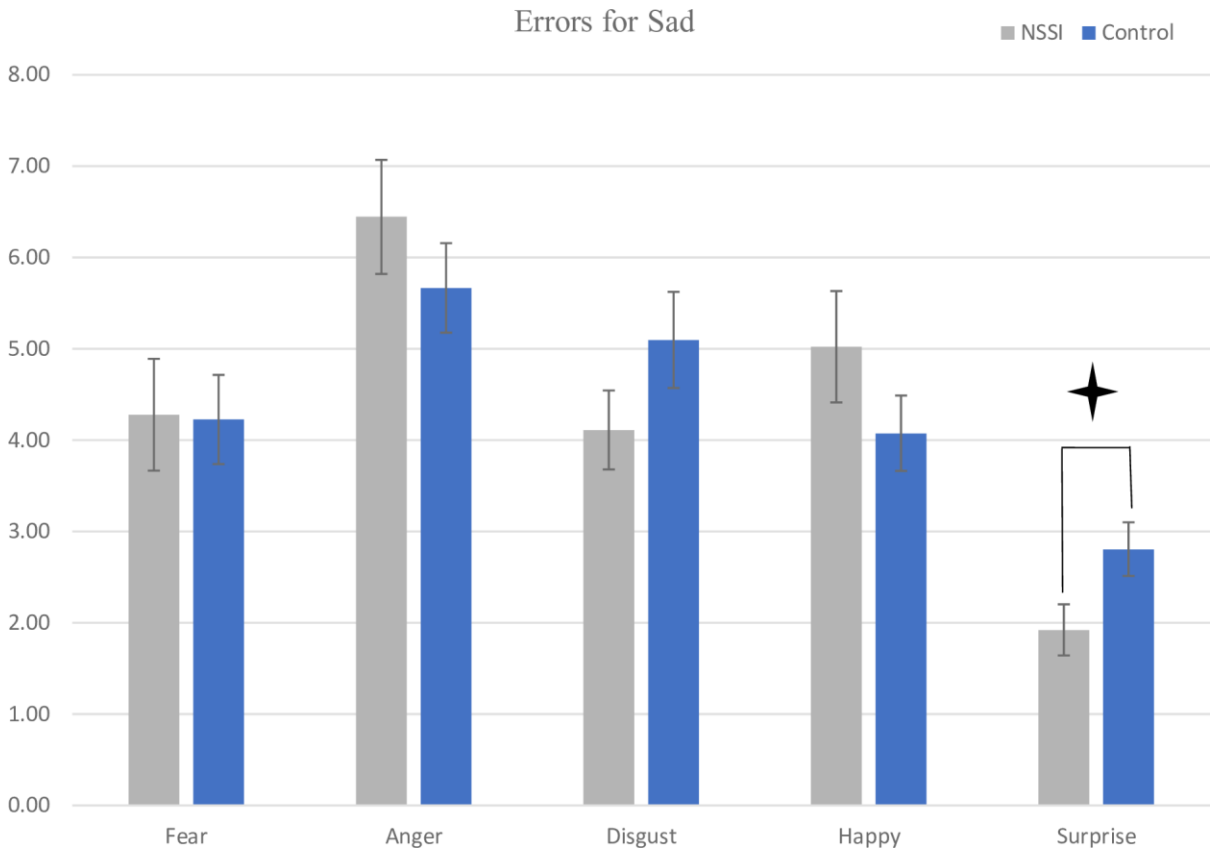


Figure S9. Group differences in errors made for sad collapsed across intensities.

Chapter 4

Study 3: Electromyographic Evidence of Reduced Emotion Mimicry in Individuals with a History of Non-Suicidal Self-Injury

Study 3 was published in PLoS ONE in 2020 and is generally formatted in accordance with the requirements of that journal.

Ziebell, L., Collin, C., Mazalu, M., Rainville, S., & Weippert, M., & Skolov, M. (2020). Electromyographic evidence of reduced emotion mimicry in individuals with a history of non-suicidal self-injury. *PLoS ONE*, *15*(12), e0243860.

4.1 Abstract

Engaging in facial emotion mimicry during social interactions encourages empathy and functions as a catalyst for interpersonal bonding. Decreased reflexive mirroring of facial expressions has been observed in individuals with different non-psychotic disorders, relative to healthy controls. Given reports of interpersonal relationship difficulties experienced by those who engage in non-suicidal self-injury (NSSI), it is of interest to explore facial emotion mimicry in individuals with a history of this behaviour (HNSSI). Among other things, this will enable us to better understand their emotion regulation and social interaction challenges. Surface facial electromyography (fEMG) was used to record the reflexive facial mimicry of 30 HNSSI and 30 controls while they passively observed a series of dynamic facial stimuli showing various facial expressions of emotion. Beginning with a neutral expression, the stimuli quickly morphed to one of 6 prototypic emotional expressions (anger, fear, surprise, disgust, happiness, or sadness). Mimicry was assessed by affixing surface electrodes to facial muscles known to exhibit a high degree of electrical activity in response to positive and negative emotions: the corrugator supercilii and the zygomaticus major. HNSSI participants, relative to controls, exhibited significantly less electrical activity in the corrugator muscle in response to viewing angry stimuli, and significantly less of an expected relaxation in muscle activity in response to viewing happy stimuli. Mirroring these results, greater endorsement of social influence as a motivator for engaging in NSSI was associated with less mimicry, and greater endorsement of emotion regulation as a motivator was associated with greater incongruent muscle response when viewing happy faces. These findings lend support to the theory that social interaction difficulties in HNSSI might be related to implicit violations of expected social rules exhibited through facial mimicry nonconformity.

4.2 Introduction

Non-suicidal self-injury (NSSI) is broadly defined as the direct and deliberate damage to one's own body tissue in the absence of suicidal intent [1]. Common methods of NSSI include cutting, scratching, burning, biting, hitting, and skin picking [2], but do not include forms of socially sanctioned self-injury, such as tattoos, ritual scarification, or piercings [3,4]. Engaging in these behaviours typically begins during early adolescence [5] with prevalence rates up to 17% in community samples [6] and between 40-80% in clinical samples [7]. NSSI is also a robust risk factor for predicting suicidal thoughts and behaviours [8,9]. Diagnostically, NSSI currently appears as a symptom of Borderline Personality Disorder (BPD) in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition [3]; however, the prevalence of engagement in NSSI behaviour is far higher in adolescents than are rates of BPD [6,7], suggesting that NSSI can both co-occur with BPD and exist independently of it. Consequently, it has been proposed that NSSI may be a diagnostic entity of its own, and it has been included in the third section of the DSM-5 as a condition requiring further study [3]. This highlights the need for greater research into this behaviour.

Although several motivations have been identified for engaging in NSSI (i.e. NSSI functions), many models of this behaviour postulate that it primarily serves an intrapersonal function, such as regulating emotions by reducing aversive states, like sadness or anxiety [10-12]. However, secondary motivations for this behaviour have also been identified and involve interpersonal functions, like interpersonal influence or peer-bonding, that can directly or indirectly socially reinforce NSSI [11, 12]. For example, interpersonal stress, perceived criticism, and social rejection have been found to be common triggers of NSSI. Hence, a sensitivity to interpersonal stress, high emotional distress, and in some cases chronic romantic stress [13] are

thought to play a role in the development and maintenance of NSSI, with self-injury being used as a means to both regulate general affective states as well as regulate emotional responses to social experiences [14].

A recent hypothesis postulates that violations of social rules may contribute to the interaction difficulties and social rejection experiences reported by many individuals who engage in NSSI [15]. For instance, interpersonal interactions are highly governed by rules that guide emotional behaviour [16]. These rules are perceived as normative by interaction partners, and even minor violations of the rules can create problems for people during interactions [17]. In particular, it has been suggested that individuals who engage in NSSI may be violating the expected social rules of interaction through nonconformity in facial mimicry [15]. This nonconformity may contribute to the increased interpersonal challenges and social rejection experiences reported by this population, which are known to trigger and maintain self-harming behaviour [18, 19]

In conversation, automatically and subtly mimicking the facial expression of an interaction partner (also known as micro-expressions or automatic facial expressions), is a naturally occurring and important social phenomenon that contributes to liking and rapport building between individuals [20, 21]. It is defined as the imitation of facial expressions of another person through the activation of corresponding facial muscles in the observer [22], often arising in response to an emotion. The movement of facial muscles mirroring the expression of another can be either visible (overt) or non-visible (covert), and typically occurs at an unconscious level [17]. In instances where emotion mimicry is covert, and movement of the skin is not easily perceptible, muscle activation can be measured using Electromyography (EMG). In 1982, Dimberg used EMG equipment to systematically demonstrate that individuals responded with

elevated activity in the zygomaticus major muscle and corrugator supercilii muscle in response to happy and angry facial expressions respectively [23]. Dimberg's study [23] was one of the first to suggest that individuals tend to automatically and covertly mimic the observed facial expressions of others. Although the activity of many different facial muscles can be measured, that of the zygomaticus major is primarily thought to correspond with positive emotional expressions, whereas the response of the corrugator supercilii is primarily thought to correspond with negative emotions [24-26]. The zygomaticus major is responsible for stretching the lips to create a smile, whereas the corrugator supercilii lowers the brows in response to emotions such as fear, anger, and sadness [27].

Following this early research, the mimicry-eliciting effects of other facial emotions, such as happiness, anger, sadness, fear, disgust, and surprise have been examined [28]. Results continued to confirm that happy and angry expressions produced greater EMG activity in the zygomaticus major and corrugator supercilii respectively compared to neutral expressions. The corrugator supercilii has also been found to consistently show relaxation in response to happy faces [28, 29, 30, 31]. While evidence primarily exists for the emotion mimicry effect in corrugator supercilii and zygomaticus major muscles in response to anger and happiness [22, 32], other research has found corrugator supercilii responses to fearful [33, 34, 35], sad [28, 36, 37], disgusted [28, 38, 39] and surprised faces [40, 41]. However, these results are somewhat inconsistent across the literature and further investigation is continuing into the mimicry-eliciting effects of these emotional expressions. Due to the exploratory nature of this research, and to add to the above literature, our study opted to present all six basic emotions to investigate if group differences could be observed in the activity elicited in these two facial muscles. Furthermore, research has found that the intensity of facial mimicry can be modulated by stimulus type. For

instance, facial mimicry is more pronounced in response to dynamic facial expressions compared to static ones [42,43].

In the past, mimicry reactions were thought to be an automatic response based on a link between perception and behaviour. Perception of a specific facial expression was thought to automatically evoke the same expression in the perceiver [44]. However, current researchers believe that emotion mimicry is more complex than this. For example, Hess and Fischer consider emotion mimicry to be a case of embodied simulation, in which a person understands the affect of another by simulating the affect in themselves [22]. This process would allow the perceiver to simulate the emotion on a motor, somatosensory, and affective level, to deduce its meaning and reward value [45, 46]. This more complex view of facial mimicry is supported by data showing that it can vary across contexts, as one's own emotional state can have an influence on emotion mimicry. For example, being in a good relationship [47] or belonging to a social group [48, 36] has been found to increase facial mimicry, whereas having a negative attitude toward someone can inhibit it [49, 48, 50]. Not surprisingly, mimicking behaviours appear to be a key factor in successful interactions, as this process supports empathy and emotional understanding, as well as eliciting liking and rapport in conversational partners [20, 21]. However, the imitation of positive emotions appears to be more likely to lead to liking and affiliation from others than the imitation of negative ones such as anger and disgust, whose mimicry can be viewed more negatively by others [51]. Nonetheless, the act of mimicking emotions, both positive and negative, may still help build relationships through affective empathy, which means to feel what others are feeling [52].

In contrast, suppressing the mimicry of emotions, also known as expressive suppression, has been found to have negative effects on interpersonal functioning. Expressive suppression has

been linked to increased physiological responding in individuals interacting with suppressors [53], decreased liking and rapport, as well as decreased willingness to form a friendship with suppressors [53]. The mechanisms that underly the link between expressive suppression and impaired social functioning are not well articulated. However, one hypothesis is that those engaged in expressive suppression may also have impairments in perceiving the emotions of others. Emotion mimicry is thought to facilitate emotion recognition by having facial muscles function as a feedback system for an individual's own experience of emotions [20, 21, 23]. Indeed, blocking facial mimicry has been shown to produce less accurate identification of happiness [53, 45, 55], as well as slower recognition of happy, sad and fearful emotion stimuli [56]. However, it is important to note that some studies have found no link between the degree of mimicry and emotion recognition ability [47, 57]. Expressive suppression has also been identified as an emotion regulation strategy in several psychological disorders, including posttraumatic stress [58, 59], eating disorders [60, 61], and depressive symptomatology [62, 63]. This research has shown that expressive suppression can act to paradoxically increase the experience of emotion within the suppressor [53, 62].

Although substantial research exists on automatic facial expressions in individuals diagnosed with schizophrenia or depressive disorders, very little is known about individuals diagnosed with non-psychotic disorders. A systematic review conducted by Davies et al., revealed altered emotion expression across all disorders examined, with the exception of anxiety disorders [64]. In depression, decreased facial expression was mainly evident for positive affect, and in eating disorders decreased facial expression was observed in response to both positive and negative stimuli. Overall, the data included in the review pointed toward decreased facial emotion expressivity in individuals with different non-psychotic disorders [64]. Interestingly, a

bias toward attenuated expression was also reported for people in remission and those at risk for mental illness, particularly schizophrenia [65, 66]. In two BPD studies that explored facial emotion expression with EMG and observational coding [64]. Results from both studies reported an attenuation of positive and negative facial expressions in the BPD groups [67, 68]. Two other studies examining a BPD population found no group differences for zygomaticus activity during positive emotions, but increased corrugator activity for negative emotions when pictures of disgust, anger and sadness were displayed [69, 70]. However, activity of the levator labii (a muscle of the upper lip related to disgust) was noted to not differ between groups.

As demonstrated by the aforementioned literature, a crucial aspect of social interaction and emotion regulation is engaging in facial mimicry during social interactions, which encourages empathy and functions as a social catalyst between individuals. Because mirroring facial expressions of emotion is a robust effect in healthy individuals, and generally decreased facial emotion expressivity has been documented in individuals with different non-psychotic disorders, it is of interest to determine if blunted or incongruent affect in facial mimicry is observed in individuals with a history of NSSI (HNSSI). If so, altered facial expressivity may be a contributing factor to difficulties with emotion regulation and social rejection, which can trigger or perpetuate the cycle of self-harm [15].

Although no known previous EMG studies have examined emotion mimicry with a history of NSSI population, it is known that individuals with different non-psychotic disorders generally display decreased facial emotion expressivity [64]. Given reports of relationship problems frequently experienced by those who engage in NSSI [71,72], and our previous findings of deficits at the perceptual level for recognizing impoverished fear stimuli [73], it is of interest to explore whether this group displays similar attenuation in facial emotion mimicry that may

contribute to social interaction problems. Additionally, this study seeks to investigate whether there is a correlation between facial emotion mimicry and motivations for engaging in NSSI. Emotion suppression has been identified as an emotion regulation strategy in several psychological disorders that paradoxically results in an increased emotional experience and negative relationship outcomes. Hence, it is hypothesized that those who more strongly endorse emotion regulation and social motivations for engaging in NSSI behaviours may also show less emotion mimicry responses. Investigating the mimicry behaviours of individuals who have engaged in NSSI will help further develop research into factors that contribute to the social problems observed in this population, an underdeveloped area of research in the literature. It will also help inform treatment strategies for clinicians working with the population, particularly because interpersonal difficulties are known triggers and maintaining factors for emotion dysregulation and self-injury.

4.3 Materials and methods

Participants. The study sample was composed of young adults (between 17 to 24 years of age) recruited from an undergraduate subject pool at the University of Ottawa. The University of Ottawa Ethics Review Board approved this research study. A total of 60 participants (30 HNSSI and 30 control participants) were recruited. Refer to Table 1 for demographic characteristics of the sample by group. No differences were found between HNSSI and the control groups for age, sex or ethnicity. Not surprisingly, the HNSSI group had higher rates of past comorbid depression and anxiety compared to the control group.

Table 1. Participant demographics

Variable	HNSSI group (n = 30)	Control group (n = 30)	p
Mean Age: years	18.87 ± 1.31	18.87 ± 1.31	1
Sex: male	13% (4)	17% (5)	0.72
Ethnicity: White	57% (17)	33% (10)	0.64

Past Diagnosis:			
Depression	30% (9)	3% (1)	<0.01
GAD	47% (14)	7% (2)	<0.01
PTSD	3% (1)	0% (0)	-
OCD	3% (1)	0% (0)	-
Other	3% (1)	0% (0)	-
None	43% (13)	93.3% (28)	<0.01

Eligibility criteria. Pre-screening questions were used to identify a subset of the university population who had a history of NSSI but reported no history of a BPD diagnosis. In order to be included in the HNSSI group, a participant had to have engaged in intentional self-inflicted injury to the surface of his or her body at least 5 times in their lifetime, with the expectation that the injury would lead to only minor or moderate physical harm (i.e., no suicidal intent). Pre-screening questions asked, "Have you ever intentionally self-inflicted damage to the surface of your body to cause bleeding, bruising, or pain (e.g., cutting, burning, stabbing, and/or hitting), without the intent to kill yourself? Please note that this does not include ear piercing, tattooing, circumcision, or cultural healing rituals." Potential responses included Never; Once; 2-4 times; 5 or more times. Only individuals who responded "Never" or "5 or more times" were screened in to participate as controls or HNSSI respectively. Pre-screening exclusion criteria for both HNSSI and control groups included self-injury only once or 2-4 times, as well as a self-reported diagnosis of Borderline Personality Disorder. HNSSI individuals were also excluded if their self-injury status was unclear based on their subsequent responses to the Ottawa Self Injury Inventory (OSI) or the Inventory of Statements About Self-Injury (ISAS).

All HNSSI participants reported having engaged in intentional self-inflicted injury to the surface their body at least 5 times or more within their lifetime. Nearly half of the HNSSI participants 47% (n = 14), reported thinking about self-injuring within the past month and 27%

(n = 8) had actually engaged in the behaviour within the month. Additionally, 70% (n = 21) of the HNSSI participants reported thinking about self-injuring within the past 6 months and 37% (n =11) of the sample reported actually engaging in self-injury within that period.

4.4 Measures

Socio-demographic questionnaire. This demographic questionnaire collected standard participant information such as age, gender, primary language, ethnicity, education, and current or past mental health diagnosis, health conditions, as well as medications.

The Ottawa Self Injury Inventory. This questionnaire (OSI - Functions 1.1) assessed self-injurious behaviours and their functions [74]. It is a 33-item self-report measure designed to identify the psychosocial functions of NSSI. It addressed cognitive, affective, behavioural, and environmental aspects of self-injury and requires approximately 20 minutes to complete. Example questions included "why do you think you started" and "if you continue, why do you still self-injure?" and example responses include "to release unbearable tension" or "to punish myself". Answers were provided on a 5-point scale (0 = never a reason, 2 = sometimes a reason, 4 = always a reason). This scale provided cumulative scores for the subscales of internal emotional regulation (0 to 32), external emotional regulation (0 to 12), social influence (0 to 36), and sensation seeking (0 to 12). The OSI has also been shown to be valid and reliable with excellent internal consistency scores of 0.67 to 0.87 in a university sample of young adults [75].

The Inventory of Statements About Self-Injury. This questionnaire (ISAS - Section II) assessed an individual's reasons for engaging in self-injurious behaviours [76]. Section II of this questionnaire was administered as a 39-item self-report measure that assessed an individual's reasons for engaging in self-injurious behaviours on a scale from 0 ("not relevant") to 2 ("very relevant"). Questionnaire items begin with "when I self-harm, I am…" and example responses

include “causing pain so I will stop feeling numb” or “creating a physical sign that I feel awful”. Based on previous research [77], 13 functions of NSSI were identified through this questionnaire. The scores on these 13 functions were summed (ranging from 0 to 6) to create separate factors that index interpersonal functions of NSSI (i.e., autonomy, interpersonal boundaries, interpersonal influence, peer-bonding, self-care, revenge, sensation seeking, toughness; Cronbach's alpha = 0.94) and intrapersonal functions (i.e., affect-regulation, anti-dissociation, anti-suicide, marking distress, self-punishment; Cronbach's alpha = 0.84). The interpersonal functions and intrapersonal functions factors show moderate correlation ($r = 0.40$).

4.5 Procedure

Consent. Prior to the task, and after having the study described to them verbally, participants read and signed an informed consent.

Questionnaires. All participants completed the socio-demographic questionnaire. Two additional questionnaires, the Ottawa Self Injury Inventory (OSI) and the Inventory of Statements About Self-Injury (ISAS), were completed by the HNSSI group only. If participants screened into the HNSSI group did not report any self-injury behaviours on one or both of the OSI or ISAS questionnaires, there were removed from the study sample. Additionally, if HNSSI participants reported suicidal ideation or severe harm, by endorsing Q3, Q4, Q5, or Q6 on the OSI, a suicide protocol was implemented. Furthermore, NSSI participants were all given a list of resources in the event they wished to seek further psychological support. Questionnaires were administered prior to starting the experiment to identify any participants actively engaged in suicidal ideation, and to administer the appropriate suicidal assessment protocol to these vulnerable participants. Moreover, approximately 40 minutes elapsed between completion of the questionnaires, attaching EMG sensors, and the beginning of study administration. This lengthy

time between questionnaire completion and study commencement mitigates any concerns regarding emotional arousal arising from completion of the questionnaires that might otherwise have affected participants' reactions to the study.

Instructions. During the emotion mimicry task, participants' automatic and unconscious reflections of emotional expressions were recorded via EMG measurements as they passively viewed images of emotionally expressive faces. However, to record these reactions successfully, only partial disclosure of the research intent was revealed to participants during consent and throughout testing. Participants were not explicitly informed that their emotion mimicry was being recorded with EMG electrodes. Instead, in accordance with the procedures of Achaibou, Pourtois, Schwartz, and Vuilleumier [78], and Hermans, van Wingen, Bos, Putman, and van Honk [79] participants were left blind to the exact purpose of the EMG recordings, being told only that the facial electrodes were to monitor ‘‘physiological changes’’ such as "skin conductance" and "ocular activities". Participant information remained confidential and anonymous after collection and all data were labelled using a 5-digit code.

EMG set-up. The non-invasive technique of facial electromyography (fEMG) was used to evaluate and record the physiological properties of participants' facial muscles at rest and while contracting. A Bionex™ bio-potential amplifier instrument and its electrodes (Model# 50-371102-00) were used. Facial muscle activity was measured using five Ag/AgCL miniature electrodes with a diameter of 4 mm that were externally attached to facial muscles in order to record changes in electrical potentials originating in the muscles over time and in reaction to the stimuli. Each participant's skin was cleaned with alcohol and rubbed with an abrasive exfoliating paste to remove oils and skin residue (Lemon Prep^{TM}). Pairs of electrodes were placed along the zygomaticus major and the corrugator supercilii muscle regions of the left side of the face, as

recommended by Fridlund and Cacioppo [80]. A ground electrode was also placed on the upper half of the forehead (See Fig 1 for electrode placement).

Impedances were kept below 10 kΩ using a conductive EMG-gel (Signa Gel). Electromyography Analysis Software (Model 60-0103-3.1) from MindWare Technologies, LTD. (Gahanna, Ohio) was used to record the electromyography data. The EMG signal was acquired at a rate of 1000 Hz and stored on a password protected laboratory computer.

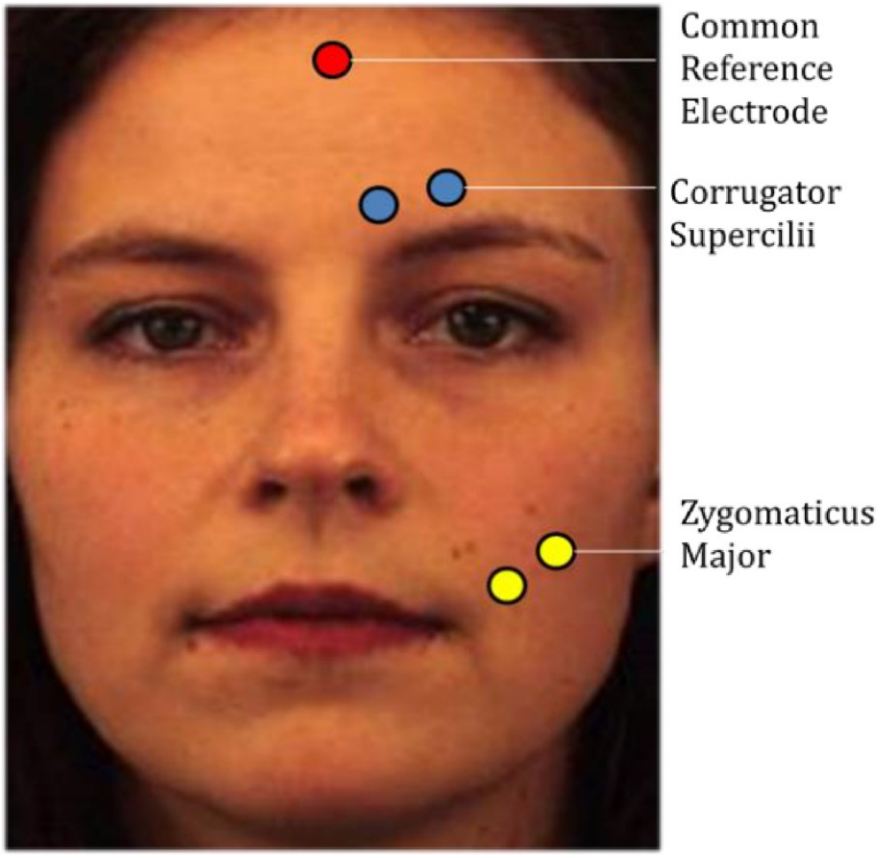


Fig 1. Electrode placement for measuring facial EMG. Guidelines from Fridlund and Cacioppo (1986) were used to determine correct electrode placement. This image is modified from the Karolinska Directed Emotional Faces database, with "AF06NES" displayed. Reprinted from Lundqvist, D., Flykt, A., & Öhman, A. under a CC BY license, with permission from the Karolinska Institutet original copyright (1998)[81].

Emotion mimicry task. Participants were asked to passively observe a series of dynamically morphing emotional face stimuli that changed from a neutral expression to one of happiness, sadness, anger, fear, disgust or surprise. While observing the morphs, participant's facial muscle activity was recorded through electromyography. Before stimulus presentation, the experimenter instructed the participants to restrict movement as much as possible, to watch the screen continuously, and to look directly at the morph stimuli. Participants were placed in a chin rest to help reduce excessive facial and body movement. The task began with participants recording a baseline measurement of a neutral, relaxed facial expression for 20 seconds while observing a fixation cross. A series of 6 practice trials, one for each emotion expression, were then provided to ensure participants were comfortable and understood the instructions to passively observe the morphing stimuli. Following this training period, participants were presented with the experimental stimuli as their facial muscle responses were recorded. A total of 144 novel facial morphing videos were presented, each separated by a 3 second inter-trial interval fixation cross stimuli. After presenting the videos, participants were again instructed to maintain a neutral expression for 20 seconds to ensure proper electrode contact was maintained throughout the experiment. Finally, following completion of the observational task, participants were instructed to produce their maximum contraction of each muscle (corrugator supercilii and zygomaticus major) individually, for three separate trials, resulting in 6 maximum contractions, each held for 4 seconds. If a participant produced a poor contraction, an additional trial was recorded. The entire task including instructions, practice and wrap-up, took approximately 15 minutes for participants to complete.

Emotion mimicry stimuli. During stimulus presentation, 150 still images were compressed, using temporal interpolation, into a video of 1.5 seconds duration to produce a

seamless progress from 0 (neutral) to 100% (prototypic expression) in 0.5 seconds, followed by a 1 second hold of the emotion expression at full intensity (Fig 2). This was done to create a realistic simulation of emotion expression dynamics and to evoke maximum facial mimicry in participants [42]. To create these morphing videos, a set of 24 identities (equal numbers of Caucasian male (12) and female (12) coloured photos) were selected from the Karolinska Directed Emotional Faces database [81] based on subjective image quality. The images were of amateur actors aged 20 to 30 years old with no beards, mustaches, earrings, or eyeglasses, and no visible makeup. Stimuli were pre-processed using the MATLAB image processing toolbox so that they all had equal overall lightness and color composition. A video of each of the 6 basic emotions was produced for each identity. Hence, all participants viewed 24 unique morphing videos per each of the 6 emotions (happy, sad, anger, fear, disgust, and surprise) resulting in the total of 144 facial morphing videos. These were viewed in random order.

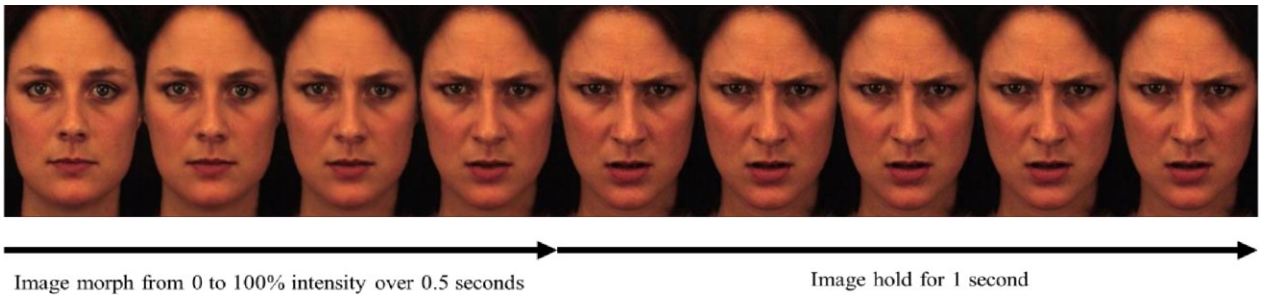


Fig 2. Emotion Mimicry Stimuli. Example stimuli intended to create a realistic simulation of dynamic emotion expressions where 150 still images were compressed into a seamless 1.5 second video progress from 0 (neutral) to 100% (prototypic expression) in 0.5 seconds then followed by a 1 second hold at full emotion intensity. These images were modified from the Karolinska Directed Emotional Faces database, with “AF01NES” and “AF01ANS” displayed. Reprinted from Lundqvist, D., Flykt, A., & Öhman, A. under a CC BY license, with permission from the Karolinska Institutet original copyright (1998)[81].

Debriefing. Upon study completion, participants were given a debriefing form describing the true purpose of the EMG electrodes. Participants were then provided with the opportunity to provide complete informed consent, thus allowing for inclusion of their data in the study if they agreed, or withdrawal of their data from the study if they did not. All participants opted to have their data included. All subjects were also asked to indicate if they were aware of the true intent to record their facial muscle responses and of any (voluntary or involuntary) facial mimicry that they perceived. The HNSSI (M = 0.47, SD = 0.51) and control groups (M = 0.57, SD = 0.51) did not significantly differ in their level of awareness of the true purpose of the facial muscle recordings $t(58) = -0.77$, $p = 0.45$. Similarly, the HNSSI (M = 0.43, SD = 0.51) and control groups (M = 0.57, SD = 0.51) did not differ in their self-perception of facial muscle mimicry $t(58) = -1.03$, $p = 0.31$.

EMG data reduction. Off-line analyses of the EMG activity were conducted with MATLAB. The raw signal was filtered with a band-pass filter between 30 Hz to 500 Hz with a 60 Hz notch filter to account for the frequency of the connected power supply and any external electrical activity. Subsequently, the data was rectified by implementing a Hilbert rectification to conserve all signal energy and convert the signal to positive polarity [82]. A baseline correction was then applied by subtracting mean signal amplitude from the 2 s prior to stimulus presentation for each epoch. An epoch rejection algorithm was then applied to the data using 3 SD from the mean as a rejection criterion and a 50-ms shift. Visual inspection of the data was used to confirm the effectiveness of the artifact rejection process. The rejection rate was < 5% of cases for both the corrugator and zygomaticus signals. The EMG signal was smoothed using a 250 ms moving average, and EMG activity over the 24 trials for each of the six emotion conditions were collapsed and averaged for each participant. This allowed us to compare EMG

activity across time during the 1500 ms stimulus presentation. The processed EMG data was then imported into SPSS 24 for further statistical analysis.

4.6 Data analysis

Power analysis. A priori power analyses were conducted using GPower 3.1.9.2 to determine the sample size required for adequate power to detect predicted differences. Several prior studies have used EMG recordings to elicit emotion mimicry reactions in various non-psychiatric populations. A meta-analysis, by Davies et al. [64] examining facial reactions to emotionally expressive face stimuli, reported Cohen's D effect sizes based on the activation of the zygomaticus muscle in response to emotion stimuli. These Cohen's D values varied between 0.06 and 0.78, depending on the study and population tested [83 – 87]. Likewise, the Cohen's D effect sizes reported in the meta-analysis for the activation of the corrugator muscle varied widely, between 0.08 to 0.66, depending on the study [84, 86, 88]. Due to the variability in the effect sizes reported above, a medium effect size f = 0.25 (Cohen's D = 0.5) was selected. Additional parameters entered into the analysis were a power of 0.8, an α of 0.05, and a mixed factorial design with a 2 (NSSI and Control, between subjects) x 6 (happy, sad, anger, fear, disgust, and surprise, within subjects) structure. The power analysis yielded an estimated minimum total sample size of 20 participants (10 control and 10 NSSI).

A second a priori power analysis was calculated using GPower 3.1.9.2 to determine the minimum sample size needed to detect a possible correlation between emotion mimicry, as measured by fEMG amplitude values, and motivations for engaging in NSSI, obtained by the OSI and ISAS questionnaires. Given that little research has been previously conducted to inform the selected effect size, a medium Cohen's effect size for Pearson's r (Correlation □ H1 = 0.31) was selected with a power of 0.8 and α of 0.05 for a two-tailed correlational analysis. This

calculation yielded a total sample size of 79 NSSI participants. Given that a smaller than predicted sample size was recruited due to population limitations, it is possible that the study may not have achieved sufficient power to observe the hypothesized effects for the second analysis. With our samples size of 30 participants, α of 0.05 and power of 0.8, GPower 3.1.9.2 predicted the minimum correlations size that could be detected as significant would be 0.485.

4.7 Results

Emotion mimicry. To analyze between-groups differences in the degree of facial EMG elicited in participants in response to observing the various emotional expression stimuli, a series of 12 planned contrasts were conducted between the HNSSI group and the control group, one for each of the 6 emotions presented and each of the 2 muscles whose activity was measured [89]. The error term for these analyses were taken from a series of 2 (Group: NSSI vs. controls) x 6 (Time bin: 0-250 ms, 251-500 ms, 501-750 ms, 751-1000 ms, 1000 ms-1250 ms, 1251- 1500 ms) x 6 facial expression categories (happy, sad, anger, fear, disgust, surprise) mixed ANOVAs, one for each of the 2 facial muscles (refer to Tables 2 and 3).

Table 2. Calculation of error term from mixed factorial ANOVA for corrugator supercilii EMG activity.

Source	*df*	*MS*	*F*	η^2_p	*p*
Group	1	5.304^{e-5}	3.400^{e-5}	5.877^{e-7}	0.995
Emotion	2.56	10.02	11.27	0.163	< 0.001
Emotion x Group	2.56	1.766	1.988	0.033	0.128
Error	148.48	0.888			
Time	2.282	1.94	4.205	0.068	0.013
Time x Group	2.282	0.103	0.222	0.004	0.829
Error	132.33	0.461			

Emotion x Time	7.498	1.096	5.925	0.093	< 0.001
Emotion x Time x Group	7.498	0.258	1.396	0.024	0.200
Error	434.90	0.185			

In order to obtain the error term for the planned contrasts conducted between the HNSSI and the control groups for the corrugator supercilii muscle [89], a 2 (Group: NSSI or Control) × 6 (Time bin: 0-250 ms, 251-500 ms, 501-750 ms, 751-1000 ms, 1000 ms-1250 ms, 1251- 1500 ms) x 6 (Facial expression category: happy, sad, anger, fear, disgust, surprise) mixed factorial ANOVA was conducted. Mauchly's test indicated that the assumption of sphericity had been violated, and therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon < 0.75$).

Table 3. Calculation of error term from mixed factorial ANOVA for zygomaticus major EMG activity.

Source	*df*	*MS*	*F*	η^2_p	*p*
Group	1	0.034	0.155	0.003	0.695
Emotion	3.979	0.101	0.515	0.009	0.724
Emotion x Group	3.979	0.119	0.603	0.010	0.660
Error	230.77	0.197			
Time	2.849	0.078	2.390	0.040	0.074
Time x Group	2.849	0.062	1.906	0.032	0.134
Error	165.22	0.032			
Emotion x Time	4.336	0.054	0.674	0.011	0.623
Emotion x Time x Group	4.336	0.040	0.494	0.008	0.755
Error	251.51	0.081			

The error term for the planned contrasts conducted between the HNSSI and the control groups for the zygomaticus major muscle [89], a 2 (Group: NSSI or Control) × 6 (Time bin: 0-

250 ms, 251-500 ms, 501-750 ms, 751-1000 ms, 1000 ms-1250 ms, 1251- 1500 ms) x 6 (Facial expression category: happy, sad, anger, fear, disgust, surprise) mixed factorial ANOVA was conducted. Mauchly's test indicated that the assumption of sphericity had been violated, and therefore the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon < 0.75$).

Thus, for each of the two facial muscles, six planned contrasts were performed, one for each emotion across time. Considering that only a small number of planned contrasts were conducted relative to the total number of possible comparisons, the alpha level was not adjusted and remained at $\alpha=0.05$ [89]. Effect sizes for contrasts were measured using correlation coefficient *r* [89]. The results of these contrast analyses are reported in the text.

The planned contrasts revealed attenuated EMG activity in the corrugator supercilii within the HNSSI group in response to the anger stimuli ($F [1, 434.89] = 7.04$, $p < 0.008$, $r = 0.126$). Likewise, the response of the corrugator supercilii was analyzed during presentation of happy facial stimuli. The typical mimicry behaviour of the corrugator supercilii is to decrease activity in response to happy faces [28]. Planned contrasts were again used to compare EMG activity of the corrugator supercilii between groups and also revealed attenuated EMG activity of the HNSSI group throughout the presentation of the happy stimuli ($F [1, 434.89] = 15.84$, $p < 0.000$, $r = 0.187$), as indicated by the negative polarity of the signal representing a decrease in activity, or relaxation, compared to baseline.

These results illustrate that the HNSSI group did not exhibit as strong a mimicry response in the corrugator supercilii muscle when observing angry and happy emotion stimuli, as compared to the control group in response to the same stimuli (Fig 3).

The EMG activity of corrugator supercilii was also analyzed in response to the presentation

of the remaining four emotions (sadness, fear, surprise and disgust), but no statistically significant results were observed. Similarly, the response of the zygomaticus major was compared between the HNSSI and control groups in response to viewing all six emotions. Little mimicry was observed in this muscle in response to the stimuli presented and no statistically significant differences were observed between the HNSSI and control groups.

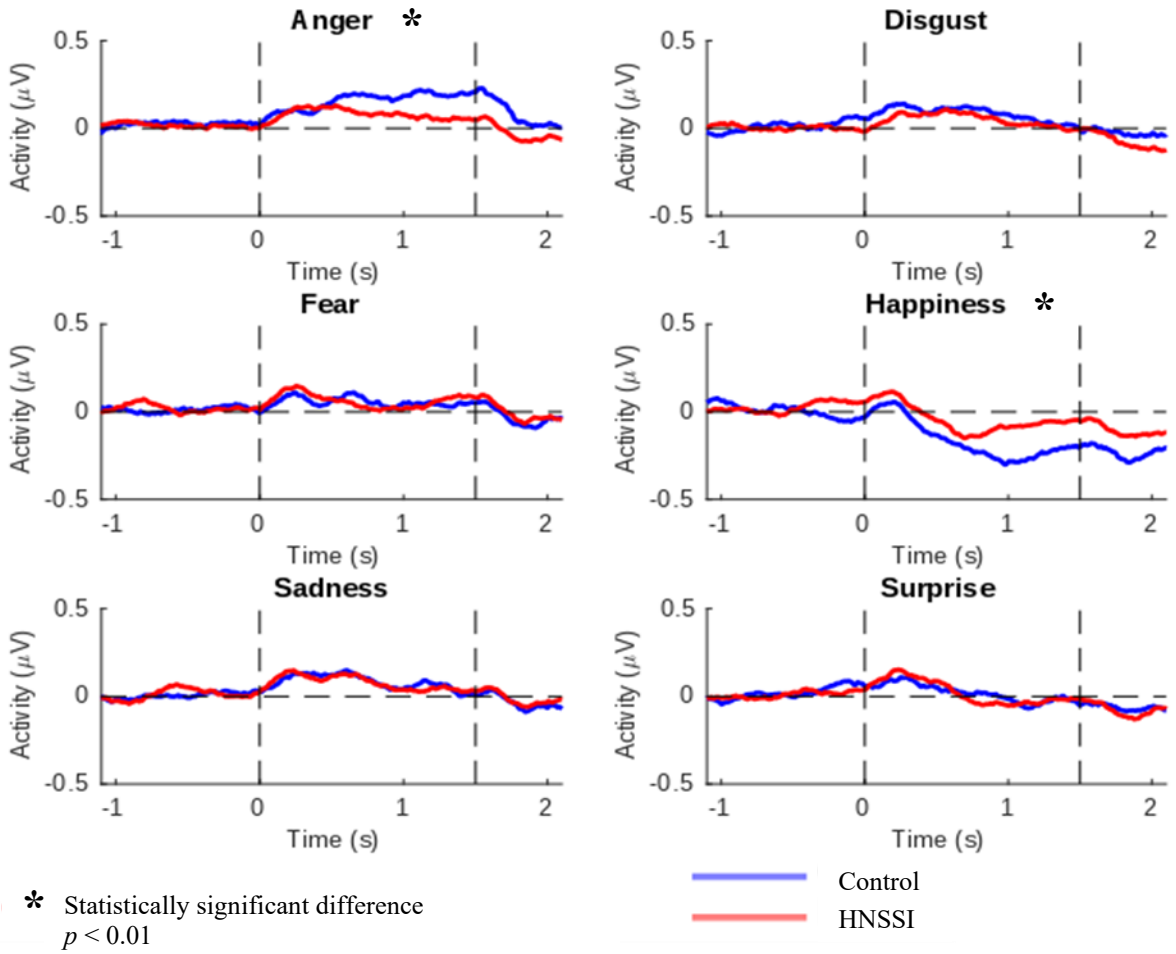


Fig 3. Facial EMG activity of control and HNSSI participants in the corrugator supercilii muscle. Positive values indicate increased activity compared to baseline and negative values indicate decreased activity compared to baseline, signaling muscle relaxation. The HNSSI participants showed less corrugator supercilii activity in response to viewing angry facial stimuli

and less of an expected decrease in activity of the corrugator supercilii in response to viewing happy faces.

Emotion mimicry and NSSI functions. Correlational analyses were conducted to determine if zygomatic and corrugator EMG activity in response to viewing facial expressions of emotion were linked to the functions reported by HNSSI participants for engaging in the behaviour. In particular, scores for the internal emotion regulation and social influence functions of the OSI questionnaire and scores for the affect regulation and peer bonding functions of the ISAS questionnaire were analyzed for their degree of correlation with participant's overall zygomatic and corrugator EMG activity in response to viewing happy and angry facial stimuli. Correlation results for the OSI questionnaire showed that scores of emotion regulation as a motivation for engaging in NSSI were positively related to stronger contraction of the corrugator muscle in response to viewing happy facial expressions ($r = 0.375$, $p = 0.04$). Recall that the typical behaviour of the corrugator supercilii in response to viewing happy faces is to relax. Hence, this response shows greater incongruent facial mimicry than would be typically expected with greater endorsement of emotion regulation as a motivation for self-injury. In contrast, the social influence scale of the OSI was negatively correlated with zygomatic EMG muscle activity in response to viewing happy facial expressions ($r = -0.382$, $p = 0.04$). This result suggests that greater endorsement of the social influence motivation is associated with less mimicry. Likewise, peer bonding as a motivator for engaging in NSSI, as measured by the ISAS, showed a trend toward negatively correlating with EMG activity of the corrugator muscle in response to viewing angry facial expressions ($r = -0.361$, $p = 0.05$). These findings provide preliminary evidence that engaging in NSSI as a means to socially influence or bond with others may be linked with reduced mimicry of the zygomatic and corrugator facial muscles.

4.8 Conclusion

To our knowledge, the present study is the first to investigate the facial mimicry responses of an HNSSI population in reaction to observing realistic depictions of emotional facial expressions. Several findings emerged from this study. First, attenuated EMG activity was observed in the corrugator supercilii in our HNSSI sample in response to observing angry and happy facial expressions of emotion. Second, we found evidence in support of the hypothesis that different motivations for engaging in NSSI are associated with different facial reactions to observing facial expressions of emotion. Specifically, the more strongly individuals with a history of NSSI endorsed self-injury as a means of social influence, the less mimicry they exhibited in response to happy and angry stimuli in the zygomaticus major and the corrugator supercilii, respectively. Furthermore, in HNSSI individuals, the degree to which emotion regulation was endorsed as a motivation for self-injury was found to be correlated with an incongruent mimicry response of the corrugator facial muscle in response to happy stimuli.

These findings support the hypothesis that social interaction difficulties of those who have engaged in NSSI may be related to implicit violations of expected social rules through facial mimicry nonconformity. That is, the non-verbal signs of facial emotion mimicry induced by facial stimuli are atypical in HNSSI participants compared to controls, and this divergence could play an important role in the disturbed social interactions reported by many individuals who have engaged in self-injury [90-92]. The first diverging mimicry response observed in the HNSSI group was the attenuated response in the corrugator supercilii muscle when viewing angry faces. The expected contraction of this muscle was significantly less compared to the control group. Additionally, in response to viewing happy faces, the corrugator muscle of the HNSSI group showed significantly less of an expected relaxation compared to the control group.

Recall that a relaxation of the corrugator is a consistently observed response in this muscle when viewing happy faces [28, 29, 30, 31]. The contraction and relaxation of the corrugator in response to these two emotions are typically observed in the emotion mimicry literature, yet the HNSSI group showed less of a response.

One possible explanation for the finding of attenuated facial mimicry in HNSSI individuals stems from Linehan's (1993) theory as to the etiology of this behaviour. According to Linehan, the creator of dialectical behavior therapy for BPD, people engage in self-injurious behaviours because they do not appropriately recognize or manage negative emotions that arise from aversive mental states or external events. This inability to manage negative emotions is hypothesized to be the result of both a biological disposition and an emotionally invalidating environment, in which a child's emotions (particularly negative emotions) were neither recognized nor validated by their parents. Consequently, children whose emotions were either ignored or even punished, likely failed to develop adaptive strategies to regulate their feelings and learned to use NSSI as a way to restore their emotional arousal to a tolerable level [93]. These children may have also learned to hide their overt facial expressions, causing the degree to which they also reflexively mimic expressions or produce micro-expressions to become suppressed later on.

Based on this theory one can posit that, because facial expressions communicate intent, individuals raised in an emotionally invalidating environment might have learned to adopt a more consistently neutral facial expression as a means to protect themselves from rejection by being less "visible" to their interaction partners, and by being perceived as less engaged in interactions. That is, since showing signs of emotion leaves a person vulnerable, particularly if the emotion displayed is not reciprocated or is dismissed by others as invalid or inappropriate,

reduced facial expression mimicry may be a way for HNSSI individuals to protect themselves from signs of social rejection or scrutiny [94].

While the above explanation works well with regards to reduced mimicry of negative stimuli (e.g., angry faces), it is less clear why individuals with a history of NSSI would also mimic positive emotions less (e.g., happy faces) by relaxing the brow. Mimicking negative emotions tends to be viewed more negatively by others [51], so suppressing one's tendency to reflect them makes sense as a measure for avoiding rejection or negative judgment. However, mimicking of positive emotions tends to be viewed positively and to increase feelings of liking and affiliation from others [20, 21], so it is less clear why those with a history of NSSI would exhibit reduced mimicry in this case. One possibility is that these individuals have taken on a general strategy of not displaying any emotion, so as to hide all information about their emotional status from others. This strategy might be considered adaptive to hide one's negative emotional states. This in turn may explain the trend in our results showing that peer bonding as a motivator for NSSI is associated with less EMG activity in the corrugator muscle in response to viewing angry facial expressions. However, in a situation where exhibiting a positive emotion may be socially expected, not doing so could easily be interpreted by others as reflecting an overall negative state. Again, our results found that greater endorsement of social influence as a motivator for engaging in NSSI was associated with less activity in the zygomatic muscle in response to viewing happy facial stimuli. In short, HNSSI individuals may have learned to hide their reflection of all emotions as a form of self-protection.

Considered through this lens, it becomes clear how such a self-reinforcing pattern of reduced spontaneous mimicry of facial expressions could contribute to ongoing social interaction difficulties frequently reported by individuals with a HNSSI [69, 95]. This hypothesis might be

taken to predict attenuated responses to all the emotions presented. However, our study showed only the typically observed results of mimicry effects in the corrugator supercilii muscles in response to angry and happy emotion stimuli [22]. Recall that the majority of studies have found elevated activity in the zygomaticus major and corrugator supercilii muscles in response to happy and angry facial expressions respectively [22], and many studies have found relaxation of the corrugator supercilii in response to happy faces [28, 29, 30, 31]. Although some studies report corrugator activity to other emotions presented, we did not observe these differences. The fact that corrugator activity to emotions other than happiness and anger is only observed in some studies and not others may indicate that these effects are weak, which may in turn explain why we did not observe them. To investigate the above hypothesis further, other muscle groups that may better index the mimicry responses of disgust, sadness, fear and surprise should be examined. As such, future investigations into mimicry differences are encouraged to record activity in the frontalis for fear and surprise, the levator labii for disgust, and the mentalis for sadness. Recordings in these muscle groups may prove to be a better index for the mimicry response of these emotions and could further highlight possible group differences like those seen in the corrugator.

Another potential explanation for our results may be that some individuals with HNSSI have a greater tendency to exhibit mixed or ambiguous facial emotion expressions. Staebler et al. [70], found that a sample of participants with a diagnosis of BPD, as compared to healthy controls, tended to more often exhibit a blend of basic emotional expressions (e.g., flexing both the zygomaticus major and the corrugator supercilii) when faced with situations inducing feelings of inclusion or rejection. If this finding generalizes to the motivations for why people engage in NSSI, then it may be the case that those who more strongly endorsed emotion

regulation as a motivation for NSSI in our sample were more likely to have an incongruent muscle response of contracting the corrugator muscle, as opposed to relaxing it, when viewing happy stimuli because their muscles reflected an experience of mixed emotions in response to signs of social inclusion. This hypothesis could be a suggestion for future research, as a greater number of research participants would be needed to fully investigate this theory. Also note that this explanation is not mutually exclusive to one based on incongruent mimicry. Indeed, it could well be that our results reflect some combination of attenuated and incongruous mimicry on the part of individuals with HNSSI. Either of these kinds of behaviours, or any combination of them, would be expected to lead to difficulties with social interactions.

Like all studies, several limitations of the current study need to be considered in interpreting its results. First, due to the cross-sectional design of this study, and the analysis using correlational methods, we cannot ascertain causation from the results. Second, the self-reported data collected from participants is inherently vulnerable to response bias. Since self-harm is a sensitive topic, participants may have been reluctant to report honestly about their self-injuring behaviours or motivations for engaging in the behaviour. Also, some participants may have felt stigma for endorsing interpersonal functions, such as eliciting attention from others, and thus may have under-reported interpersonal reasons as a motivation for self-injury. Third, our sample was collected from university students, which limits the generalizability of these results to other populations. Fourth, as NSSI is highly co-morbid with other disorders, it is pervasive in the literature that studies investigating NSSI include participants who have current or past co-morbid disorders. Although our sample size did not allow for examination of the potential confounding variable of comorbidity, it will be important for future studies to describe any possible influence of comorbid disorders on HNSSI emotion mimicry responses. Fifth, because

this study is the first of its kind, our data need to be replicated in an independent and larger sample before they can be considered definitive.

Since a history of self-injury is an important clinical marker for increased risk of suicide, it is especially pertinent to better understanding its etiology [96]. Social dysfunctions are known to play an important role in initiating NSSI [77], and continued difficulties with social interactions often maintain the behaviour [19]. However, research into fully understanding the factors that contribute to these social interaction difficulties in NSSI is still in its infancy. Results from this study provide support for the recommendation to place greater emphasis on appropriate emotion expression and social skills training when working with this population as a complement to existing treatment approaches for NSSI in clinical practice.

4.9 References

1. Nock, MK. Understanding nonsuicidal self-injury: Origins, assessment, and treatment. American Psychological Association; 2009.
2. Klonsky, ED. Non-suicidal self-injury in United States adults: prevalence, sociodemographics, topography and functions. Psychological medicine. 2011;41(9): 1981-6. doi: 10.1017/S0033291710002497
3. American Psychiatric Association. Diagnostic and statistical manual of mental disorders (DSM-5®). American Psychiatric Pub; 2013 May 22.
4. Lloyd-Richardson, EE, Perrine, N, Dierker, L, Kelley, ML. Characteristics and functions of non-suicidal self-injury in a community sample of adolescents. Psychological medicine. 2007;37(8):1183–92. doi: 10.1017/S003329170700027X
5. Jacobson, CM, Gould, M. The epidemiology and phenomenology of non-suicidal self-injurious behavior among adolescents: A critical review of the literature. Archives of Suicide Research. 2007; 11(2), 129–47. doi: 10.1080/13811110701247602
6. Muehlenkamp, J.J, Claes, L, Havertape, L, Plener, PL. International prevalence of adolescent non-suicidal self-injury and deliberate self-harm. Child and adolescent psychiatry and mental health. 2012;6(1):10. doi: 10.1186/1753-2000-6-10
7. Klonsky, ED, Muehlenkamp, JJ. Self-injury: A research review for the practitioner. Journal of Clinical Psychology. 2007;63(11):1045-56. doi: 10.1002/jclp.20412
8. Klonsky ED, May AM, Glenn CR. The relationship between nonsuicidal self-injury and attempted suicide: Converging evidence from four samples. Journal of abnormal psychology. 2013;122(1):231. doi: 10.1037/a0030278
9. Whitlock J, Muehlenkamp J, Eckenrode J, Purington A, Abrams GB, Barreira P, Kress V. Nonsuicidal self-injury as a gateway to suicide in young adults. Journal of adolescent health. 2013;52(4):486-92. doi: 10.1016/j.jadohealth.2012.09.010
10. Klonsky, ED. The functions of deliberate self-injury: A review of the evidence. Clinical psychology review. 2007;27(2):226–39. doi: 10.1016/j.cpr.2006.08.002
11. Nock, MK, Prinstein, MJ. A functional approach to the assessment of self-mutilative behavior. Journal of consulting and clinical psychology. 2004:72(5), 885–90. doi: 10.1037/0022-006X.72.5.885
12. Nock, MK, Prinstein, MJ. Contextual features and behavioral functions of self-mutilation among adolescents. Journal of abnormal psychology. 2005;114(1):140–6. doi: 10.1037/0021-843X.114.1.140
13. Miller, AB, Linthicum, KP, Helms, SW, Giletta, M, Rudolph, KD, Hastings, PD, Nock, MK, Prinstein, MJ. Reciprocal associations between adolescent girls' chronic interpersonal stress and nonsuicidal self-injury: A multi-wave prospective investigation. Journal of adolescent health. 2018; 63(6):694-700. doi: 10.1016/j.jadohealth.2018.06.033
14. Nock, MK. Self-injury. Annual review of clinical psychology. 2010;6:339-63. doi: 10.1146/annurev.clinpsy.121208.131258
15. In-Albon, T, Bürli, M, Ruf, C, Schmid, M. Non-suicidal self-injury and emotion regulation: A review on facial emotion recognition and facial mimicry. Child and adolescent psychiatry and mental health. 2013; 7, 1-11. doi: 10.1186/1753-2000-7-5.
16. Hall, ET. The silent language. Garden City, NY: Double Day;1959.

17. Hess, U, Bourgeois, P. You smile–I smile: Emotion expression in social interaction. Biological psychology. 2010;84(3):514-20. doi: 10.1016/j.biopsycho.2009.11.001.
18. Nock, MK. Why do people hurt themselves? New insights into the nature and function of self-injury. Current directions in psychological science. 2009;18(2):78–83. doi: 10.1111/j.1467-8721.2009.01613.x
19. Nock, MK, Mendes, WB. Physiological arousal, distress tolerance, and social problem-solving deficits among adolescent self-injurers. Journal of consulting and clinical psychology. 2008;76(1):28-38. doi: 10.1037/0022-006X.76.1.28.
20. Hatfield, E, Cacioppo, JT, Rapson, RL. Emotional contagion: Studies in emotion and social interaction. Cambridge: Cambridge University Press; 1994.
21. Dimberg, U, Thunberg, M, Elmehed, K. Unconscious facial reactions to emotional facial expressions. Psychological science. 2000;11(1):86-9. doi: 10.1111/1467-9280.00221
22. Hess, U, Fischer, A. Emotional mimicry as social regulation. Personality and social psychology eview, 2013;17(2):142-157. doi:10.1177/1088868312472607
23. Dimberg, U. Facial reactions to facial expressions. Psychophysiology. 1982;19(6):643–7. doi: 10.1111/j.1469-8986.1982.tb02516.x
24. van Boxtel, AV. Zygomatic muscle. In: Sander, D, Scherer, KR, (Eds.), The Oxford companion to emotion and the affective sciences (pp. 419). Oxford: Oxford University Press; 2009 .
25. van Boxtel, AV. Zygomatic muscle. In: Sander, D, Scherer, KR, (Eds.), The Oxford companion to emotion and the affective sciences (pp. 105). Oxford: Oxford University Press; 2009.
26. Jiang, M., Rahmani, AM, Westerlund, T, Liljeberg, P, Tenhunen, H. (2015, October). Facial Expression Recognition with sEMG Method. In Computer and Information Technology; Ubiquitous Computing and Communications; Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing, 2015 IEEE International Conference, 981-8.
27. Gosselin, P., Kirouac, G. Le décodage de prototypes émotionnels faciaux / The decoding of facial emotional prototypes. Canadian Journal of Experimental Psychology / Revue Canadienne De Psychologie Expérimentale. 1995;49(3):313-29. doi:10.1037/1196-1961.49.3.313
28. Lundqvist, L, Dimberg, U. Facial expressions are contagious. Journal of psychophysiology. 1995;9:203-11. doi:10.1016/S0167-8760(97)85514-6
29. Hietanen JK, Kylliäinen A, Peltola MJ. The effect of being watched on facial EMG and autonomic activity in response to another individual's facial expressions. Scientific reports. 2019;9(1):1-10. doi: 10.1038/s41598-019-51368-6
30. Hess U, Arslan R, Mauersberger H, Blaison C, Dufner M, Denissen JJ, Ziegler M. Reliability of surface facial electromyography. Psychophysiology. 2017;54(1):12-23. doi: 10.1111/psyp.12676
31. Hühnel I, Kuszynski J, Asendorpf JB, Hess U. Emotional mimicry of older adults' expressions: effects of partial inclusion in a Cyberball paradigm. Cognition and Emotion. 2018;32(1):92-101. doi:10.1080/02699931.2017.1284046
32. Dimberg UL, Petterson M. Facial reactions to happy and angry facial expressions: Evidence for right hemisphere dominance. Psychophysiology. 2000;37(5):693-6.

33. Lundqvist, LO. Facial EMG reactions to facial expressions: A case of facial emotional contagion?. Scandinavian journal of psychology. 1995;36(2):130-41. doi: 10.1111/j.1467-9450.1995.tb00974.x
34. Scarpazza C, Làdavas E, Cattaneo L. Invisible side of emotions: somato-motor responses to affective facial displays in alexithymia. Experimental brain research. 2018;236(1):195-206. doi: 10.1007/s00221-017-5118-x
35. van der Schalk, J, Fischer, A, Doosje, B, Wigboldus, D, Hawk, S, Rotteveel, M, Hess, U. Convergent and divergent responses to emotional displays of ingroup and outgroup. Emotion. 2011;11(2):286-98. doi: 10.1037/a0022582
36. Likowski KU, Mühlberger A, Seibt B, Pauli P, Weyers P. Modulation of facial mimicry by attitudes. Journal of experimental social psychology. 2008;44(4):1065-72. doi: 10.1016/j.jesp.2007.10.007
37. Weyers P, Mühlberger A, Kund A, Hess U, Pauli P. Modulation of facial reactions to avatar emotional faces by nonconscious competition priming. Psychophysiology. 2009;46(2):328-35. doi: 10.1111/j.1469-8986.2008.00771.x
38. Rymarczyk K, Żurawski Ł, Jankowiak-Siuda K, Szatkowska I. Emotional empathy and facial mimicry for static and dynamic facial expressions of fear and disgust. Frontiers in psychology. 2016;7:1853. doi: /10.3389/fpsyg.2016.01853
39. Rymarczyk K, Żurawski Ł, Jankowiak-Siuda K, Szatkowska I. Empathy in facial mimicry of fear and disgust: simultaneous EMG-fMRI recordings during observation of static and dynamic facial expressions. Frontiers in psychology. 2019;10:701. doi: 10.3389/fpsyg.2019.00701
40. Neta M, Norris CJ, Whalen PJ. Corrugator muscle responses are associated with individual differences in positivity-negativity bias. Emotion. 2009;9(5):640. doi: 10.1037/a0016819
41. Zhu Y, Suzuki N. Your Face is Even More Surprised Than You Are: Evidence from Facial Electromyographic Activity Exposing the Genuine Surprise. The north american journal of psychology. 2016;18(1):45-58.
42. Rymarczyk, K., Biele, C., Grabowska, A., Majczynski, H. EMG activity in response to static and dynamic facial expressions. International Journal of Psychophysiology. 2011; 79, 330–3. doi: 10.1016/j.ijpsycho.2010.11.001
43. Rymarczyk, K, Żurawski, Ł, Jankowiak-Siuda, K, Szatkowska, I. Do dynamic compared to static facial expressions of happiness and anger reveal enhanced facial mimicry?. PLoS One. 2016;11(7):e0158534.
44. Chartrand, TL, Bargh, JA. The chameleon effect: The perception-behaviour link and social interaction. Journal of personality and social psychology. 1999;76(6):893-910. doi:10.1037/0022-3514.76.6.893
45. Niedenthal, PM, Mermillod, M, Maringer, M, Hess, U. The simulation of smiles (SIMS) model: Embodied simulation and the meaning of facial expression. Behavioural and brain sciences. 2010;33(6):417-80. doi:10.1017/S0140525X10000865.
46. Zajonc, RB, Muphy, ST, Inglehart, M. Feeling and facial efference: Implications of the vascular theory of emotion. Psychological review. 1989;96(3):395-416. doi: 10.1037/0033-295X.96.3.395
47. Fischer, AH, Becker, D, Veenstra, L. Emotional mimicry in social context: The case of disgust and pride. Frontiers in psychology. 2012;3:475. doi: 10.3389/fpsyg.2012.00475

48. Bourgeois, P, Hess, U. The impact of social context on mimicry. Biological psychology. 2008;77(3):343-52. doi: 10.1016/j.biopsycho.2007.11.008.
49. Moody, EJ, McIntosh, DN, Mann, LJ, Weisser, KR. More than mere mimicry? The influence of emotion on rapid facial reactions to faces. Emotion. 2007;7(2):447-57. doi: 10.1037/1528-3542.7.2.447
50. Likowski, KU, Mühlberger, A, Seibt, B, Pauli, P, Weyers, P. Modulation of facial mimicry by attitudes. Journal of experimental social psychology. 2008;44(4):1065-72. doi:10.1016/j.jesp.2007.10.007
51. Van Kleef, GA. How emotions regulate social life: The emotions as social information (EASI) model. Current directions in psychological science. 2009;18(3):184-8. doi:10.1111/j.1467-8721.2009.01633.x
52. Hess U, Fischer AH, editors. Emotional mimicry in social context. Cambridge University Press; 2016 Mar 11.
53. Butler EA, Egloff B, Wlhelm FH, Smith NC, Erickson EA, Gross JJ. The social consequences of expressive suppression. Emotion. 2003 ;3(1):48-67. doi:10.1037/1528-3542.3.1.48
54. Oberman, LM, Winkielman, P, Ramachandran, VS. Face to face: Blocking facial mimicry can selectively impair recognition of emotional expressions. Social neuroscience. 2007;2(3-4):167-178. doi: 10.1080/17470910701391943.
55. Maringer, M, Krumhuber, EG, Fischer, AH, Niedenthal, PM. Beyond smile dynamics: Mimicry and beliefs in judgments of smiles. Emotion. 2011;11(1):181-7. doi: 10.1037/a0022596
56. Lydon, DM, Nixon, E. Facial mimicry interference affects reaction time but not accuracy on an emotion recognition task in children, adolescents and adults. The Irish Journal of psychology. 2014;35(2-3):106-20. doi: 10.1080/03033910.2014.982145
57. Hess, U, Blairy, S. Facial mimicry and emotional contagion to dynamic emotional facial expressions and their influence on decoding accuracy. International journal of psychophysiology. 2001;40(2):129-41. doi: 10.1016/s0167-8760(00)00161-6
58. Roemer L, Litz BT, Orsillo SM, Wagner AW. A preliminary investigation of the role of strategic withholding of emotions in PTSD. Journal of traumatic stress. 2001;14(1):149-56. doi: 10.1023/A:1007895817502
59. Wastell CA. Exposure to trauma: The long-term effects of suppressing emotional reactions. The Journal of nervous and mental disease. 2002;190(12):839-45. doi: 10.1097/00005053-200212000-00006
60. Piran N, Cormier HC. The social construction of women and disordered eating patterns. Journal of counseling psychology. 2005;52(4):549-58. doi: 10.1037/0022-0167.52.4.549
61. Waller G, Babbs M, Milligan R, Meyer C, Ohanian V, Leung N. Anger and core beliefs in the eating disorders. International journal of eating disorders. 2003;34(1):118-24. doi: 10.1002/eat.10163
62. Gross JJ, John OP. Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. Journal of personality and social psychology. 2003;85(2):348-62. doi: 10.1037/0022-3514.85.2.348
63. Kopper BA, Epperson DL. The experience and expression of anger: Relationships with gender, gender role socialization, depression, and mental health functioning. Journal of counseling psychology. 1996;43(2):158-65. doi: 10.1037/0022-0167.43.2.158

64. Davies, H, Wolz, I, Leppanen, J, Fernandez-Aranda, F, Schmidt, U, Tchanturia, K. Facial expression to emotional stimuli in non-psychotic disorders: A systematic review and meta-analysis. Neuroscience & biobehavioural reviews. 2016;64:252-71. doi: 10.1016/j.neubiorev.2016.02.015
65. Mattes, RM, Schneider, F, Heimann, H, Birbaumer, N. Reduced emotional response of schizophrenic patients in remission during social interaction. Schizophrenia research. 1995;17(3):249-55. doi: 10.1016/0920-9964(95)00014-3
66. Walker, EF, Grimes, KE, Davis, DM, Smith, AJ. Childhood precursors of schizophrenia: Facial expressions of emotion. The American journal of psychiatry. 1993;150:1654-60. doi: 10.1176/ajp.150.11.1654
67. Herpertz, SC, Werth, U, Lukas, G, Qunaibi, M, Schuerkens, A, Kunert, HJ, Freese, R, Flesch, M, Mueller-Isberner, R, Osterheider, M, Sass, H. Emotion in criminal offenders with psychopathy and borderline personality disorder. Archives of general Ppsychiatry. 2001;58(8):737-45. doi: 10.1001/archpsyc.58.8.737
68. Renneberg, B, Heyn, K, Gebhard, R, Bachmann, S. Facial expression of emotions in borderline personality disorder and depression. Journal of behaviour therapy and experimental psychiatry. 2005;36(3):183-96. doi: 10.1016/j.jbtep.2005.05.002
69. Matzke, B, Herpertz, SC, Berger, C, Fleischer, M, Domes, G. Facial reactions during emotion recognition in borderline personality disorder: A facial electromyography study. Psychopathology. 2014;47(2):101-10. doi: 10.1159/000351122
70. Staebler, K, Renneberg, B, Stopsack, M, Fiedler, P, Weiler, M, Roepke, S. Facial emotional expression in reaction to social exclusion in borderline personality disorder. Psychological medicine. 2011;41(9):1929-38. doi: 10.1017/S0033291711000080
71. Lundh, LG, Wangby-Lundh, M, Bjärehed, J. Deliberate self-harm and psychological problems in young adolescents: evidence of a bidirectional relationship in girls. Scandinavian journal of psychology. 2011;52(5):476–83. doi:10.1111/j.1467-9450.2011.00894.x.
72. Lundh, LG, Wångby-Lundh, M, Paaske, M, Ingesson, S, Bjärehed, J. Depressive symptoms and deliberate self-harm in a community sample of adolescents: a prospective study. Depression research and treatment. 2011;935871 doi:10.1155/2011/935871.
73. Ziebell L, Collin C, Rainville S, Mazalu M, Weippert M. Using an ideal observer analysis to investigate the visual perceptual efficiency of individuals with a history of non-suicidal self-injury when identifying emotional expressions. PloS ONE. 2020;15(2):e0227019. doi: 10.1371/journal.pone.0227019
74. Nixon, MK, Cloutier, P. Ottawa Self-Injury Inventory. Victoria BC: University of British Columbia and Victoria. 2005.
75. Martin, J, Cloutier, PF, Levesque, C, Bureau, JF, Lafontaine, MF, Nixon, MK. Psychometric properties of the functions and addictive features scales of the Ottawa Self-Injury Inventory: A preliminary investigation using a university sample. Psychological assessment. 2013;25(3):1013. doi: 10.1037/a0032575.
76. Klonsky, ED Olino, TM. Identifying clinically distinct subgroups of self-injurers among young adults: A latent class analysis. Journal of consulting and clinical psychology. 2008;76(1), 22-7. doi: 10.1037/0022-006X.76.1.22
77. Klonsky, ED, Glenn, CR. Assessing the functions of non-suicidal self-injury: Psychometric properties of the Inventory of Statements about Self-Injury (ISAS).

Journal of psychopathology and behavioural assessment. 2009;31(3):215-19. doi: 10.1007/s10862-008-9107-z
78. Achaibou, A, Pourtois, G, Schwartz, S, Vuilleumier, P. Simultaneous recording of EEG and facial muscle reactions during spontaneous emotional mimicry. Neuropsychologia. 2008;46(4), 1104–13. doi: 10.1016/j.neuropsychologia.2007.10.019
79. Hermans, EJ, van Wingen, G, Bos, PA, Putman, P, van Honk, J. Reduced spontaneous facial mimicry in women with autistic traits. Biological psychology. 2009;80(3):348–53. doi: 10.1016/j.biopsycho.2008.12.002
80. Fridlund, AJ, Cacioppo, JT. Guidelines for human electromyographic research. Psychophysiology. 1986;23(5):567–89. doi: 10.1111/j.1469-8986.1986.tb00676.x
81. Lundqvist, D., Flykt, A., Öhman, A. (1998). The Karolinska directed emotional faces - KDEF [CD ROM]. Stockholm, Sweden: Karolinska Institutet. Available from http://www.facialstimuli.com
82. Taffler, S, Kyberd, PJ. The use of the Hilbert transforra in EMG Analysis. Myoelectric Symposium. 1999.
83. de Wied, M, van Boxtel, A, Matthys, W, Meeus, W. Verbal, facial and autonomic responses to empathy-eliciting film clips by disruptive male adolescents with high versus low callous-unemotional traits. Journal of abnormal child psychology. 2012;40(2):211-23. doi: 10.1007/s10802-011-9557-8
84. Litz, BT, Orsillo, SM, Kaloupek, D, Weathers, F. Emotional processing in posttraumatic stress disorder. Journal of abnormal psychology. 2000;109(1):26-39. DOI: 10.1037//0021-843x.109.1.26
85. Rottenberg, J, Gross, JJ, Gotlib, IH. Emotion context insensitivity in major depressive disorder. Journal of abnormal psychology. 2005;114(4):627-39. doi: 10.1037/0021-843X.114.4.627
86. Rozga, A, King, TZ, Vuduc, RW, Robins, DL. Undifferentiated facial electromyography responses to dynamic, audio-visual emotion displays in individuals with autism spectrum disorders. Developmental science. 2013;16(4):499-514. doi: 10.1111/desc.12062
87. Soussignan, R, Jiang, T, Rigaud, D, Royet, JP, Schaal, B. Subliminal fear priming potentiates negative facial reactions to food pictures in women with anorexia nervosa. Psychological medicine. 2010;40(3):503-14. doi: 10.1017/S0033291709990377
88. Carlson, JG, Singelis, TM, Chemtob, CM. Facial EMG responses to combat-related visual stimuli in veterans with and without posttraumatic stress disorder. Applied psychophysiology and biofeedback. 1997;22(4), 247-59. doi:10.1023/A:1022295912624
89. Rosenthal, R, Rosnow, RL. Contrast analysis: Focused comparisons in the analysis of variance. New York, NY: Cambridge University Press; 1985.
90. Hilt LM, Cha CB, Nolen-Hoeksema S. Nonsuicidal self-injury in young adolescent girls: Moderators of the distress-function relationship. Journal of consulting and clinical psychology. 2008;76(1):63. doi: 10.1037/0022-006X.76.1.63
91. Turner, BJ, Chapman, AL, Layden, BK. Intrapersonal and interpersonal functions of non suicidal self-injury: Associations with emotional and social functioning. Suicide and life-threatening behavior. 2012;42(1):36-55. doi: 10.1111/j.1943-278X.2011.00069.
92. Vonderlin E, Haffner J, Behrend B, Brunner R, Parzer P, Resch F. Welche Probleme berichten Jugendliche mit selbstverletzendem Verhalten?. Kindheit und Entwicklung. 2011; 20:111-8. /doi: 10.1026/0942-5403/a000047

93. Adrian, M, Berk, MS, Korslund, K, Whitlock, K, Mccauley, E, Linehan, M. Parental validation and invalidation predict adolescent self-harm. Professional psychology: research and practice. 2018;49(4):274–81. doi:10.1037/pro0000200
94. Fridlund AJ. Human facial expression: An evolutionary view. Academic Press; 2014.
95. Sonnby-Borgström, M. Alexithymia as related to facial imitation, mentalization, empathy, and internal working models-of-self and-others. Neuropsychoanalysis. 2009;11(1):111-28. doi:10.1080/15294145.2009.10773602
96. Wilkinson P, Kelvin R, Roberts C, Dubicka B, Goodyer I. Clinical and psychosocial predictors of suicide attempts and nonsuicidal self-injury in the Adolescent Depression Antidepressants and Psychotherapy Trial (ADAPT). American journal of psychiatry. 2011;168(5):495-501. doi:10.1176/appi.ajp.2010.10050718
97. Muehlenkamp J, Brausch A, Quigley K, Whitlock J. Interpersonal features and functions of nonsuicidal self-injury. Suicide and life-threatening behavior. 2013;43(1):67-80. doi:10.1111/j.1943-278X.2012.00128.x

Chapter 5: Summary and Conclusions

In this thesis I sought to investigate the question of whether individuals with a history of NSSI perceived and responded to facial expressions of emotion differently than individuals who have not engaged in self-injury. Self-injurious acts are typically preceded by either an interpersonal difficulty and/or a negative emotional/cognitive state that leads an individual to engage in the behaviour in an attempt to gain relief from the unpleasant interpersonal situation or emotional state (Bentley et al., 2014). As self-injury is thought to play a role in emotion regulation for these individuals, emotion recognition may also play a role as a precursor to emotion regulation (Yoo et al., 2006). Facial emotion perception is a vital feature of social functioning, as it allows individuals to infer the emotional states of others, helps guide one's own behaviour, and impacts regulation of one's internal state of emotion in a social context (Reeck, Ames & Ochsner, 2016). However, if facial expressions are incorrectly recognized or attended to differently as compared to other individuals, then this difference in perception may contribute to engaging in various emotion regulation strategies, including the dysfunctional strategy of self-injury. Likewise, subtly and unconsciously mimicking the facial expressions of an interaction partner can serve the role of embodied simulation during a social interaction by providing feedback for the mimicker on another's emotional experience. Such mimicry also provides information on one's own emotions and encourages liking and empathy between individuals (Blair, 2005; Hatfield, Cacioppo, & Rapson., 1994; Dimberg et al., 2000). To better understand the possible differences in emotion perception and mimicry in individuals with a history of non-suicidal self-injury as compared to controls, the three studies in this thesis investigated several specific aspects of emotion perception and mimicry using differing but inter-related experimental measures.

5.1 What was learned from these studies

Study 1. Individuals with a history of non-suicidal self-injury were found to require lower levels of stimulus intensity to categorize expressions of anger, disgust and sadness with the same degree of accuracy as compared to control participants. The HNSSI group also performed slightly more accurately at correctly categorizing the facial expression of fear compared to controls. Considering that in the biosocial model, an invalidating environment where children's emotions were either ignored or punished is thought to play a role in the development of NSSI, a hypersensitivity to fearful facial expressions may not be surprising. No evidence of a response bias toward any particular category for either group was observed and no differences in reaction time between groups were seen. This mitigates any concern regarding effects of impulsivity or speed-accuracy trade-offs.

Participants with a history of NSSI also showed an ability to categorize surprise at a lower intensity level. Although surprise has an ambiguous valence and could be interpreted as either positive or negative, there is some evidence that individuals with related condition tend to see neutral facial expressions as negative. It is possible, therefore, that our HNSSI participants saw surprised expressions as negative. This is a question for further investigation.

Study 2. When images of facial expressions of emotion were obscured with varying levels of fractal noise, individuals with a history of non-suicidal self-injury did not show superior signal-proportion thresholds or efficiency scores compared to controls. Although seemingly in contrast to the results of the first study, this result may not be particularly surprising, as the facial emotion stimuli presented were more impoverished and lacking in contextual elements of colour and animation. Interestingly, it was the recognition of fearful expressions that showed deficits at the perceptual level for the history of NSSI participants, possibly suggesting that higher order

elements of visual and cognitive processing, such as memories of past experience and prior knowledge, are importantly evoked by richer and dynamic stimuli that more closely compare to realistic social situations.

In examining the pattern of errors made by participants, it was found that the errors made my HNSSI participants revealed a possible negativity bias. Specifically, they had a tendency to mistake angry faces for happy ones, which is a contrasting emotion that may have been perceived as more similar by the HNSSI participants as less of the stimulus was available to process**.**

Study 3. In response to viewing the positively and negatively valenced emotions of anger and happiness, individuals with a history of NSSI showed less of an expected activity in their corrugator supercilii muscles. In particular, as compared to controls, their corrugator muscles contracted significantly less in response to viewing angry faces and relaxed significantly less in response to viewing happy faces.

Other findings from this study showed correlations between the reasons people identified for engaging in NSSI and their facial mimicry behaviour. In particular, the more individuals with a history of NSSI endorsed interpersonal reasons for engaging in self-injury, the less activation was recorded in the corrugator and zygomatic muscles when viewing angry and happy faces, respectively, suggesting less mimicry. Furthermore, there was a relationship between endorsing NSSI as a method to regulate emotions and mimicry in the corrugator muscle. Specifically, the more they endorsed NSSI as a method to regulate their emotions, the stronger they contracted their corrugator muscle when viewing happy faces, which is an incongruent reaction, as the expected behaviour when viewing happy faces is to relax the corrugator muscle.

5.2 Conclusions of this research

Research has provided evidence that individuals engaging in NSSI may be uniquely characterized by increased emotional reactivity, interpersonal problems and interpersonal sensitivity (Washburn, 2019). Interpersonal situations are of high relevance to those engaging in NSSI, and experiencing interpersonal distress is itself associated with self-injurious behaviour (Bentley et al., 2014). For instance, those who have self-injured report feeling more hurt and rejected in the context of conflicts with others (Turner et al., 2016). It is possible that these individuals may be detecting and perceiving negative emotions that could signal social rejection, like anger, disgust and sadness at lower intensity levels, which could contribute to their increased feelings of hurt and rejection. However, an excessive sensitivity to perceived negative emotions does not necessarily constitute an asset in real-world interactions. As Linehan's (1993) model predicts, a sensitivity to negative or ambiguous emotions can also lead to heightened reactivity and emotion dysregulation if the development of adaptive emotion regulation skills is impeded by early emotionally invalidating experiences.

In a recent preliminary study by Laghi et al., (2019), an emotion recognition task involving a "reading the mind in the eyes" task (a theory of mind test examining the eye portion of natural human faces) found some heightened sensitivity to negative emotions among psychiatric NSSI inpatients who engaged in more different types of self-injury behaviours compared to those who engaged in fewer types. Likewise, adolescents engaging in NSSI reported more stress during an interpersonal laboratory task than adolescents with recent suicidality (Kim et al., 2015), suggesting that interpersonal sensitivity may in fact be uniquely associated with self-injurious behaviours compared to other types of problematic behaviours (Washburn, 2019).

In particular, recognizing the facial expression of fear is thought to predict prosocial behaviour (Marsh et al., 2007), yet the misinterpretation of fear may contribute to emotional disturbances, inadequate social behaviour, lack of social skills, and less adaptive social problem-solving skills - all problems often observed in individuals who engage in NSSI behaviour (Nock & Mendes, 2008; Claes et al., 2010). In our first study, when fear was presented in the form of a morphing colour image, individuals with a history of NSSI presented as more attuned to the emotion of fear in that they could categorize this emotion more accurately compared to controls. Although the HNSSI participants were not able to recognize fear at a lower stimulus intensity, like the other negative emotions, their identification of fear at the same intensity was superior compared to controls.

Our results are in contrast to those found by In-Albon et al. (2015), who reported similar accuracies for recognizing facial expressions of emotion between a clinical control group and a non-clinical control group. However, their study had several distinct differences from ours, including a sample of participants whose NSSI behaviours were much more severe and required inpatient psychiatric hospitalization, a younger age range, and an entirely female sample of subjects. In-Albon et al's study also employed sad and neutral mood-indication prior to stimulus presentation. However, comparable with our findings, they did show that the NSSI group, relative to non-clinical controls, found angry, sad and happy expressions more arousing, and neutral and happy expressions more unpleasant.

One possible explanation for the increased accuracy for recognizing fear observed in our study could be related to the etiology of NSSI. For example, the emotional experience of fear, evoked by a lack of care and protection from one's primary caregiver, has been found to be a predicting factor for engaging in NSSI (Bureau, 2010). However, when we subsequently

presented more impoverished, ambiguous (similar to dim light) emotion stimuli to a comparable HNSSI sample at varying intensities, these sensitivities to negative emotions were no longer observed. These results were similar to those from Copps (2018), who also presented static, black and white facial images of emotion at varying intensities. Paradoxically, the HNSSI participants struggled to correctly identity the emotion of fear that was initially very salient during the morphing task. Results from our second study show some agreement with the results of Seymour et al., (2016), who found that psychiatric inpatient adolescents engaging in NSSI made more errors on child fearful face compared to typically developing controls. The stimulus used in this experiment was also composed of static images. A possible explanation for the difference in observed emotion recognition performance may be related to the fact that perceiving fear within the context of a relationship may be particularly important for evoking the higher-order visual and cognitive processes, like prior knowledge or memory, needed for categorization accuracy. Indeed, young adults who have reported engaging in NSSI in the last six months also describe childhood feelings of fear related to parents' abdication of their roles and failed protection, as well as feelings of alienation from their parents (Bureau, 2010).

Another possible explanation is that viewing lower intensity emotions associated with threat might enhance arousal just enough to improve emotion recognition, while viewing these same emotions at full intensity might induce hyperarousal that interferes with cognitive processing and in turn leads to poorer recognition. A heightened sensitivity to facial expressions of fear has been associated with a heightened stress response (Chikovani et al., 2015; Engert, Plessow, Miller, Kirschbaum, & Singer, 2014). To further expand upon the results of the emotion recognition tasks in this thesis and to better understand how fear recognition may be intricately linked to NSSI, future research endeavours should consider investigating emotion

recognition capabilities in this population with methodologies that include difficult, stressful or even fear-inducing interpersonal interactions versus static or morphing image paradigms, particularly since social interaction problems are often a trigger for engaging in NSSI (Nock & Mendes, 2008).

A third possible explanation for the increased accuracy of fear recognition in our first study with the morphing paradigm, and decreased fear recognition in our second study using the signal-to-noise ratio paradigm, could be related to growing evidence that suggests NSSI may be associated with alexithymia (Demers, 2019; Iskric, 2020; Greene, 2020). Alexithymia is a personality construct in which an impairment in conscious introspection about emotions often co-occurs with poor emotion recognition in the self and others (Grynberg et al., 2012). It is hypothesized that atypical processing of emotional information is occurring for alexithymia individuals who engage in self-injury through automatic sensory activation and physiological arousal. For instance, one study found that self-injurers who reported not caring about or attending to their own feelings showed heightened activity in brain regions involved in visual attention and processing to masked fear faces and attenuated activation in these brain regions to masked happy faces (Demers, 2019). This pattern of results suggests that adolescents who self-injure and show higher externally oriented thinking (tendency to focus on external rather than internal events) may be more vigilant to fearful faces and less reactive to happy faces. Most importantly for the present discussion, alexithymia has also been shown to be related to impairments in emotion labelling when faces are rapidly presented or presented with visual degradation (Grynberg et al., 2012; Kätsyri et al., 2008; Parker et al., 2005; Prkachin et al., 2009; Swart et al., 2009), a situation analogous to the impoverished stimuli shown in the Study 2. The

above results are in line with the notion of an association between alexithymia and NSSI, which may help to understand some of the results observed our first two experiments.

Alexithymia has also been linked to reduced spontaneous mimicry of facial expressions (Sonnby-Borgstrom, 2009). The ability to unconsciously and rapidly mimic observed emotional facial expressions in others is thought to facilitate an appropriate empathic response in the observer (Adolphs, 2002; Decety & Meyer, 2008). Contraction of facial muscles serve as a feedback system, such that unconsciously matching the facial expression of the sender, provides the receiver with feedback from their own facial reactions to induce a similar emotion (Adelmann & Zajonc, 1989; Dimberg et al., 2011). This rapid and automatically synchronizing of facial expressions with another person arguably helps to share the state with the other and facilitates empathy (Blair, 2005). Facial expressions also help to communicate intent, thus the reduced facial mimicry observed in the HNSSI individuals may protect them from scrutiny or social rejection yet contribute to the ongoing social interaction difficulties frequently reported by these individuals through mimicry nonconformity. Furthermore, a blending of emotion expressions leading to a reduced mimicry response, or a combination of attenuation and incongruent mimicry on the part of individuals with HNSSI, may be occurring. Any combination of these behaviours could be expected to lead to difficulties with social interactions resulting from violations of social rules of facial mimicry non-conformity. Results from our third study support early research suggesting that altered and attenuated mimicry reactions may be occurring in an NSSI population (In-Albon, Ruf, Wilhelm, & Schmid, 2013; Bürli, In-Albon, Schmid, Wilhelm, & Bruggisser, 2012), possibly exacerbating the frequently reported social interaction difficulties and contributing to further NSSI behaviour. Further research should explicitly investigate if alexithymia in individuals with a history of NSSI is a linking factor impacting the

emotion identification capabilities and facial reactions in response to observing the emotional expressions of others.

5.3 Clinical implications

Daily social interactions require the accurate perception of emotions for successful interactions with others. If emotions are attended to differently, whether by hypersensitivity or misperception, this can lead to an increase in emotional arousal and a worsening of mood state (Chapman, Gratz, & Brown, 2006; Nock 2009). A vicious circle of differentiated emotion perception may lead to misinterpretations and strong negative emotions that require adaptive emotion regulation strategies. Individuals with a history of NSSI appear to be attending to emotions differently compared to typically developing individuals in that they may be attending to emotions such as anger, disgust and sadness, recognizing them with less intensity or more accurately, as in the case with fear, in social interactions. This may be particularly problematic as growing evidence suggests that individuals engaging in NSSI also struggle to recognize or correctly appraise their own emotions, likely a crucial step for adaptive emotion regulation, emotion recognition and successful interactions. Given the limited validated treatments available for adolescents who repeatedly engage in NSSI (Gonzales & Bergstrom, 2013, Muehlenkamp, 2006), results from the present thesis support the suggestion by Demers et al. (2019) that focusing treatment on increasing attention to positive emotions may be particularly relevant for this population. As self-harm is often engaged in following emotionally distressing social interactions, and adolescents engaging in NSSI tend to have difficulty interpreting interpersonal situations (Bentley et al., 2014; Tatnell et al., 2017), increasing attention to positive emotions could be particularly appropriate for therapeutic intervention.

Likewise, decreased facial responding violates the social norms expected when interacting with others. In BPD, less facial mimicry in response to viewing happy faces was associated with reports of lower levels of happiness while processing the expression (Matzke, 2014). In the HNSSI group, the positive social stimuli of a smiling face also appeared less potent at triggering corresponding 'facial mimicry,' and was likely less effective at inducing positive feelings from embodied simulation that helps with understanding the emotions of others. This is particularly relevant as happy expressions have been found to be significantly less pleasant and more arousing in NSSI individuals compared to controls (In-Albon, 2015). Not only can less mimicry likely result in less understanding of other's emotions, but even minor violations of the robust effect of mirroring facial expressions, can create substantial problems in the social interaction process (Dimberg, 1990; Hess & Bourgeois, 2010).

Our results support the notion that therapy focusing on social interaction skills and improving the quality of interpersonal relationships may be particularly useful for future treatment of NSSI. From a prevention perspective, these results highlight the importance of developing, supporting, and maintaining healthy interpersonal bonds and emphasizing social and familial support for this population. Elements of therapies related to emotion regulation strategies, interpersonal effectiveness skills, and the practice of mentalization, may also be effective. For example, practice focusing on the mental states of others and oneself, especially for positive emotions, may be expressly therapeutic. If individuals with a history of NSSI are attending more to negative emotions in a social interaction, and reflecting positive emotions less, then mindfulness techniques focusing on the pertinent features of a positive emotional response could be targeted. Moreover, mentally representing a positive response, and the related bodily sensations, could also help to target some of the decreased automatic processing and reflection

observed in this population.

5.4 Limitations and Future Research

Despite efforts to control for as many potential sources of error as possible, like all studies, several important limitations should be acknowledged when interpreting the results. One important limitation is the use of a university student sample. While the participants included in this thesis were diverse, and comprised of both males and females, they nonetheless represent a small segment of the population. This limits the generalizability of results to other populations who differ on variables such as age and education. Continued research is encouraged to explore samples collected from the community as their results may differ from our sample and the inpatient samples used in similar NSSI research (In-Albon et al., 2015; Seymour et al., 2016).

Additionally, the self-report nature of the data collected from participants is inherently vulnerable to response bias. Since self-harm is a sensitive topic, some participants may have been reluctant to report honestly about their self-injuring behaviours or motivations for engaging in the behaviour or lacked awareness about the functions their self-injury serves. Self-report measures also rely on participants' willingness to report honestly on their areas of difficulty.

A further area of concern is that HNSSI participants had higher comorbidity with other disorders. The frequency and diversity of comorbid disorders with NSSI is high (Bentley et. al., 2015), and NSSI as a stand-alone diagnosis is rarer (Ghinea et al., 2020). Much of the NSSI literature includes populations that report some past or present comorbid diagnoses, such as major depressive disorder and generalized anxiety disorder in their samples. Our sample sizes precluded dividing groups into sub-groups with different comorbidities, so we were unable to quantitatively address their potential effects on our results. However, because the data were

screened for extreme outliers on the dependent variables, it seems unlikely that the presence of individual psychopathology could be systematically responsible for the current findings. Nonetheless, future studies should further investigate the influence of comorbid disorders on emotion perception and emotion mimicry in this population.

Another possible limitation is that the current mood state of participants was not controlled. It is conceivable that some individuals may have been biased toward attending to emotional information consistent with their own current mood state. Although mood state was not manipulated in this study, all participants did have enough time between the consent process, completing demographic information and NSSI questionnaires before beginning study procedures. Additionally, attempts were made to ensure that participants were not exposed to any intense emotional stimulus in the period immediately prior to a study task. While this does not ensure that all participants were in the same mood state at the beginning of the task, there is no reason to believe that participants varied significantly in their current mood state by condition in any systematic way. Additionally, in a study conducted with NSSI participants, in which mood was explicitly manipulated, no mood effects were found on emotion recognition or accuracy (In-Albon, 2015).

Furthermore, data collection for the first and third study included some overlap of participants. All participants in the first study received the same procedure, in which EMG data was first collected through stimulus observation, before engaging in the categorizing task. However, the procedure did not differ between NSSI and control groups, so any potential contamination between tasks would be equally distributed to both groups. Moreover, a break was provided to participants between data collection for the first and third study to allow for the removal of equipment and preparation for the second phase of data collection. It is unlikely that

this procedure varied in any systematic way between groups. It is nonetheless a limitation that must be acknowledged, as participation in the first task (study 3) could have primed individuals or increased arousal, possibly influencing performance on the second task (study 1). However, no differences were found between the frequency of response categories between the NSSI and control groups for study 1, which mitigates concerns related to priming or study contamination.

As is often the case with experimental research, it is necessary to sacrifice some degree of ecological validity to control the quality of the emotional stimuli presented. In real life, expressions can be even more brief, rapidly changing, and with mixed emotions frequently occurring. Although this does not negate the importance of the research findings in this thesis, it would be interesting to examine whether the current findings could be reproduced in interaction dyads. Reproducing the results of the first and third study in vivo could be valuable, as receiving feedback from an interaction partner could also elicit greater arousal symptoms. Future investigations are also encouraged to record additional measures such as heart rate, skin conductance and breathing rate as indices of arousal.

In summary, this body of research provides an important contribution to the existing NSSI literature. Results of these studies help to deepen our understanding of those suffering from NSSI and contribute to both theoretical and clinical implications.

5.5 References

Adolphs, R. (2002). Neural systems for recognizing emotion. *Current Opinion in Neurobiology*, *12*(2), 169-177.

Adelmann, P. K., & Zajonc, R. B. (1989). Facial efference and the experience of emotion. *Annual Review of Psychology*, *40*(1), 249-280.

Bentley, K. H., Cassiello-Robbins, C. F., Vittorio, L., Sauer-Zavala, S., & Barlow, D. H. (2015). The association between nonsuicidal self-injury and the emotional disorders: A meta-analytic review. *Clinical Psychology Review*, *37*, 72-88.

Bentley, K.H., Nock, M.K., Barlow, D.H., (2014). The four-function model of nonsuicidal self-injury: key directions for future research. *Clinical Psychological Science, 2*(5), 638–656.

Blair, R. J. R. (2005). Responding to the emotions of others: Dissociating forms of empathy through the study of typical and psychiatric populations. *Consciousness and Cognition*, *14*(4), 698-718.

Bureau, J. F., Martin, J., Freynet, N., Poirier, A. A., Lafontaine, M. F., & Cloutier, P. (2010). Perceived dimensions of parenting and non-suicidal self-injury in young adults. *Journal of Youth and Adolescence*, *39*(5), 484-494.

Bürli, M., In-Albon, T., Schmid, M., Wilhelm, F., & Bruggisser, M. (2012). Facial mimicry of dynamic emotional facial expressions in adolescents with non-suicidal self-injury. *Neuropsychiatrie de l'enfance et de l'adolescence*, *5*(60), S80.

Chapman, A. L., Gratz, K. L., & Brown, M. Z. (2006). Solving the puzzle of deliberate self-harm: The experiential avoidance model. *Behaviour research and therapy*, *44*(3), 371-394.

Chikovani, G., Babuadze, L., Iashvili, N., Gvalia, T., & Surguladze, S. (2015). Empathy costs: Negative emotional bias in high empathisers. *Psychiatry research*, *229*(1-2), 340-346.

Claes, L., Houben, A., Vandereycken, W., Bijttebier, P., & Muehlenkamp, J. (2010). Brief report: The association between non-suicidal self-injury, self-concept and acquaintance with self-injurious peers in a sample of adolescents. *Journal of Adolescence*, *33,* 775–778.

Copps, E. C. (2019). *Interpersonal Functions of Non-Suicidal Self-Injury and Their Relationship to Facial Emotion Recognition and Social Problem-Solving* (Doctoral dissertation, Xavier University).

Decety, J., & Meyer, M. (2008). From emotion resonance to empathic understanding: A social developmental neuroscience account. *Development and psychopathology*, *20*(4), 1053-1080.

Demers, L. A., Schreiner, M. W., Hunt, R. H., Mueller, B. A., Klimes-Dougan, B., Thomas, K. M., & Cullen, K. R. (2019). Alexithymia is associated with neural reactivity to masked emotional faces in adolescents who self-harm. *Journal of Affective Disorders*, *249*, 253-261.

Dimberg, U. (1990). Facial electromyography and emotional reactions. *Psychophysiology*, *27*(5), 481-494.

Dimberg, U., Andréasson, P., & Thunberg, M. (2011). Emotional empathy and facial reactions to facial expressions. *Journal of Psychophysiology*, *25*(1), 26.

Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious facial reactions to emotional facial expressions. *Psychological Science*, *11*, 86-89.

Engert, V., Plessow, F., Miller, R., Kirschbaum, C., & Singer, T. (2014). Cortisol increase in empathic stress is modulated by emotional closeness and observation modality. *Psychoneuroendocrinology*, *45*, 192-201.

Ghinea, D., Edinger, A., Parzer, P., Koenig, J., Resch, F., & Kaess, M. (2020). Non-suicidal self-injury disorder as a stand-alone diagnosis in a consecutive help-seeking sample of adolescents. *Journal of Affective Disorders*, *274*, 1122-1125.

Gonzales, A. H., & Bergstrom, L. (2013). Adolescent non-suicidal self-injury (NSSI) interventions. *Journal of Child and Adolescent Psychiatric Nursing, 26*(2), 124-130.

Greene, D., Boyes, M., & Hasking, P. (2020). The associations between alexithymia and both non-suicidal self-injury and risky drinking: A systematic review and meta-analysis. *Journal of Affective Disorders*, *260*, 140-166.

Grynberg, D., Chang, B., Corneille, O., Maurage, P., Vermeulen, N., Berthoz, S., Luminet, O., 2012. Alexithymia and the processing of emotional facial expressions (EFEs): systematic review, unanswered questions and further perspectives. *PLoS ONE, 7* (8), e42429.

Hatfield, E., Cacioppo, J. T., & Rapson, L. R. (1994). *Emotional contagion*. Cambridge: Cambridge University Press.

Hess, U., & Bourgeois, P. (2010). You smile–I smile: Emotion expression in social interaction. *Biological Psychology*, *84*(3), 514-520.

In-Albon, T., Ruf, C., Wilhelm, F. H., & Schmid, M. (2013, September). Do adolecents with non-suicidal self-injury have deficits in facial mimicry?. In *psychopysiology* (Vol. 50, pp. S4-S4). 111 River St., Hoboken 07030-5774, NJ USA: Wiley-Blackwell.

In-Albon, T., Ruf, C., & Schmid, M. (2015). Facial emotion recognition in adolescents with nonsuicidal self-injury. *Psychiatry Research*, *228,* 332-339.

Iskric, A., Ceniti, A. K., Bergmans, Y., McInerney, S., & Rizvi, S. J. (2020). Alexithymia and self-harm: a review of nonsuicidal self-injury, suicidal ideation, and suicide attempts. *Psychiatry Research*, 112920.

Kätsyri, J., Saalasti, S., Tiippana, K., von Wendt, L., Sams, M., 2008. Impaired recognition of facial emotions from low-spatial frequencies in Asperger syndrome. *Neuropsychologia 46*(7), 1888–1897.

Kim, K. L., Cushman, G. K., Weissman, A. B., Puzia, M. E., Wegbreit, E., Tone, E. B., … Dickstein, D. P. (2015). Behavioral and emotional responses to interpersonal stress: A comparison of adolescents engaged in non- suicidal self- injury to adolescent suicide attempters. *Psychiatry Research*, 228, 899– 906.

Laghi, F., Cerutti, R., Terrinoni, A., Lonigro, A., Pongetti, A., Ferrara, M., & Fantini, F. (2019). Evaluation of the "Reading the Mind in the Eyes Test" with Non-Suicidal Self-Injury (NSSI) adolescents: A pilot study. *Current Psychology*, 1-7.

Linehan, M. (1993). *Cognitive-behavioral treatment of borderline personality disorder*. New York, NY: Guilford Press.

Marsh, A. A., Kozak, M. N., & Ambady, N. (2007). Accurate identification of fear facial expressions predicts prosocial behavior. *Emotion*, *7*(2), 239.

Matzke, B., Herpertz, S. C., Berger, C., Fleischer, M., & Domes, G. (2014). Facial reactions during emotion recognition in borderline personality disorder: a facial electromyography study. *Psychopathology*, *47*(2), 101-110.

Muehlenkamp, J. J. (2006). Empirically supported treatments and general therapy guidelines for non-suicidal self-injury. *Journal of Mental Health Counseling*, *28*(2), 166-185.

Nock, M. K. (2009). Why do people hurt themselves? New insights into the nature and functions of self-injury. *Current directions in psychological science*, *18*(2), 78-83.

Nock, M. K., & Mendes, W. B. (2008). Physiological arousal, distress tolerance, and social problem-solving deficits among adolescent self-injurers. *Journal of Consulting and Clinical Psychology, 76*, 28-38.

Parker, P. D., Prkachin, K. M., & Prkachin, G. C. (2005). Processing of facial expressions of negative emotion in alexithymia: the influence of temporal constraint. *Journal of Personality*, *73*(4), 1087-1107.

Prkachin, G. C., Casey, C., & Prkachin, K. M. (2009). Alexithymia and perception of facial expressions of emotion. *Personality and Individual Differences*, *46*(4), 412-417.

Reeck, C., Ames, D. R., & Ochsner, K. N. (2016). The social regulation of emotion: An integrative, cross-disciplinary model. *Trends in Cognitive Sciences*, *20*(1), 47-63.

Seymour, K. E., Jones, R. N., Cushman, G. K., Galvan, T., Puzia, M. E., Kim, K. L., Spirito, A., & Dickstein, D. P. (2016). Emotional face recognition in adolescent suicide attempters and adolescents engaging in non-suicidal self-injury. *European Child & Adolescent Psychiatry*, *25,* 247-259.

Sonnby-Borgström, M., 2009. Alexithymia as related to facial imitation, mentalization, empathy, and internal working models-of-self and-others. *Neuropsychoanalysis, 11*(1), 111–128.

Swart, M., Kortekaas, R., & Aleman, A. (2009). Dealing with feelings: characterization of trait alexithymia on emotion regulation strategies and cognitive-emotional processing. *PloS ONE*, *4*(6), e5751.

Tatnell, R., Hasking, P., Lipp, O. V., Boyes, M., & Dawkins, J. (2018). Emotional responding in NSSI: examinations of appraisals of positive and negative emotional stimuli, with and without acute stress. *Cognition and Emotion*, *32*(6), 1304-1316.

Turner, B. J., Yiu, A., Claes, L., Muehlenkamp, J. J., & Chapman, A. L. (2016). Occurrence and co-occurrence of nonsuicidal self-injury and disordered eating in a daily diary study: Which behavior, when?. *Psychiatry research*, *246*, 39-47.

Washburn, J. J. (Ed.). (2019). *Nonsuicidal Self-injury: Advances in Research and Practice*. Routledge.

Yoo, S. H., Matsumoto, D., & LeRoux, J. A. (2006). The influence of emotion recognition and emotion regulation on intercultural adjustment. *International Journal of Intercultural Relations*, *30,* 345-363.

Appendices

Appendix A

Pre-screening Questions and Recruitment Text for ISPR

Title: Emotion Perception and Recognition

Description of Study: The purpose of this study is to better understand if variability exists in an individual's ability to recognize emotional faces, and whether or not this variability is linked to emotion coping strategies. Participation will consist of one lab session lasting approximately 90 minutes. During this session, participants will view images on a computer monitor and indicate whether or not they recognize the facial expression presented. Participants will also be asked to passively observe emotionally expressive facial images while their physiological changes are measured. Participants may also be asked to complete questionnaires about emotional coping strategies. Please note that this study will only be administer in English.

Inclusion criteria: 17-24 years of age. Ability to read and understand English.

Exclusion criteria: Diagnosis of Borderline Personality Disorder

Screening questions:
Have you ever intentionally self-inflicted damage to the surface of your body to cause bleeding, bruising, or pain (e.g., cutting, burning, stabbing, and/or hitting), **without the intent to kill yourself?** Please note that this **does not** include ear piercing, tattooing, circumcision, or cultural healing rituals.

Never

Once

2-4 times

5 or more times

Have you ever been diagnosed with Borderline Personality Disorder?

Note: A psychological disorder pre-screening question is already present within the ISPR

system.

Appendix B

Emotion Perception and Recognition Consent Form

Affiliation: School of Psychology, Faculty of Social Sciences, University of Ottawa.

Invitation to Participate: I am invited to participate in the abovementioned research study conducted by the researchers listed above.

Purpose of the Study: The purpose of this study is to better understand if variability exists in an individual's ability to recognize emotional faces, and whether or not this variability is linked to emotion coping strategies.

Participation: My participation will consist of coming into the lab for one session lasting between 90-120 minutes. During this session, I will be asked to view images on a computer monitor. I will be asked to give responses to the images that I see in accordance with written instructions provided by a computer program and/or verbal instructions given by the researcher. I will be asked to wear facial Electromyography (fEMG) electrodes, an electrodermal activity (EDA) amplifier and a pulse plethysmograph on one hand while doing these tasks. I will be asked to sit while the research assistant cleans three small areas of my face with a mild exfoliating lotion containing lemon. One or two sensors will be placed on each of these areas. I will first be shown the cleaning process on my wrist, and then the researcher will proceed with cleaning the areas on my face if I feel comfortable. They will also place Ag-AgCl electrodes on my palm and the pulse monitor on the index finger of my non-dominant hand. This will take up to 30 minutes, after which the researchers will ensure that the quality of the recordings is good. Tasks I may be asked to do are:

1. Indicate whether or not I recognize the facial expression of a presented image.
2. Indicate what expression is presented
3. Passively observe emotionally expressive facial images.
4. Fill out a demographic questionnaire.
5. I may be asked to complete other questionnaires that ask about emotional coping strategies.

Risks: For tasks 1 to 4 (listed above) my participation in this study will entail no significant risks. For task 5 there is a small risk that answering some of the questions may cause minor emotional or psychological distress. This distress is likely to be brief in duration and minor in severity. Upon completion of the study, I will receive a resource sheet directing me to nearby mental health resources that I can refer to. Furthermore, the electrodermal activity (EDA) amplifier and the pulse plethysmograph are non-invasive recording instruments that pose no significant risk. **Facial Electromyography.** I understand that some people find the skin cleaning somewhat uncomfortable. The skin may be slightly red after the removal of electrodes, but this will disappear within a few hours. In rare cases, the cleaning of the skin may leave a scab that will be apparent on the skin for a few days. I should warn the researcher if the skin cleaning becomes painful; it may be uncomfortable, but it should not be painful. A demonstration on the arm will be a good indication of how it will feel on my face. I understand that I can withdraw from the study at any time without incurring any penalty.

Suicidal ideation: I understand that the research team may not be able to keep confidentiality if I disclose or endorse any suicidal thoughts. In the event that I tell the research staff that I am thinking about killing myself or if I answer "yes" to a question about having thoughts about suicide, the research staff will ask me more questions about these thoughts. Depending on how intense my thoughts are or how much I feel like hurting myself, the research staff may need to call 911 to direct emergency professionals to the main entrance of the building and/or university security staff. I also understand that depending on the intensity

of my suicidal thoughts, the research staff may also need to ensure that I am taken to a hospital by emergency professionals.

Benefits: I understand that my participation in this study will help expand knowledge of human behaviour and the human brain, particularly in the realm of facial emotion recognition.

Confidentiality and anonymity: I have received assurance from the researcher that the information I will share will remain strictly confidential. I understand that the information will be used only for publication and presentation in scholarly media and that my confidentiality will be protected by having the data stored on a computer that only the researchers have access to. I also understand that the data collected might be analyzed and used for student theses. **Anonymity** will be protected in the following manner: Only grouped data will be published and a code number will be used in place of my name on all data reports.

Conservation of data: The electronic data collected, which consists of automatically-recorded keyboard responses, physiological responses and reaction times to images presented on a computer monitor will be kept in a secure manner. The data will be stored on computer hard disks on the University of Ottawa campus. Any written responses to questionnaires will be kept in a locked cabinet on the University of Ottawa campus, and will be de-identified with a 5 digit code. Only the researchers will have access to it. It will be kept for a period of 5 to 10 years before being securely deleted or shredded.

Compensation: I understand that I am participating as part of the University of Ottawa's Integrated System of Participation in Research (ISPR), and that I will receive course credit for participating in this research in accordance with the rules of the ISPR. I understand that I may withdraw from the study at any time and nonetheless receive these credits in full.

Voluntary Participation: I understand that I am under no obligation to participate and that if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions, without suffering any negative consequences. If I choose to withdraw, all data gathered until the time of withdrawal will be deleted.

Acceptance: I, _____ (print name), agree to participate in the above research study conducted by the researchers listed at the beginning of this document. I understand that these researchers are affiliated with the School of Psychology, Faculty of Social Sciences, University of Ottawa and that the research is being done under the supervision of Professor Charles A. Collin.

If I have any questions about the study, I may contact the researcher or the supervisor.

If I have any questions regarding the ethical conduct of this study, I may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON K1N 6N5.

There are two copies of the consent form, one of which is mine to keep.

Participant's signature: _____ Date: _____

Researcher's signature: _____ Date: _____

Appendix C

An Emotion Recognition Experiment Consent Form

Affiliation: School of Psychology, Faculty of Social Sciences, University of Ottawa.

Invitation to Participate: I am invited to participate in the abovementioned research study conducted by the researchers listed above.

Purpose of the Study: The purpose of this study is to better understand if variability exists in an individual's ability to recognize emotional faces, and whether or not this variability is linked to emotion coping strategies.

Participation: My participation will consist of coming into the lab for one session lasting between 90-120 minutes. During this session, I will be asked to view images on a computer monitor. I will be asked to give responses to the images that I see in accordance with written instructions provided by a computer program and/or verbal instructions given by the researcher. Tasks I may be asked to do are:

1. Indicate whether or not I recognize the facial expression of a presented image.
2. Indicate what expression is presented
3. Fill out a demographic questionnaire.
4. I may be asked to complete other questionnaires that ask about emotional coping strategies.

Risks: For tasks 1 to 3 (listed above) my participation in this study will entail no significant risks. For task 4 there is a small risk that answering some of the questions may cause minor emotional or psychological distress. This distress is likely to be brief in duration and minor in severity. Upon completion of the study, I will receive a resource sheet directing me to nearby mental health resources that I can refer to.

Suicidal ideation: I understand that the research team may not be able to keep confidentiality if I disclose or endorse any suicidal thoughts. In the event that I tell the research staff that I am thinking about killing myself or if I answer "yes" to a question about currently having thoughts about suicide, the research staff will ask me more questions about these thoughts. Depending on how intense my thoughts are or how much I feel like hurting myself, the research staff may need to call 911 to direct emergency professionals to the main entrance of the building and/or university security staff. I also understand that depending on the intensity of my suicidal thoughts, the research staff may also need to ensure that I am taken to a hospital by emergency professionals.

Benefits: I understand that my participation in this study will help expand knowledge of human behaviour and the human brain, particularly in the realm of facial emotion recognition.

Confidentiality and anonymity: I have received assurance from the researcher that the information I will share will remain strictly confidential. I understand that the information will be used only for publication and presentation in scholarly media and that my confidentiality will be protected by having the data stored on a computer that only the researchers have access to. I also understand that the data collected might be analyzed and used for student theses. Anonymity will be protected in the following manner: Only grouped data will be published and a code number will be used in place of my name on all data reports.

Conservation of data: The electronic data collected, which consists of automatically-recorded keyboard responses, physiological responses and reaction times to images presented on a computer monitor will be kept in a secure manner. The data will be stored on computer hard disks on the University of Ottawa

campus. Any written responses to questionnaires will be kept in a locked cabinet on the University of Ottawa campus, and will be de-identified with a 5 digit code. Only the researchers will have access to it. It will be kept for a period of 5 to 10 years before being securely deleted or shredded.

Compensation: I understand that I am participating as part of the University of Ottawa's Integrated System of Participation in Research (ISPR), and that I will receive course credit for participating in this research in accordance with the rules of the ISPR. I understand that I may withdraw from the study at any time and nonetheless receive these credits in full.

Voluntary participation: I understand that I am under no obligation to participate and that if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions, without suffering any negative consequences. If I choose to withdraw, all data gathered until the time of withdrawal will be deleted.

Acceptance: I, _____ (print name), agree to participate in the above research study conducted by the researchers listed at the beginning of this document. I understand that these researchers are affiliated with the School of Psychology, Faculty of Social Sciences, University of Ottawa and that the research is being done under the supervision of Professor Charles A. Collin.

If I have any questions about the study, I may contact the researcher or the supervisor.

If I have any questions regarding the ethical conduct of this study, I may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 154, Ottawa, ON K1N 6N5.
Tel.: (613) 562-5387
Email: ethics@uottawa.ca
There are two copies of the consent form, one of which is mine to keep.

Participant's signature: _____ Date: _____

Researcher's signature: _____ Date: _____

Appendix D

Suicide Risk Assessment Protocol

OSI 3. Have you ever thought about taking your life?

If participant endorses "yes" response to this question then risk assessment protocol should be completed.

OSI 4. Have you ever made an attempt to take your life?

If participant endorses a suicide attempt in the "past 1 month" or "past 6 months" then risk assessment protocol should be completed.

OSI 5. Have you been treated by a doctor after injuring yourself on purpose?

If participant endorses "yes" response to this question then risk assessment protocol should be completed.

OSI 6. Have you been kept in hospital because of hurting yourself on purpose?

If participant endorses "yes" response to this question then risk assessment protocol should be completed.

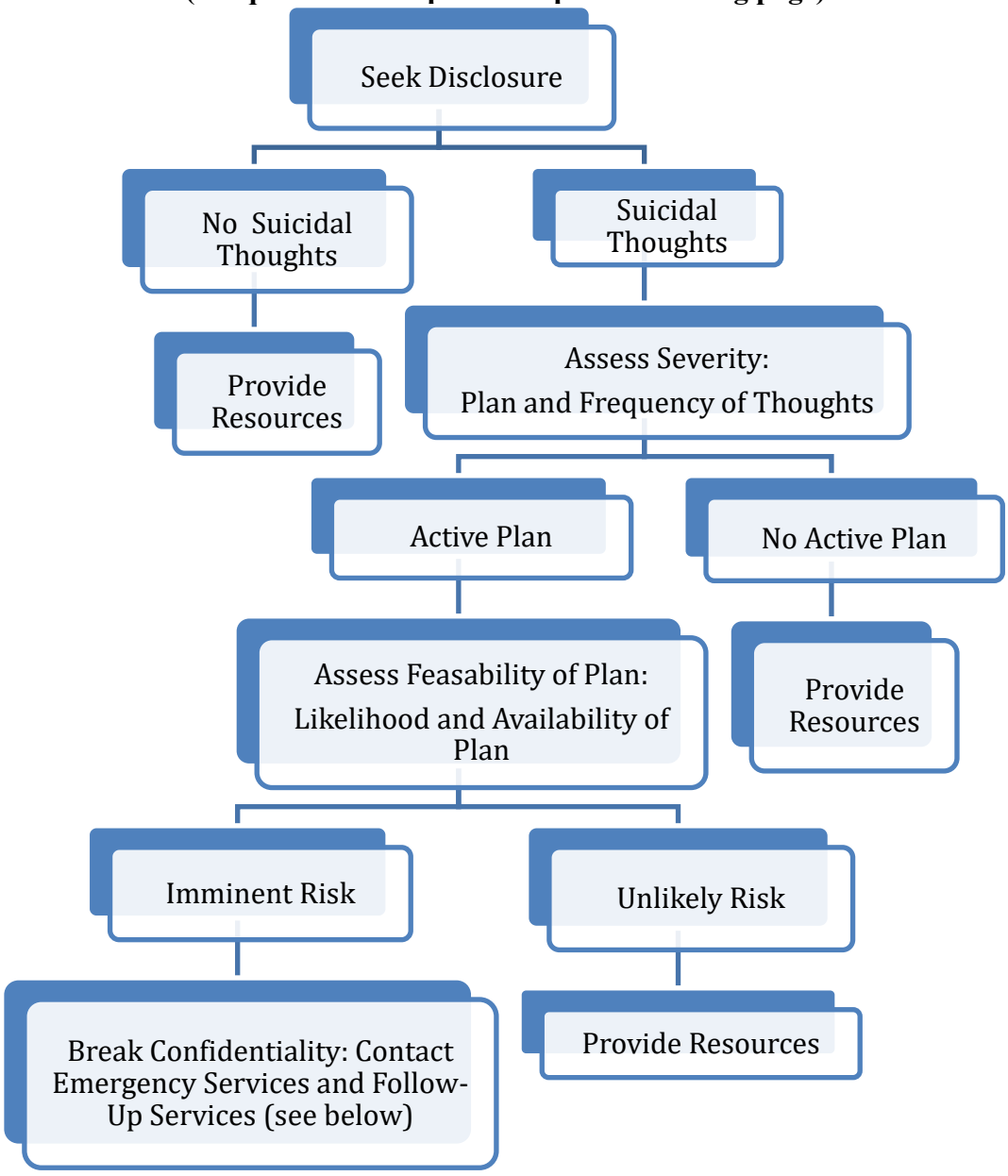
RA should check for this response on participant's OSI immediately following completion of the questionnaires. If evaluation protocol requirement (any <u>one</u> of the above) is met, risk assessment evaluation must be followed.

Risk assessment evaluation is conducted privately and confidentially. When asking the participant to accompany you to a private room, inform the participant that you *"have to verify some questions on (your) questionnaires"*.

After risk assessment, all participants who undergo the evaluation should be provided with the *Mental Health Resource List*, and informed that they will receive a follow-up phonecall one week later from the RA who completed the risk assessment (record contact information, and set date for follow up call). Follow-up is to reiterate the usefullness of the resources provided, and to ensure that the participant does not require further assistance. If, at the time of follow-up, the participant appears to be experiencing increased distress, additional follow-up with a principle investigator will be scheduled. See risk assessment flow chart and specified questions below:

Risk Assessment Evaluation Protocol

(see questions for specific steps on following page)



University of Ottawa Centre for Psychological Services	(613)562-5289
University of Ottawa Mental Health Services	(613)562-3950 ext 225
Ottawa Distress Centre	(613)238-3311
Centre d'Aide 24/7 (Francophone)	(819)595-9999
Emergency Services	911

Seek Disclosure:

1. "You indicated on your questionnaires that you have previously *thought about suicide/attempted suicide/been treated by doctor for self-injury/been kept in hospital for hurting yourself* (choose whichever phrase applies based on applicable responses on OSI). Could you tell me a bit about that?"

- Here you're looking for details about the incident, to get them talking about it, how they did it, how it was dealt with afterwards etc. Use prompts to get these answers if needed.

- Other questions that could be helpful: "Had you planned to hurt yourself, or was it spontaneous?", "If something like that happened again, how do you think you would handle it now?"

Assess Severity: plan and thoughts:

2. "Are you thinking about suicide currently?"

3. "Do you have a suicide plan?"

- If yes to thoughts and yes to plan, proceed to next question

- If yes to thoughts only OR yes to plan only (unlikely) OR yes to thoughts and no to plan: "How often do you think about suicide?" and "How would you rate the risk of killing yourself: low, medium, or high risk?"

    - If medium or high risk, proceed to next question

    - If low risk, provide resource list, review list with participant, and obtain contact info in order to schedule one week follow up phone call with RA (should be same RA as completed the risk assessment)

Assess Feasibility of Plan:

4. "Have you thought about how and when and where you're going to kill yourself?"

5. "Do you have access to (*method*)?"

- If yes, continue with question #6 below

- If no or vague response: “Do you have plans to kill yourself in the next 24 hours?”
    - If yes, proceed directly to Emergency Procedures to break confidentiality
    - If no, continue with questions below

6. “Have you taken any steps to prepare for suicide, such as write a note, get your financial affairs in order, or anything else?”

- If yes, proceed directly to Emergency Procedures to break confidentiality
- If no, provide resource list, review list with participant, and obtain contact info in order to schedule one week follow up phone call with RA (should be same RA as completed the risk assessment)

Emergency Procedures

- Inform the participant that according to the law we have to break confidentiality when there is a risk of imminent harm to the self or other.
- RA should call 911 and notify the operator that she/he has a research participant who is at risk of suicide. The operator should ask you to confirm address and location, etc. The adress is 136 Jean Jacques Lussier, Vanier Building (INSIRE lab 5th Floor). Try to met them at the main entrance (this is where assistance from security may be helpful).
- Should also notify the other RA (if applicable) and the university’s security emergency number (613-562-5411) to provide additional support, should it be needed
- Await emergency professionals, and accompany the participant to hospital to ensure the risk is acknowledged

Appendix E

Emotion Perception and Recognition Debriefing Form

Dear participant,

Thank you for taking part in our study. Your participation will help us to better understand emotion recognition and emotion mimicry. The purpose of the study you have participated in is to better understand if variability exists in an individual's ability to recognize and unconsciously mimic emotional faces, and whether or not this variability is linked to emotion coping strategies. Please note that the true purpose of the EMG electrodes were to measure your facial muscle mimicry response to the emotional faces that you were asked to passively observe, and not to measure "physiological changes'', "skin conductance" and "ocular activities".

Were you aware of the recording of your facial muscle responses?

Yes No

Were you aware of any (voluntary or involuntary) facial mimicry on your part?

Yes No

As a result of the partial disclosure/deception, we would like to provide you with the opportunity to consent to your EMG data remaining in the study or to request its withdrawal from the study.

Consent Withdraw

There are two copies of this debriefing form, one of which is yours to keep.

Participant's signature: _____

Date:_____

Researcher's signature: _____

Date: _____

Some of the questions that you were asked to fill out in the writing portion of the study may have dealt with very personal and sensitive issues. Because of this, we are including some detailed information about referral sources that may be beneficial for you. If at any time you would like to speak with members of our research team, we invite you to call us at (613) 562-5800, ext. 7150.

Additional resources are listed on the following pages.

Please make use of the resources below should you require any additional support. Do not hesitate to call our research team if you have any questions or concerns.

Thank you,

The Perception and Cognition Lab
University of Ottawa

Appendix F

Resource List

Crisis Call Centres		
Ottawa Distress Centre (www.dcottawa.on.ca)	613-238-3311	24-hr general crisis intervention.
Mental Health Crisis Line (www.crisisline.ca)	613-722-6914 (in Ottawa) 1-866-996-0991	24-hr mental health crisis line serving individuals 16 years and older.
Ottawa Rape Crisis Centre (www.orcc.net)	613-562-2333	24-hr crisis line for women experiencing current or past sexual abuse and/or assault, including childhood sexual abuse and ritual abuse.
Tel-Aide Outaouais (www.tel-aide-outaouais.org)	613-741-6433 (Ottawa/Gatineau) 1-800-567-9699 (rural)	24-hr crisis line for Francophones living in Ottawa/Gatineau region. Services available to all ages.
Le Centre d'Aide (www.pierre-janet.qc.ca/centre24_7.htm)	819-595-9999	24-hr French distress line for Outaouais region.

Mental Health & Social Service Resources		
www.ementalhealth.ca		A comprehensive online list of mental health resources available in the Ottawa-Carleton region.

Centre for Psychological Services (University of Ottawa)	613-562-5289	Offers individual therapy for adolescents and adults, couple therapy and child and family services.
University of Ottawa Student Academic Success Counselling Services (www.sass.uottawa.ca/personal)	613-562-5800	Offers personal counselling regarding topics such as depression, anxiety, stress, self-esteem, relationships, and sexual harassment to students registered at the University of Ottawa.
Sandy Hill Community Health Centre (www.sandyhillchc.on.ca/)	613-789-1500	Offers free individual, couple, marital and family counselling, and crisis intervention to residents of Sandy Hill.
Somerset West Community Health Centre (www.swchc.on.ca)	613-238-8210	Offers free crisis intervention, individual counselling, women's counselling, and educational and support groups.
Centretown Community Health Centre (www.centretownchc.org)	613-233-4443	Offers free counselling and social support services to residents of Old Ottawa South, the Glebe, and Centretown.
Family Services Ottawa (www.familyservicesottawa.org)	613-725-3601	Offers individual, family and couples counselling, as well as support groups for women survivors of abuse.
Ottawa Academy of Psychologists (www.ottawa-psychologists.org)	613-235-2529	Comprehensive list of registered psychologists and their specialties in the Ottawa area

Appendix G

Socio-demographics Questionnaire

1. What is your age? _____
2. What is your gender?
   - ○ Female
   - ○ Male
3. What is your primary language?
   - ○ English
   - ○ French
   - ○ Other _____
4. What is the highest level of education you have completed?
   - ○ High school or equivalent
   - ○ 1st year university
   - ○ 2nd year university
   - ○ 3rd year university
   - ○ 4th year university
   - ○ More than 4 years of university
   - ○ Graduate studies
5. How would you classify yourself?
   - ○ Arab
   - ○ Asian/Pacific Islander
   - ○ Black
   - ○ Caucasian/White
   - ○ Hispanic
   - ○ Indigenous or Aboriginal
   - ○ Latino
   - ○ Multiracial
   - ○ Would rather not say

- ○ Other _____

6. Have you ever received a diagnosis of any of the following?

   Select all that apply.

   - ○ Depression
   - ○ Dysthymia
   - ○ Bipolar Disorder
   - ○ Generalized anxiety disorder
   - ○ Post-traumatic stress disorder
   - ○ Obsessive compulsive disorder
   - ○ Substance use disorder
   - ○ Eating disorder
   - ○ Would rather not say
   - ○ Other _____
   - ○ None

7. Do you currently have a diagnosis of any of the following?

   Select all that apply.

   - ○ Depression
   - ○ Dysthymia
   - ○ Bipolar Disorder
   - ○ Generalized anxiety disorder
   - ○ Post-traumatic stress disorder
   - ○ Obsessive compulsive disorder
   - ○ Substance use disorder
   - ○ Eating disorder
   - ○ Would rather not say
   - ○ Other _____
   - ○ None

8. Are you taking any medications?
   - ○ No
   - ○ Yes Please specify: _____

9. Did you have coffee before testing?
   - ○ No
   - ○ Yes Approximately how long ago: _____

10. Did you eat food before testing?
    - ○ No
    - ○ Yes What did you eat? _____
      Approximately how long ago: _____

11. How would you rate your current stress level?

No stress				Moderate stress					Extremely high stress
0	2	3	4	5	6	7	8	9	10

12. Do you have a heart condition?
    - ○ No
    - ○ Yes Please specify: _____

13. Do you have a health condition?
    - ○ No
    - ○ Yes Please specify: _____

Appendix H

Ottawa Self-Injury Inventory (OSI-clinical)

Name: _____ **Sex:** _____Male _____ Female

Today's Date: _____ DD _____ MM _____ YY **Date of Birth:** _____ DD _____ MM _____ YY

Age: _____

1. *circle "0" if not at all and circle "3" if daily.*

How often in the past **month** have you:	not at all	at least once	weekly	daily
Thought about injuring yourself without the intention to kill yourself?	0	1	2	3
Actually injured yourself, without the intention to kill yourself?	0	1	2	3

2. *circle "0" if not at all and circle "4" if daily.*

How often in the past **6 months** have you:	not at all	1 to 5 times	monthly	weekly	daily
Thought about injuring yourself without the intention to kill yourself?	0	1	2	3	4
Actually injured yourself, without the intention to kill yourself?	0	1	2	3	4

3. *circle "0" if not at all and circle "4" if daily.*

How often in the past **year** have you:	not at all	1 to 5 times	monthly	weekly	daily
Thought about taking your life (killing yourself)?	0	1	2	3	4

4. Have you ever made an actual attempt to take your life? _____ no _____ yes

   If yes, then please indicate the number of times: in the past month: _____ in the past 6 months: _____

   in the past year:_____ prior to one year ago: _____

5. Have you ever been treated by a doctor after injuring yourself on purpose? (e.g., stitches, wound dressings, etc.)

   _____ no
   _____ yes → how often did a doctor treat you in the *past year* for hurting yourself on purpose? _____ time(s)

6. Have you been kept in hospital because of hurting yourself on purpose?

   _____ no
   _____ yes → how many times in the *past year* did you stay overnight in emergency _____

   how many times in the *past year* did you get admitted to a hospital unit _____

WHY DID YOU START?	never a reason		sometimes a reason		always a reason
1. to release unbearable tension	0	1	2	3	4
2. to experience a "high" that feels like a drug high	0	1	2	3	4
3. to stop my parents from being angry with me	0	1	2	3	4
4. to stop feeling alone and empty	0	1	2	3	4
5. to get care or attention from other people	0	1	2	3	4
6. to punish myself	0	1	2	3	4
7. to provide a sense of excitement that feels exhilarating	0	1	2	3	4
8. to relieve nervousness/fearfulness	0	1	2	3	4
9. to avoid getting into trouble for something I did	0	1	2	3	4
10. to distract me from unpleasant memories	0	1	2	3	4
11. to change my body image and/or appearance	0	1	2	3	4
12. to belong to a group	0	1	2	3	4
13. to release anger	0	1	2	3	4
14. to stop my friends/boyfriend/girlfriend from being angry with me	0	1	2	3	4
15. to show others how hurt or damaged I am	0	1	2	3	4

IF YOU CONTINUE WHY DO YOU CONTINUE?	never a reason		sometimes a reason		always a reason
1. to release unbearable tension	0	1	2	3	4
2. to experience a "high" that feels like a drug high	0	1	2	3	4
3. to stop my parents from being angry with me	0	1	2	3	4
4. to stop feeling alone and empty	0	1	2	3	4
5. to get care or attention from other people	0	1	2	3	4
6. to punish myself	0	1	2	3	4
7. to provide a sense of excitement that feels exhilarating	0	1	2	3	4
8. to relieve nervousness/fearfulness	0	1	2	3	4
9. to avoid getting into trouble for something I did	0	1	2	3	4
10. to distract me from unpleasant memories	0	1	2	3	4
11. to change my body image and/or appearance	0	1	2	3	4
12. to belong to a group	0	1	2	3	4
13. to release anger	0	1	2	3	4
14. to stop my friends/boyfriend/girlfriend from being angry with me	0	1	2	3	4
15. to show others how hurt or damaged I am	0	1	2	3	4

	never a reason			sometimes a reason	always a reason
16. to show others how strong or tough I am	0	1	2	3	4
17. to help me escape from uncomfortable feelings or moods	0	1	2	3	4
18. to satisfy voices inside or outside of me telling me to do it	0	1	2	3	4
19. to experience physical pain in one area, when the other pain I feel is unbearable	0	1	2	3	4
20. to stop people from expecting so much from me	0	1	2	3	4
21. to relieve feelings of sadness or feeling "down"	0	1	2	3	4
22. to have control in a situation where no one can influence me	0	1	2	3	4
23. to stop me from thinking about ideas of killing myself	0	1	2	3	4
24. to stop me from acting out ideas of killing myself	0	1	2	3	4
25. to produce a sense of being real when I feel numb and "unreal"	0	1	2	3	4
26. to release frustration	0	1	2	3	4
27. to get out of doing something that I don't want to do	0	1	2	3	4
28. for no reason that I know about - it just happens sometimes	0	1	2	3	4
29. to prove to myself how much I can take	0	1	2	3	4
30. for sexual excitement	0	1	2	3	4
31. to diminish feeling of sexual arousal	0	1	2	3	4
32.					
33. other (please specify) _____	0	1	2	3	4

	never a reason			sometimes a reason	always a reason
16. to show others how strong or tough I am	0	1	2	3	4
17. to help me escape from uncomfortable feelings or moods	0	1	2	3	4
18. to satisfy voices inside or outside of me telling me to do it	0	1	2	3	4
19. to experience physical pain in one area, when the other pain I feel is unbearable	0	1	2	3	4
20. to stop people from expecting so much from me	0	1	2	3	4
21. to relieve feelings of sadness or feeling "down"	0	1	2	3	4
22. to have control in a situation where no one can influence me	0	1	2	3	4
23. to stop me from thinking about ideas of killing myself	0	1	2	3	4
24. to stop me from acting out ideas of killing myself	0	1	2	3	4
25. to produce a sense of being real when I feel numb and "unreal"	0	1	2	3	4
26. to release frustration	0	1	2	3	4
27. to get out of doing something that I don't want to do	0	1	2	3	4
28. for no reason that I know about - it just happens sometimes	0	1	2	3	4
29. to prove to myself how much I can take	0	1	2	3	4
30. for sexual excitement	0	1	2	3	4
31. to diminish feeling of sexual arousal	0	1	2	3	4
32. I am "addicted" to doing it	0	1	2	3	4
33. other (please specify) _____	0	1	2	3	4

Appendix I

INVENTORY OF STATEMENTS ABOUT SELF-INJURY (ISAS) – SECTION II. FUNCTIONS

Name:_____

Date:_____

Instructions

This inventory was written to help us better understand the experience of non-suicidal self-harm. Below is a list of statements that may or may not be relevant to your experience of self-harm. Please identify the statements that are most relevant for you:

- Circle **0** if the statement **not relevant** for you at all
- Circle **1** if the statement is **somewhat relevant** for you
- Circle **2** if the statement is **very relevant** for you

"When I self-harm, I am ...	**Response**		
1. ... calming myself down	0	1	2
2. ... creating a boundary between myself and others	0	1	2
3. ... punishing myself	0	1	2
4. ... giving myself a way to care for myself (by attending to the wound)	0	1	2
5. ... causing pain so I will stop feeling numb	0	1	2
6. ... avoiding the impulse to attempt suicide	0	1	2
7. ... doing something to generate excitement or exhilaration	0	1	2
8. ... bonding with peers	0	1	2
9. ... letting others know the extent of my emotional pain	0	1	2
10. ... seeing if I can stand the pain	0	1	2
11. ... creating a physical sign that I feel awful	0	1	2
12. ... getting back at someone	0	1	2
13. ... ensuring that I am self-sufficient	0	1	2
14. ... releasing emotional pressure that has built up inside of me	0	1	2
15. ... demonstrating that I am separate from other people	0	1	2
16. ... expressing anger towards myself for being worthless or stupid	0	1	2

Response Key: 0 – not relevant, **1** – somewhat relevant, **2** – very relevant

"When I self-harm, I am ...

17. ... creating a physical injury that is easier to care for than my emotional distress	0	1	2
18. ... trying to feel something (as opposed to nothing) even if it is physical pain	0	1	2
19. ... responding to suicidal thoughts without actually attempting suicide	0	1	2
20. ... entertaining myself or others by doing something extreme	0	1	2
21. ... fitting in with others	0	1	2
22. ... seeking care or help from others	0	1	2
23. ... demonstrating I am tough or strong	0	1	2
24. ... proving to myself that my emotional pain is real	0	1	2
25. ... getting revenge against others	0	1	2
26. ... demonstrating that I do not need to rely on others for help	0	1	2
27. ... reducing anxiety, frustration, anger, or other overwhelming emotions	0	1	2
28. ... establishing a barrier between myself and others	0	1	2
29. ... reacting to feeling unhappy with myself or disgusted with myself	0	1	2
30. ... allowing myself to focus on treating the injury, which can be gratifying or satisfying	0	1	2
31. ... making sure I am still alive when I don't feel real	0	1	2
32. ... putting a stop to suicidal thoughts	0	1	2
33. ... pushing my limits in a manner akin to skydiving or other extreme activities	0	1	2
34. ... creating a sign of friendship or kinship with friends or loved ones	0	1	2
35. ... keeping a loved one from leaving or abandoning me	0	1	2
36. ... proving I can take the physical pain	0	1	2
37. ... signifying the emotional distress I'm experiencing	0	1	2
38. ... trying to hurt someone close to me	0	1	2
39. ... establishing that I am autonomous/independent	0	1	2