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I'll Cry Instead: The Neural Correlates of Empathy

Dissertation submitted by

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Abstract

Tears demand attention. A compelling form of emotional expression, tears fascinate both scientists and lay people alike (Trimble, 2012). Despite this fascination, surprisingly little is known about the functions of tears, as crying has been neglected by emotion researchers relative to other expressions (Vingerhoets, 2013). Emotional tears are believed to signal sadness and distress, which in turn reliably elicit help and empathic responses from observers (Balsters, Krahmer, Swerts, & Vingerhoets, 2013; Hendriks & Vingerhoets, 2006; Lockwood, Millings, Hepper, & Rowe, 2013; Provine, Krosnowski, & Brocato, 2009). However, it is unknown why tears elicit such strong responses from observers. To put it simply, why do we care when others cry?

This thesis details a series of studies investigating the way that unconscious physiological responses influence the way we outwardly respond to emotional tears. First, it was established that tears signal sadness in the absence of context, regardless of the valence of the facial expression. Moreover, tearful displays of sadness, and happy faces without tears are particularly distinctive displays that are rapidly interpreted. Therefore, tears modulate the way that emotional faces are perceived at the behavioural level.

Next, I sought to explore whether these pronounced responses to tears had a biological basis. To address this aim, I explored the way that mimicry, early event-related potentials (ERP), and neural mirroring were influenced by the presence of tears on a face. Chapter 4 demonstrated that mimicry largely was not affected by tear presence. As such, it was concluded that mimicry of tearful displays may not be adaptive. Conversely, Chapter 5 demonstrated that tears were preferentially processed at the early neural level. Moreover, tearful sadness and happy faces without tears elicited larger face-related ERPs than other expressions. This increased responding is in line with the social relevance hypothesis, which posits that emotional expressions with increased social relevance are preferentially processed.

Therefore, the results in Chapter 5 demonstrate the same pattern of results as the behavioural data reported in Chapter 3, demonstrating a biological basis for the behavioural results. Finally, Chapter 6 details one of the first studies to explore whether neural mirroring is modulated by tearful displays. The results obtained were the inverse of that reported in Chapters 3 and 5, where more ambiguous expressions (i.e. neutral, happy-tear, and sad tear-free) elicited greater neural mirroring. This result is in accord with recent research, which has demonstrated that ambiguous faces require greater neural mirroring. Therefore, tearful expressions—particularly those of sadness—are interpreted rapidly. Moreover, humans appear to be biologically hard-wired to respond to socially relevant information. This thesis has provided both behavioural and psychophysiological evidence to demonstrate that tears enhance the social relevance of sad faces. However, *what* is it about tears that make them such an effective signal?

The final aim of this thesis was to explore the type of stimuli used in tear research. Tears have been touted as an honest signal of emotion; however, there is limited empirical evidence to support this assertion. Chapter 8 details the results of some of the first experiments exploring perceptions of genuineness in tearful displays. It was demonstrated that people are sensitive to the difference between posed and genuine crying, and that tears increase the perception of genuineness for posed displays. Thus, this research has provided a rationale for continued investigation of the ideal type of stimuli to be used in tear research and has highlighted the potential to use tears as a means of determining how humans distinguish between sincere and insincere emotion.

Overall, the results of this thesis detail the way that subconscious physiological responses influence the way we outwardly respond to emotional tears. Through the use of novel methodologies, this thesis has demonstrated the unique way that tears shape responses to facial expressions. Therefore, this research affords a new understanding of a uniquely human phenomenon, and by extension, provides insight into the development of empathy and prosocial behaviour in society as a whole.

Wordcount: 650 words (min 500)

Declaration

I declare that this dissertation is my own work and has not been submitted in any other form for another degree or diploma at any other university or other institution of tertiary education. Information derived from published or unpublished work of others has been acknowledged in the text and a list of references given.

Sarah Krivan

28/03/2020

Statement of Contributions

This thesis is made up of my own work, except for the normal contributions of a supervisory panel. Chapters 1, 2, and 9 are completely my own work. Chapters 3, 4, 5, 6, 7, and 8 are prepared as manuscripts for publication and the contribution of co-authors is outlined below and at the beginning of each chapter. I also acknowledge the aid of Aidan Possemiers in implementing the Python script for the processing of the EEG data in Chapter 6. Table 1 denotes the intellectual and financial support received throughout my candidature.

Table 1.

Overarching support throughout doctoral candidature.

Nature of Assistance	**Contribution**	**Names, Titles and Affiliation of Co-Contributors**
Financial support	Fee offset/waiver Research costs RTP Stipend JCU Stipend	Australian Government Research Training Program and James Cook University
Intellectual Support	Supervision Conceptualisation of the research Revision of manuscripts	A/Prof. Nerina Caltabiano (James Cook University), Dr. David Cottrell (James Cook University – Adjunct), and Dr. Nicole Thomas (Monash University)

Publications arising from this dissertation and the contributions of the candidate and co-authors

One scientific paper has already been published:

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This paper is included in the thesis exactly as it is reported in the published version (except for minor formatting changes). The text in this thesis and the published document is identical.

I conceptualized and designed the article and wrote the first draft of the manuscript. I re-drafted subsequent manuscript versions, implemented the changes recommended by reviewers and approved the submitted version.

Thomas contributed to manuscript revision, read and approved the submitted version.

I confirm the candidate's contribution to this paper and consent to the inclusion of the paper in this thesis:

Name	Signature
Dr. Nicole Thomas	Content has been removed for privacy reasons

Two scientific papers have been resubmitted after 'revise and resubmit' recommendations:

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I conceptualized and designed the experiment, programmed the experiment, created the stimuli, collected the data, decided the pre-processing techniques, analysed the data, and wrote the first draft of the manuscript. I re-drafted subsequent manuscript versions, implemented the changes recommended by reviewers and approved the submitted version.

Caltabiano and Cottrell provided supervision for the project. Cottrell aided in experiment conceptualisation.

Thomas contributed to manuscript revision, read and approved the submitted version.

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Dr. David Cottrell	Content has been removed for privacy reasons
Dr. Nicole Thomas	Content has been removed for privacy reasons

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Caltabiano provided supervision for the project.

Cottrell aided in experiment conceptualisation and provided supervision for the project.

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Dr. David Cottrell	Content has been removed for privacy reasons
Dr. Nicole Thomas	Content has been removed for privacy reasons

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Dr. Nicole Thomas	Content has been removed for privacy reasons

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Cottrell aided in conceptualisation of the project and provided supervision.

Thomas contributed to manuscript revision and provided supervision.

I confirm the candidate's contribution to this paper and consent to the inclusion of the paper in this thesis:

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Dr. Nicole Thomas	Content has been removed for privacy reasons

Krivan, S. J., & Thomas, N. A. (2020). *Tears alter the perceived genuineness of emotional displays.* Manuscript in preparation.

I conceptualized and designed the experiment, programmed the experiment, created the stimuli, collected the data, analysed the data, and drafted the manuscript.

Thomas contributed to experiment conceptualisation, provided the funding for the experiments, and aided in manuscript revision.

I confirm the candidate's contribution to this paper and consent to the inclusion of the paper in this thesis:

Name	**Signature**
Dr. Nicole Thomas	Content has been removed for privacy reasons

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Abbreviations

ASE = Anger Superiority Effect

BECV = Behavioural Ecology View

BET = Basic Emotion Theory

EEG = Electroencephalography

EMG = Electromyography

ERP = Event-Related Potential

fMRI = Functional Magnetic Resonance Imaging

HFA = Happy Face Advantage

KDEF = Karolinska Directed Emotional Faces

MEG = Magnetoencephalography

MNS = Mirror Neuron System

MEG = Magnetoencephalography

PAM = Perception Action Model

TMS = Transcranial Magnetic Stimulation

Chapter 1: Responses to Emotional Facial Expressions and Crying

The land of tears is so mysterious.

- Antoine de Saint-Exupéry, The Little Prince.

1.1 Introduction Overview

Tears demand attention. A compelling form of emotional expression, tears fascinate both scientists and lay people alike (Trimble, 2012). Despite this fascination, surprisingly little is known about the functions of tears, as crying has been neglected by emotion researchers relative to other universal expressions (Vingerhoets, 2013). Tears act as a cue for empathic responses; they are a salient distress signal, which elicit attention and prosocial responses from those witness to the display (Hasson, 2009; Kret, 2015). The communicative functions of emotion are increasingly being investigated to determine why tears elicit these responses from observers. Put simply, why do we care when others cry?

The overarching aim of this thesis was to investigate how people perceive and respond to emotional tears. Specifically, I sought to extend the existing research, which has identified that tears elicit pro-social responses, by using a combination of psychophysiological and behavioural measures. The use of psychophysiology provides the opportunity to validate earlier self-report studies, and additionally provide a biological basis for the communicative function of tears. The introduction of this thesis is comprised of two chapters. Chapter 1 reviews the existing literature exploring facial emotional processing and the communicative functions of tears. Chapter 2 explores the psychophysiological measurement of empathy, through the lens of a perception-action model. Furthermore, Chapter 2 discusses the neural correlates that are believed to underpin the sharing of others' affective states. Finally, Chapter 2 will conclude by bringing these two lines of inquiry together and outline how this thesis will explore the way we perceive and respond to adult emotional tears.

1.2 Facial Expressions

The face is a rich canvas through which communication with others can occur without words. Therefore, the rapid and accurate decoding of facial displays is integral to adaptive social behaviour and survival (Batty & Taylor, 2003). However, there are several competing theories about what facial expressions convey. Dimensional theory, as it stands today, argues that facial expressions of emotion can be categorised on a two-dimensional circumplex, wherein affective states are distributed on the basis of valence and arousal (Russell, 1980). Basic Emotion Theory asserts that there are six expressions of emotion which are universally recognisable (Ekman & Friesen, 1969). Finally, the Behavioural Ecology View Theory states that facial expressions are unrelated to emotion and instead are communicative signals (Fridlund, 1994). This review of the facial expression literature begins by exploring the tenets of these three theories, as well as their associated criticisms. Next, the focus shifts to the development of the view that facial expressions are both affective and communicative with a review of the literature that details a processing advantage for positive and negative affective states. Finally, the review concludes with a summary of the empirical research exploring the communicative functions of emotional tears.

1.3 Emotional Theories

Emotions are inherently complex. The main goal of emotion theorists is to understand emotion—whether that be expression, perception, or feeling. However, understanding emotion is a complicated endeavour. For this reason, the majority of emotion research has attempted to reduce emotion into constituent components. This approach has given rise to most of the models of emotion we have today—wherein emotions (in all their complexity) can be reduced to bipolar dimensions in dimensional theory; basic expressions, in Basic Emotion Theory; and targeted signals under the Behavioural Ecology View Theory.

The idea of affective dimensions began with Wundt (1897), wherein emotions could-be expressed by way of three bipolar dimensions: pleasant-unpleasant, excitement-inhibition, tension-relaxation. Since this early work, the dimensional theory typically adopts a two-dimensional structure, due to the overlap between the excitement-inhibition and tension-relaxation dimensions (Larsen & Diener, 1992; Watson & Tellegen, 1985; Yik, Russell, & Feldman Barrett, 1999). Schlosberg (1952) proposed that facial expressions (e.g. expressions of love/ happiness; and fear/ suffering), could be organised on a circular model, wherein emotions could be represented as bipolar, rather than singular states. Russell (1980) built upon this theory and developed the circumplex model of affect. The circumplex model of affect proposes that emotional states are expressed via two affective dimensions: a hedonic valence dimension encompassing the pleasantness or unpleasantness of a stimulus; and an arousal dimension encompassing alertness from arousal to sleep (Russell, 1980). In this way, facial expressions of emotion vary on the basis of these two dimensions, and as such can then be transformed into specific labels. Therefore, emotions are not independent of one and other—rather they are interrelated according to these two bipolar dimensions (Russell & Barrett, 1999). For example, happiness is considered a pleasant, positive emotion, whereas sadness is considered an unpleasant negative emotion. For this reason, happiness and sadness sit at opposite ends of the valence dimension. However, happiness is more arousing than sadness, thus they sit in opposite quadrants according to the circumplex model (see Figure 1.1). In this way, emotions are structured according to these dimensions, rather than as discrete categories.

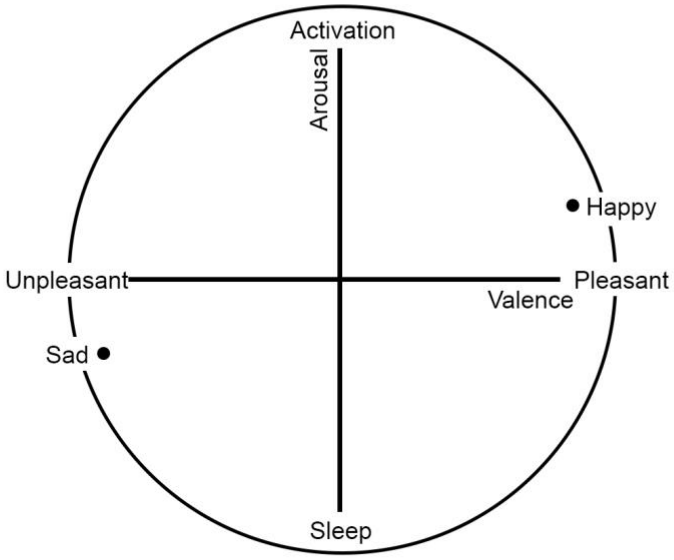

Figure 1.1. Circumplex model of affect with happy and sad plotted as bipolar emotions.

It is widely accepted that facial expressions are a means of expressing emotional states. Popularised by Darwin (1872/1979) in the book *The Expression of Emotion in Man and Animals*, it was asserted that facial expressions of emotion were expressed in a universal way. This universality meant that emotion played an important role in evolutionary theory, wherein understanding emotion via facial displays was critical for survival. Since Darwin's work, there have been several influential theories about the role of universality in facial emotion (Izard, 1971; Tomkins, 1962). This paved the way for the Neurocultural Theory of Emotion proposed by Ekman (1972), wherein emotion is spontaneously expressed through the face. This spontaneous expression provides us with the ability to understand the underlying affect a person is experiencing. These expressions are consistent across cultures, and as such are universal. However, universal facial expressions can be overridden in certain social scenarios wherein the expression of emotion would be inappropriate. Termed *display rules*, these expressions are associated with the mediation of the expression of emotion which can vary across cultures. In this way, facial expressions can be both universal and culture specific.

It has been hypothesised that there are six facial expressions of emotion that are universally expressed, and, as such, are universally recognisable (Ekman & Friesen, 1969). Known as Basic Emotion Theory (BET), these basic emotions include: happiness, sadness, anger, fear, disgust, and surprise (though occasionally other categories, such as contempt, are included; Ekman, 1992). Ekman and Friesen (1969) showed prototypical photographs of basic emotions to a remote Papua New Guinea culture known as the South Fore. All Fore individuals were capable of classifying basic emotional displays in their own language. In another study, Fore individuals were asked to pose emotions from their own language, and these emotions were accurately decoded by other Fore observers, as well as western populations, albeit classification accuracy was lower in the former group (Ekman, Sorenson, & Friesen, 1969). Further evidence for universality was demonstrated, as the least westernised Fore members were capable of correctly selecting a facial display that accompanied an emotional story (i.e. a happy facial display was selected for a happy story) for most basic expressions (Ekman & Friesen, 1971). These studies provide evidence for the universality of emotion, wherein facial affect is both expressed and recognised across cultures.

By contrast, cultural specificity has been demonstrated through the experimental investigation of the facial displays of United States and Japanese students, which were activated in response to films (Ekman, 1972). While facial displays were largely similar between US and Japanese students in a solitary condition, Japanese students were less likely to express negative facial emotions in the presence of an observer. This finding fits within the concept of display rules, wherein negative emotion is inhibited or masked (Ekman, 1972). Additionally, in further studies of American and Japanese subjects, there was agreement across the type of emotion expressed (Ekman et al., 1987); however, Japanese participants attributed lower intensity ratings to the basic emotions, with the exception of disgust (Matsumoto & Ekman, 1989). Thus, facial expressions can be both universal and culturally specific, by way of expressive intensity.

As the universality movement demonstrated that prototypical expressions were associated with emotional states, there was a growing need for a measurement system that was capable of indexing the anatomical structures associated with facial movements (Ekman & Rosenberg, 2005). The Facial Action Coding System (FACS) is a anatomically based system that distinguishes facial activity on the basis of muscular movements (Ekman & Friesen, 1978). Facial activity is broken down into singular action units (AUs), where each AU has a unique code, and is associated with a corresponding muscular movement. There are 44 AU, 13 of which are associated with basic emotions (Ekman & Rosenberg, 2005). For example, when one smiles, the corners of the lips are drawn upwards towards the ears, by the Zygomaticus Major muscle (Duchenne 1862/1990). This movement is associated with AU 12, or lip corner puller (Ekman & Rosenberg, 2005). In this way facial movements are categorised based on the outward appearance of the underlying facial muscle. Each basic emotion is associated with a selection of AUs (see Table 1.1).

Table 1.1

An Overview of the Basic Emotions; Their Associated AUs in the FACS, and the Muscles associated with each AU (Adapted from Ekman and Rosenberg, 2005).

Emotion	**FACS AU**	**Muscles**
Happy	6, 12	Orbicularis Oculi Orbitalis, Zygomaticus Major
Sad	1, 4, 15	Frontalis Medialis, Depressor Corrugator Supercilii, Triangularis
Anger	4, 5, 7, 23	Depressor Corrugator Supercilii, Levator Superioris, Orbicularis Oculi Palebralis, Orbicularis Oris
Disgust	9, 15, 16	Levator Labii Superioris, Alaeque Nasi, Triangularis, Depressor Labii
Fear	1, 2, 4, 5, 7, 20, 26	Frontalis Medialis, Frontalis Lateralis, Depressor Corrugator Supercilii, Levator Superioris, Orbicularis Oculi Palebralis, Risorius, Masetter
Surprise	1, 2, 5, 26	Frontalis Medialis, Frontalis Lateralis, Levator Superioris, Masetter

Note. AU: 1 = inner brow raiser; 2 = outer brow raiser; 4 = brow lowerer; 5 = upper lid raiser; 6 = cheek raiser; 7 = lid tightener; 9 = nose wrinkler; 12 = lip corner puller; 15 = lip corner depressor; 16 = lower lip depressor; 20 = lip stretcher; 23 = lip tightener; 26 = jaw drop.

While the BET remains the most popular emotion theory, it is not without its criticisms. One prominent problem with the BET stems from the core premise that emotions activate spontaneous facial representations, and deviations from such representations are a reflection of learned display rules (Ekman, 1972). In this way, spontaneous displays are restricted to a proscriptive set of facial movements. Therefore, variability in expressive behaviour only occurs as a result of social interaction. However, several empirical studies have failed to demonstrate these facial responses in empirical studies of spontaneous expression (Fernández-Dols & Ruiz-Belda, 1995; Fernández-Dols & Ruiz-Belda, 1995; Fernández-Dols, Sánchez, Carrera, & Ruiz-Belda, 1997). Thus, this mismatch in experienced emotion and facial expression challenges the core tenets of BET. In addition, Fridlund (2017) fundamentally disagreed with the BET, due to the circular nature of matching select emotional terms with emotional images, and select emotional images with emotional terms. In this way, the technical procedures responsible for popularising BET were flawed. It was these criticisms that resulted in the development of the Behavioural Ecology View (BECV).

By contrast, the BECV is based upon the idea that facial expressions function as social signals (Fridlund, 1991, 1994, 2017). Under the BECV facial expressions are not related to an underlying emotional state. Instead, human emotional experience is unrelated to facial expression. Moreover, Fridlund (1994) asserts that fundamental emotions, and their accompanying expressions, do not exist. Rather, facial displays are dependent on intention and context. As a result, a facial expression of a frown or a scowl, which would be associated with the expression of anger under BET, is associated with signalling intention to attack, or eliciting submission from interaction targets (Fridlund, 2017). Table 1.2 summarises the functions of facial expressions under the BECV. In this way, facial expressions are not expressed when one feels intense emotion, but rather when one can elicit the optimum response in social scenarios.

Table 1.2

Facial Expressions and their Associated Emotions under the BET, and Functions under the BECV (Adapted from Fridlund, 1994).

Expression	**BET**	**BECV**
Smiling	Happy	Affiliation
Pouting	Sad	Elicit support; display of surrender
Scowling	Anger	Readiness to attack; elicit submission
Gasping	Fear	Submission; withdrawal
Nose scrunching	Disgust	Rejection

The BECV has predominantly been bolstered through research demonstrating that emotional expressions are maximal during social interaction. Therefore, the context in which the facial expression occurs contributes more to outward expression than the emotion experienced. For example, humans smile for a variety of reasons—to signal affiliation, to engage in pleasant social interactions (i.e. a polite smile), to engage in social dominance behaviours (Martin, Rychlowska, Wood, & Niedenthal, 2017; Niedenthal, Mermillod, Maringer, & Hess, 2010)—and these smiles need not be accompanied by an underlying positive affective state. Thus, it is insufficient to propose that basic emotions accompany prototypical smiling faces. This argument has received experimental support wherein positive facial displays occur more frequently in the presence of social others, as opposed to alone (Fridlund, 1991; Hess, Banse, & Kappas, 1995; Jakobs, Manstead, & Fischer, 1999).

Young and Fry (1966) demonstrated that laughter and smiling in response to humorous jokes occurred more in the presence of peers than when alone. Further evidence for this conclusion was demonstrated in a series of studies wherein increased smiles were exhibited to films when accompanied by friends, as opposed to being alone or with strangers (Jakobs et al., 1999; Jakobs, Manstead, & Fischer, 1999). Similarly, Fridlund (1991) concluded that humorous content viewed with friends elicits greater smiling responses than content viewed alone. A similar conclusion was demonstrated from naturalistic observations of victorious athletes (Fernández-Dols & Ruiz-Belda, 1995). Moreover, gold medal winners exhibited increased smiling behaviour during social interaction contexts (i.e. podium waving), than during non-interactive stages (i.e. waiting to proceed to the podium). Relatedly Crivelli, Carrera, and Fernández-Dols (2015) demonstrated a greater occurrence of genuine smiles when judo winners were engaging with the audience after victory, as opposed to a non-social interaction. In this way, social presence increases expressiveness.

However, the BECV is also not without its critics, as a number of studies have demonstrated that social presence *decreases* expressiveness. Zeman and Garber (1996) demonstrated that children were more likely to control their expressions when in the company of peers and attributed this restraint to the anticipation of negative interpersonal reactions. Similarly, Kraut (1982) demonstrated that when participants were seated in a room separated by a partition (so that the participants knew each other were there, but could not see one another), participants were less expressive in spontaneous facial responses to both pleasant and noxious odours than when alone. Jakobs, Manstead, and Fischer (2001) further demonstrated that although smiling behaviours increased in the presence of others, sadness displays (i.e. AU 1, AU4, and AU15) were greatest when alone. These findings contradict the BECV, wherein sadness should occur more often in the presence of friends, in order to effectively elicit help and succour. Rather, Jakobs et al. (2001) and Zeman and Garber (1996) provide evidence for the suppression of negative emotion in the presence of others, in line with display rules (Ekman, 1972).

Additionally, the BECV has been criticised as facial expressions have been found to occur when individuals are physically alone (i.e. not engaging in social interaction) (Ekman, 1972; Ekman, Davidson, & Friesen, 1990). However, Fridlund has consistently asserted that being physically alone does not preclude one from being implicitly social (Fridlund, 1991, 1994, 2017). In this way, talking to one's self when anticipating social interaction; interacting with inanimate objects; and imagining that others are present are all implicitly social (Fridlund, 2017). Thus, regardless of whether private speech is audible or subvocal (i.e. talking in one's head), it is accompanied by facial expression. Additionally, implicit sociality has been demonstrated in empirical studies (Fridlund, 1991; Fridlund, Kenworthy, & Jaffey, 1992; Fridlund et al., 1990). When engaging in affective imagery, participants in the high sociality condition smiled more than those in the low sociality condition, as indexed by increased zygomaticus major activity measured via electromyography (Fridlund et al., 1990). Similarly, participants smiled more during a humorous film when they were informed that their friend was also watching the film in a separate location (Fridlund, 1991). In this way, sociality can be implied, and as such facial expressions are inherently social.

Consequently, no theory of emotion discussed thus far can be thought of as wholly correct. Fridlund's (1994) assertion that facial expressions are devoid of emotion is unlikely. Evidence for 'what' facial expressions communicate was provided in an online study where 2000 participants were shown facial expressions and asked whether they were more likely to be associated with emotion or behavioural intention (Horstmann, 2003). Of the six basic emotions, the majority were associated with feeling; only anger was associated with behavioural intention. However, Ekman's (1972) model of basic emotions is also flawed as it does not fully encompass the range of emotions experienced by an individual, and instead groups similar emotions under one umbrella (i.e. rage, frustration, and irritation all fall under anger). Finally, the dimensional model (arousal-valence) is limited because emotions that are similar in valence and arousal (i.e. anger and fear are both arousing and negative) are difficult to differentiate due to their shared circumplex space (Wyczesany & Ligeza, 2015). Rather, it is more than likely that facial expressions are capable of reflecting underlying emotional affect, while also signalling intent to interactional partners (Hess & Thibault, 2009; Parkinson, 2005). Thus, facial displays are widely associated with the expression of emotion; however, emotion dually encompasses both feelings and intentions.

1.4 Positivity and Negativity Biases

In thinking about emotion as both a feeling and an intention, one can explore the signal value of positive and negative emotional displays. On one hand, positive emotions signal affiliation, and are a low-cost emotion because the cost of social interaction is low for senders and observers (Bourgeois & Hess, 2008). For this reason, displays such as smiles should be readily shared, as there is an evolutionary advantage to adaptive pro-social behaviours (Johnston, Miles, & Macrae, 2010). By contrast, negative emotions, such as anger and fear, signal potentially threatening and dangerous situations (Hajcak, Weinberg, MacNamara, & Foti, 2011; Ito, Larsen, Smith, & Cacioppo, 1998). In this way, the rapid interpretation of threat related signals would be biologically advantageous for survival (LeDoux, 2007; Liddell, Williams, Rathjen, Shevrin, & Gordon, 2004). Thus, both positive and negative facial displays serve an evolutionary purpose. This evolutionary purpose has seen the development of two research arguments: one is a positivity advantage (i.e., the Happy Face Advantage, HFA) and the other is a negativity bias (e.g., the Anger Superiority Effect, ASE). In both theories, it is argued that a particular display is facilitated, enhanced, or preferentially processed as a result of increased evolutionary relevance. The following paragraphs will outline the research contributing to the development of both theories and the bounds and limitations of each argument.

The preferential processing of positive stimuli has been evidenced using faces (Calvo, Avero, Fernández-Martín, & Recio, 2016; Leppänen, Tenhunen, & Hietanen, 2003; Palermo & Coltheart, 2004), images (Lehr, Bergum, & Standing, 1966), and words (Bayer & Schacht, 2014; Feyereisen, Malet, & Martin, 1986; Stenberg, Wiking, & Dahl, 1998). In this way, humans are quick to respond, preferentially process, and retain positive information, relative to unpleasant information. This concept is largely conveyed by the *Pollyanna principle* (Matlin & Stang, 1979). The Pollyanna principle stems from looking on the bright side and remaining optimistic. For example, according to the Pollyanna principle, persons would convey positive information more than negative information, use positive terms rather than negative terms, and favour positive events more than negative events. In this way, there is a positivity bias that encompasses memory, language, and perception (Matlin, 2017). By far the most evidence for a positivity bias stems from the research exploring the HFA, wherein happy faces are processed with greater accuracy and more efficiency relative to other facial displays.

The HFA has been demonstrated using photorealistic stimuli (Calvo et al., 2016; Leppänen et al., 2003; Palermo & Coltheart, 2004), digital avatars (Becker, Anderson, Mortensen, Neufeld, & Neel, 2011), and schematic smiles (Kirita & Endo, 1995; Leppänen & Hietanen, 2004). Additionally, the HFA has been demonstrated in infants, where happy faces are distinguished from other emotional expressions (LaBarbera, Izard, Vietze, & Parisi, 1976). A series of experiments exploring patients with bilateral amygdala damage has shown impairments in the recognition of emotions relative to healthy controls, with the exception of happiness (Adolphs, Tranel, & Damasio, 2003; Adolphs et al., 1999). Thus, research with both infants and neurologically impaired patients have displayed a processing advantage for happy facial displays. This processing advantage may be a result of the signal value of the emotion. Moreover, happy face classification remains accurate regardless of greater viewing distance or impaired image resolution (Du & Martinez, 2011; Hager & Ekman, 1979). The HFA has particular implications for evolutionary theory, as the ability to accurately perceive signals of affiliation from great distances aids in fostering pro-social behaviours (Mehu, Grammer, & Dunbar, 2007). Additionally, cross cultural studies demonstrate that happy facial displays are consistently recognised accurately (Ekman, 1972; Ekman & Friesen, 1976; Ekman et al., 1987). Therefore, smiling behaviours are an adaptive signal that allow for the transmission of affiliative intent across cultures.

By contrast, the negativity bias asserts that in most situations, negative events are more salient or memorable than positive events (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Rozin & Royzman, 2001). A popular example is the act of ruminating on one bad component of an otherwise good day. In this way, negative events are rarer than positive events, and as such are over emphasised (Peeters, 1971). A special case of the negativity bias stems from the adaptive value of responding rapidly to negative events (Rozin & Royzman, 2001). Known as the threat hypothesis, the rapid response to threatening information is advantageous for survival (Öhman, Lundqvist, & Esteves, 2001; Tipples, Atkinson, & Young, 2002). Given the relevance of threat detection for survival, researchers proposed that there should be a hard-wired network responsible for the detection of threatening or negative stimuli (LeDoux, 2007; Liddell et al., 2004). This biological basis for the preferential processing of threatening stimuli has been demonstrated using electroencephalography (EEG) and functional magnetic resonance imaging (fMRI).

When groups of neurons fire in synchrony they generate electrical currents that travel through the brain and can be measured at the scalp. This electrical current can be measured using EEG (Larsen, Bertson, Poehlemann, Ito, & Cacioppo, 2008). When used as a standalone measure, or in conjunction with fMRI, EEG has excellent temporal resolution, which is capable of detecting changes rapidly after stimulus onset (< 1 ms) (Sakkalis, 2011). This temporal resolution allows for investigation of whether early event-related potentials (ERPs) are sensitive to negative information. Ito et al. (1998) demonstrated that negative stimuli (e.g. handguns and mutilated faces) elicited larger early ERPs than positive stimuli (e.g. Ferrari and rollercoaster)[1]. In considering rapid responses to emotional faces, the ERP most frequently associated with facial processing is the N170. The N170 is a negative going potential that peaks approximately 170 ms after stimulus onset. Research exploring whether the N170 is sensitive to emotional context shows a clear negativity bias. Angry facial expressions elicit significantly larger N170 amplitudes relative to neutral expressions (Blechert, Sheppes, Di Tella, Williams, & Gross, 2012; Jiang et al., 2014). Similarly, fearful expressions are also found to elicit significantly larger amplitudes relative to neutral displays

[1] The authors chose these stimuli as they were equally arousing, and equally extreme from neutral pictures in emotional valence.

(Blau, Maurer, Tottenham, & McCandliss, 2007; Rigoulot, D'Hondt, Defoort-Dhellemmes, Despretz, & Honoré, 2011; Zhang, Wang, Luo, & Luo, 2012). Interestingly, Brenner, Rumak, Burns, and Kieffaber (2014) displayed an enhanced early processing for negative faces (i.e. angry, fearful, and sad expressions) compared to both happy and neutral displays. Thus, early neural responses are sensitive to affective information, and display enhanced responses to negative stimuli.

While EEG is capable of determining when facial affect is processed, neuroimaging is capable of demonstrating the brain structures involved. To do this task, fMRI indexes changes in blood-oxygen-level-dependent (BOLD) concentration, which is a metabolic indicator of neural activity (Detre & Floyd, 2001). In this way, fMRI can be used to determine which brain structures are involved with the processing of facial information. Just as in EEG research where a specific ERP has been associated with facial processing, the fusiform face area is believed to be a key structure in the processing of faces (Adolphs, 2009; Ghuman et al., 2014; Kanwisher, McDermott, & Chun, 1997). Additionally, enhanced hemodynamic activity in response to faces is observed in the superior temporal sulcus, and the inferior occipital gyri (Haxby, Hoffman, & Gobbini, 2000, 2002). These structures are believed to make up a core facial processing network (Haxby et al., 2000). In addition to this core network, a series of structures are related to the recognition of emotion, including the amygdala, insula, and limbic system (Hadjikhani, Kveraga, Naik, & Ahlfors, 2009; Haxby et al., 2000). Traditionally, the amygdala has been associated with fear, as evidenced through studies investigating threat processing, fight or flight responses, and fearful expressions (LeDoux, 2007). Numerous studies have demonstrated enhanced amygdala activity to fearful faces relative to other emotional displays (Breiter et al., 1996; Calder et al., 1996). Additionally, a number of studies have demonstrated increased amygdala activation in response to masked fearful faces, wherein participants were unaware of the masked stimulus, but an increased BOLD response still occurred (Kim et al., 2010; Pessoa, Japee, Sturman, & Ungerleider, 2006; Whalen et al., 1998; Williams et al., 2006). Therefore, the amygdala plays an important role in the processing of threat-related information, in line with the preferential processing of negative information.

The most support for a negativity bias in behavioural tasks stems from ASE research. The ASE is typically investigated using visual search tasks where faces are arranged in a matrix or array to simulate a crowd of faces. Angry faces are said to be automatically detected wherein angry expressions “pop out” from facial arrays depicting happy and neutral distractor expressions. First explored in a series of three experiments, Hansen and Hansen (1988) demonstrated that regardless of whether the matrix consisted of four or nine faces, angry faces attracted greater attention and participants took less time to determine their presence or absence than happy and neutral faces in visual search tasks. Since this seminal research, a series of experiments using schematic facial expressions have replicated the ASE (Calvo, Avero, & Lundqvist, 2006; Fox et al., 2000; Öhman et al., 2001). These schematic expressions minimise the variability between happy and angry expressions and allow for the investigation of emotional signals with minimal stimulus variability (see Figure 1.2). Interestingly, Calvo et al. (2006) demonstrated an ASE when schematic angry expressions were presented parafoveally, indicating that angry faces were more efficient at engaging pre-attentive visual search mechanisms. A similar conclusion was reached by Lyyra, Hietanen, and Astikainen (2014), wherein angry faces were more efficiently identified in a change blindness paradigm. Thus, there is a clear ASE effect, which is demonstrated when schematic stimuli are used.

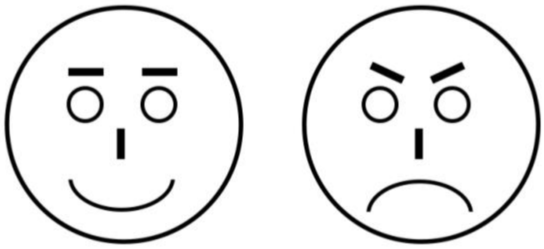

Figure 1.2. Happy and angry schematic expressions replicated from Fox et al. (2000).

In addition to the evidence for an ASE provided by schematic expressions, several studies have demonstrated the ASE using photorealistic stimuli (Ceccarini & Caudek, 2013; Horstmann & Bauland, 2006; Lipp, Price, & Tellegen, 2009; Pinkham, Griffin, Baron, Sasson, & Gur, 2010). Lipp et al. (2009) demonstrated an ASE when schematic and photorealistic stimuli were used; however, an overall negativity bias was only demonstrated in the schematic condition. Similarly, Pinkham et al. (2010) demonstrated that when black and white arrays of happy face distractors were presented, angry faces were detected faster and more accurately than when happy faces were used as targets. Additionally, when comparing angry faces and happy faces in a neutral distractor condition, angry expressions were again detected more efficiently than happy expressions. Ceccarini and Caudek (2013) further explored the ASE, using dynamic stimuli which were matched in intensity and salience. They concluded that the ASE was present amongst dynamic, but not static displays. Furthermore, they attribute the discrepancy between their results and Pinkham et al. (2010) to control over low level stimulus properties such as colour and salience. A recent meta-analysis concluded that an ASE is well evidenced in arrays depicting schematic expressions; however, the HFA is typically observed when realistic stimuli are used (Nummenmaa & Calvo, 2015). Thus, there is both facilitated *detection* of angry facial expressions, and facilitated *recognition* of happy facial expressions (Kauschke, Bahn, Vesker, & Schwarzer, 2019; Öhman et al., 2001).

Unlike the research exploring happy, angry, and fearful expressions, sad facial displays have not received the same inquiry despite being a communicative signal that elicits aid from observers (Reed & DeScioli, 2017). One possible explanation is that sad facial displays are typically less intense or arousing than other negative displays (Russell, 1980). Therefore, their use in facial expression recognition and detection tasks is limited, as they are naturally less salient than angry, fearful, and happy displays. Additionally, sad displays are more costly to respond to (Bavelas, Black, Lemery, & Mullett, 1986). In this way providing comfort to a sad person comes at a much greater cost to the observer, compared to reciprocating a smile (Bourgeois & Hess, 2008). As such, sadness displays are considered a high cost emotion, which lack the social relevance of angry, fearful, and happy displays.

In line with this cost associated with responding to sad facial displays, several experiments have demonstrated that mimicry of a sad person (wherein mimicry is designed to demonstrate understanding and facilitate interaction) is limited to personally relevant others (Bourgeois & Hess, 2008; Häfner & IJzerman, 2011). Moreover, Bourgeois and Hess (2008) demonstrated that unlike affiliative displays of happiness, displays of sadness were only mimicked if the expresser was an ingroup member. Similarly, Häfner and IJzerman (2011) demonstrated that participants were more likely to mimic a partner's display of sadness (as opposed to anger), but only if the mimicker was high in communal strength (i.e. a greater attendance to the partner's needs). However, other studies have demonstrated enhanced physiological responses in healthy controls to posed displays of sadness. Turetsky et al. (2007) demonstrated that participants' sad displays elicited larger N170 amplitudes relative to neutral expressions. Similarly, Lynn and Salisbury (2008) demonstrated that healthy control participants had significantly larger N170 ERPs for sad faces, relative to fearful expressions.

In addition, Blair, Morris, Frith, Perrett, and Dolan (1999) observed greater left amygdala activity in response to sad faces, which was not present for angry faces. In this way, enhanced physiological responses to sadness have been emphasised in studies indexing neural activity; however, in the case of outward expressions, the relationship between the mimicker and the person being mimicked has a particular importance in the response to sadness.

The behavioural studies exploring the recognition and detection of sad displays have also yielded mixed results. Sad displays have been explored through schematic detection and recognition tasks, in an effort to match the stimulus qualities as much as possible to isolate the signal value of sad expressions (see Figure 1.3a for example schematic stimuli). White (1995) demonstrated that sad schematic facial expressions of emotion are responded to more quickly than happy facial expressions. Eastwood, Smilek, and Merikle (2001) reached a similar conclusion, wherein visual search of schematic displays is more efficient for sad than happy expressions. However, in order to disentangle the negativity bias from the threat hypothesis, it is expected that under the negativity bias sad facial displays should have the same prioritisation as angry displays. This is due to both angry and sad faces sharing negative affective valence; although angry displays are threat-related, sad displays are not (LoBue, 2009). Calvo et al. (2006) explored this idea using identical schematic expressions with upturned eyebrows for sad expressions, and downturned eyebrows for angry expressions (see Figure 1.3b). A series of three experiments revealed that angry faces were detected faster in visual search tasks than happy and sad expressions. In this way, Calvo et al. (2006) demonstrated support for the threat detection hypothesis, rather than an overarching negativity bias. Similarly, LoBue (2009) demonstrated in a series of five experiments, using photographs and schematic expressions, that threat-related negative expressions were detected faster than non-threatening negative expressions (i.e. sad faces). Importantly, negative expressions (i.e. angry, fearful, and sad) were detected faster overall than positive displays.

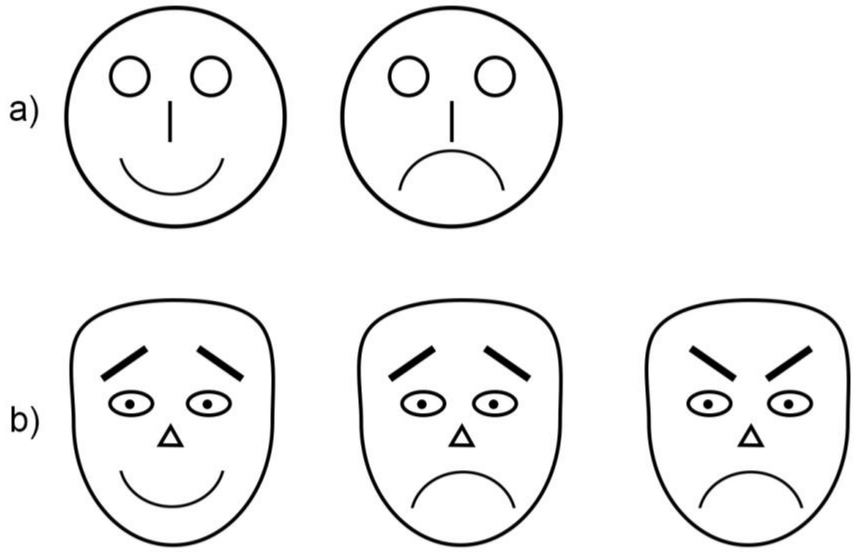

Figure 1.3. a) Examples of happy and sad schematic expressions replicated from White (1995); b) examples of happy, sad, and angry schematic expressions replicated from Calvo et al. (2006).

Additionally, some experiments have demonstrated that happy and angry expressions are detected faster than sad facial displays (Williams, Moss, Bradshaw, & Mattingley, 2005). In this way, rather than evidencing the HFA or the ASE, they demonstrated a social relevance effect, wherein more socially relevant expressions (i.e. those expressions requiring rapid interpretation: happy and angry) were detected faster than less socially relevant displays (i.e. sadness). These findings are interesting, given that the HFA is more pronounced when sad expressions are used as a comparison category (Feyereisen et al., 1986). In this way, it may be that the majority of research exploring responses to sad displays, has used stimuli which were not matched in distinctiveness to happy and angry displays. Evidence for this conclusions stems from empirical research that has demonstrated that sad faces are responded to more slowly (Calvo & Nummenmaa, 2008; Kirita & Endo, 1995; Williams et al., 2005), and are more likely to be confused for other expressions of emotion in identification tasks (Calvo & Marrero, 2009; Palermo & Coltheart, 2004; Prkachin, 2003). Therefore, further research into sad facial displays would benefit from the use of a particularly distinctive sad signal—tears.

1.5 The Communicative Value of Tears

The signal value of tears can be investigated through the lens of biological signalling (Hasson, 2009). One of the functions of biological signals is to communicate information that subsequently changes the behaviour of others (Hasson, 1997; Hasson, 2009). This signalling function has been explored under the BECV wherein sad expressions, particularly those of a tearful “cry-face” signal readiness to receive succour and attention from observers (Fridlund, 1994). However, biological signals must be an *honest* display, wherein they reliably elicit the intended response from observers (Scott-Phillips, 2008). These signals are kept honest, via the handicap principle. The handicap principle asserts that signals must be accompanied by a cost in order to convey their honesty to observers (Zahavi, 1975, 1977). In the case of tears, tears blur one’s vision and, as such, make the expresser more vulnerable. In this way, tearful displays are costly; however, the beneficial outcomes of increased support and reduced aggression are greater than the costs that are associated with the signal (Hasson, 2009; Hendriks, Croon, & Vingerhoets, 2008; Kottler & Montgomery, 2001). This review will focus on Hasson’s (2009) assertion that for tears to function as effective signals they must provide information to individuals, and the reception of such information should change the individual’s behaviour.

The information that emotional tears convey to observers has been investigated from a range of different viewpoints. Where some studies have focused on how tears influence the perception of crying individuals, others have focused on exploring tears as a signal of sadness. The former is typically investigated according to two universal dimensions: warmth and competence (Fiske, Cuddy, & Glick, 2007). Born under social cognition theory, the warmth dimension encapsulates traits such as sincerity, trustworthiness, and friendliness, whereas the competence dimension is associated with ability and efficacy (Fiske et al., 2007). In this way, numerous studies have demonstrated that crying individuals are perceived as warmer than the same individuals without tears (Fischer, Eagly, & Oosterwijk, 2013; Ven de Ven, Meijs, & Vingerhoets, 2017; Zickfeld & Schubert, 2018; Zickfeld, van de Ven, Schubert, & Vingerhoets, 2018).

Fischer et al. (2013) used vignette contexts and demonstrated that males who cried in the workplace were perceived as less competent than females who cried. Conversely, there were no gender differences in perceptions of competence when either gender cried in a relationship context at home. Fischer et al. (2013) concluded that perceptions of competence were dependent on the context in which crying is encountered. Recently, a series of studies investigated perceptions of warmth and competence in the absence of context via still photographs that included tears (Ven de Ven et al., 2017; Zickfeld & Schubert, 2018; Zickfeld et al., 2018). Ven de Ven et al. (2017) used a sample of five male and five female faces and found that the presence of tears made individuals seem warmer and less competent than the same individuals with the tears removed. In replication studies using a larger sample of the same faces, the effect of warmth has been replicated; however, the effect of competence has not (Zickfeld & Schubert, 2018; Zickfeld et al., 2018). Zickfeld et al. (2018) concluded that the original effect of competence observed by Ven de Ven et al. (2017) was target specific (i.e. limited to 10 faces), and therefore not generalisable.

Tearful individuals are not only perceived as warmer, but are also perceived as more sincere (Picó et al., 2020; Zeifman & Brown, 2011). Zeifman and Brown (2011) explored the perception of crying infants, children, and adults, and concluded that tears made no difference in perception of sincerity when exhibited by infants. By contrast, tears moderately increased perceptions of sincerity when exhibited by children, and the greatest sincerity was observed for crying adults. Thus, sincerity increased as a function of age, wherein crying adults were perceived as the most sincere. Similarly, Picó et al. (2020) demonstrated that when participants are instructed to rate the sincerity of identical vignette statements, sincerity was increased after priming participants with a tearful individual. In a similar vein, Hornsey et al. (2019) demonstrated that tears increased the perception of remorse during public apologies. Thus, tearful individuals are perceived as warmer and more sincere than the same individuals without tears.

The representation of tears as a signal of sadness has predominantly stemmed from a series of studies exploring the *tear effect* (Provine et al., 2009). Provine et al. (2009) used tearful images and digitally removed the tears to create tear-free duplicate images. Participants perceived the tearful expressions as significantly sadder than the tear-free duplicates. Furthermore, the tear-free images were perceived as ambiguous in emotional valence. Therefore, the tear effect states that tears facilitate the recognition of sadness. Since this seminal work, numerous studies have demonstrated support for the tear effect across different age categories (Zeifman & Brown, 2011), emotions (Ito, Ong, & Kitada, 2019; Reed, Deutchman, & Schmidt, 2015), and even using the isolated eye region of digital avatars (Küster, 2018). In addition, Balsters et al. (2013) demonstrated the tear effect when using brief (50 ms) presentation times, showing that tears change rapid responses to faces. Participants' reaction times were significantly faster to sad tearful expressions, compared to both tear-free sad and neutral expressions (Balsters et al., 2013). Takahashi et al. (2015) extended the paradigm originally developed by Provine et al. (2009) to include an additional neutral condition. Crying female adults were found on Google and Flickr, and their tears were digitally removed to create tear-free images. Images were rated by a separate sample on the intensity of sadness, and half of the images were classified as sad expressions, with the remaining half classified as neutral. In their main experiment, they concluded that although tearful expressions were perceived as sadder, the magnitude of the influence of tears (i.e. the increased perception of sadness as a result of the tears) was greater for neutral expressions. As such, tears serve as a marker of sadness and resolve the ambiguity associated with neutral expressions.

Interestingly, support for the tear effect is demonstrated even when exploring a second perspective, known as the *general enhancement* perspective. Under the general enhancement perspective, it is postulated that the presence of tears makes all expressions more intense, rather than simply signalling sadness (i.e. an angry face is angrier with tears) (Ito et al., 2019). However the two studies exploring this perspective have demonstrated generalised support for the tear effect (Ito et al., 2019; Reed et al., 2015). Ito et al. (2019) demonstrated that when tears are added to other negative emotional expressions such as anger, fear, and disgust, participants are significantly more likely to rate the images as sadder in appearance. They further validated this conclusion by examining the ratings in multidimensional space and demonstrated that tearful, negatively valenced faces are more tightly clustered around sadness than tear-free expressions. However, tears are not elicited solely in response to sadness (Miceli & Castelfranchi, 2003).

Although most people typically associate tears with negative events such as death, breakups and separation, tears are also elicited in response to their positive counterparts: birth, weddings, and reunion (Vingerhoets, 2013). Reed et al. (2015) demonstrated that in the case of genuine, dynamic smiling expressions (i.e. Duchenne smiles), the presence of tears increased the overall intensity and perceived sadness of the image. Conversely, non-Duchenne smiles with tears were perceived as less positive, less happy, sadder, angrier, and more fearful. In this way, there is mixed evidence, with a generalised tear effect present, however the generalised enhancement perspective cannot be ruled out. However, it must be cautioned that Reed et al. (2015) used a single actress and as such it is unclear whether the results would generalise to a larger sample of faces. Therefore, it is unclear what role tears play in the perception of happy expressions. Furthermore, studies that have used naturalistic tearful images of joy as stimuli have demonstrated that context is essential for tears of joy to be perceived as positive (Aragón, 2017; Aragón & Bargh, 2018). Thus, in the absence of context, tears seem to make all expressions seem sadder, which is in line with the tear effect, meaning tears serve as a sincere signal of sadness.

To be a biological signal, tears must also convey information that leads an individual to change their behaviour. This effect has been well documented in the literature, wherein tearful displays are responded to with greater prosocial behaviour, reduced aggression, and empathy relative to tear-free expressions (Hendriks & Vingerhoets, 2006; Hendriks et al., 2008; Vingerhoets, van de Ven, & Velden, 2016). As such, tears elicit helping responses from observers. Hendriks and Vingerhoets (2006) were some of the first to demonstrate that tearful photographs of crying persons were responded to with greater emotional support and lower ratings of avoidance relative to tear-free expressions. Since then, several studies have demonstrated that tearful expressions foster approach behaviour (relative to avoidance) in reaction time tasks (Gračanin, Krahmer, Rinck, & Vingerhoets, 2018; Riem, van Ijzendoorn, De Carli, Vingerhoets, & Bakermans-Kranenburg, 2017). Similarly, Vingerhoets et al. (2016) showed that participants attribute greater helping responses to individuals with tears, than the same expressions without tears. Furthermore, they concluded that these helping behaviours stemmed from a perception of closeness with the tearful individual, wherein feeling connected increased one's willingness to help.

Although tears are known to elicit helping responses, several studies have identified limitations to these pro-social behaviours. Stadel, Daniels, Warrens, and Jeronimus (2019) identified an increased willingness to help tearful individuals but concluded that this willingness was the strongest between female and mixed interactional dyads and reduced during male dyad interactions. Furthermore, Hendriks et al. (2008) showed that participants were significantly more likely to provide help to tearful individuals in negative scenarios, but not positive ones. Similarly, Reed, Matari, Wu, and Janaswamy (2019) identified that this increased pro-sociality was only present when tearful individuals were capable of reciprocating the assistance. Thus, pro-social responses were dependent on reciprocity. Furthermore, a number of studies have reported that although participants are more likely to aid tearful individuals, they are also more likely to feel personal distress or negative emotion during the interaction (Hendriks & Vingerhoets, 2006; Hendriks et al., 2008; Küster, 2018). In this way, it is unclear whether helping responses to tearful displays are based on altruistic or egoistic motives. Therefore, further research can validate the self-report 'willingness to help' measures via the use of psychophysiological indices of empathy, thus determining whether tears elicit increased help and empathy from observers.

1.6 Summary

Throughout this review, it is evident that tears meet the criterion proposed by Hasson (2009) to function as a biological signal. Moreover, the presence of tears on a face sincerely communicates distress and sadness to those who are witness to the display. This sadness and distress, in turn, changes the way that people respond, wherein tears elicit succour and aid from observers. However, exploring the psychophysiological responses to emotional tears has been largely neglected, despite the opportunity for validation of the existing self-report research. Therefore, in Chapter 2, the movement towards the adoption of psychophysiological indices of empathy will be explored. This exploration will conclude with a discussion on the role of the mirror neuron system in empathic responses and highlight how the intersection of emotion and empathy research will afford a greater understanding of human crying.

Chapter 2: The Psychophysiological Measurement of Empathy

2.1 Chapter Introduction

Have you ever witnessed a loved one slice their finger with a knife by mistake and winced in pain? Or have you found yourself in a room full of happy people and instantly felt your mood lift? If your answer to these questions was yes, then you are not alone. Humans are instinctively social animals. A species dependent on others, from the helpless stages of infancy to late stages of life, daily existence is punctuated with human interaction. How this interaction occurs and the mechanisms behind it will make up this review of the science of empathy.

Understanding those around us is instinctive and automatic. Often, we can "read" the intent of those around us through the smirk of a politician or the grin of a friend. Thousands of these deductions each day, without even considering or acknowledging the mechanisms that drive this behaviour. Even more astounding is the fact that this understanding has puzzled scientists for years. How do we understand what the people around us are thinking and feeling? Empathy, an umbrella term for the ability to resonate with others, is one proposed mechanism for shared affective states (Preston & Hofelich, 2012). The present review aims to clarify the role that empathy plays in human interaction. Through focusing on deconstructing the mechanisms that are known antecedents of empathy, a greater understanding of how we share the affective states of others will be obtained. To investigate these mechanisms, psychophysiology will be used as a lens, to explore the way that affective states are shared through the central and peripheral nervous systems. It is intended that this review will provide an understanding of the way that the brain is inherently social and provide a platform for future research into the neuroscience of empathy.

2.2 Empathy

2.2.1 What is empathy?

There is consensus that empathy is an important component of resonating with others (Decety & Jackson, 2004; Jankowiak-Siuda, Rymarczyk, & Grabowska, 2011); however, it is notoriously difficult to define (van Baaren, Decety, Dijksterhuis, van der Leij, & van Leeuwen, 2009). Originating from the term “feeling into” (or Einfühlung in German), empathy was initially conceptualised as a means to explain shared aesthetic experiences, typically in the form of beautiful art (Vischer, 1873/1994). Both Titchener (1909) and Lipps (1903) built upon this conceptualisation extending it into the interpersonal domain with the proposition that empathy is the mechanism by which we understand those around us. After over a century of research, there is still no universally agreed upon definition of empathy (Zahavi, 2012). However, Preston and Hofelich’s (2012) review argues that empathy research is largely consistent. Moreover, empathy is commonly used as an “umbrella term for states of feeling “with” or resonating with the other, which can occur at any level – neural to phenomenological, conceptual to affective” (p. 71).

Empathy is comprised of a myriad of interrelated phenomena, all which constitute distinct psychological states (Batson, 2009). Although not the first to theorise the importance of exploring empathy’s constituent states (see also Reik (1948) and Scheler (1913/1970)), Batson (2009) posited that exploring the eight components of empathy are critical to human sharing of affective states. These eight components of empathy include: knowing another’s internal state; adopting the posture or matching the neural responses of another; feeling as the other person feels; projecting oneself into another’s situation; imagining how another is thinking and feeling; imagining how oneself would think and feel in the other’s place; feeling distress at another’s suffering; and feeling for another who is suffering. These components can be roughly categorised into three overarching phenomena: understanding another person's cognitive and affective state; feeling for and as the other person feels (or emotional contagion); and matching the affective state of another (or mimicry).

These eight affective states tap into both the cognitive and the affective components of empathy (Preston & de Waal, 2002). Broadly, cognitive empathy encompasses the ability to understand and infer what another is thinking, similar to the concepts of perspective taking, mentalizing, and theory of mind (Preston & Hofelich, 2012). In contrast, affective empathy does not require cognitive understanding; rather, it is primarily concerned with the sharing or matching of emotional states, sometimes termed emotional empathy or emotional contagion (Decety & Lamm, 2006; Rankin, Kramer, & Miller, 2005). Batson (2009) continues that further convolution of the matter stems from the questions empathy research attempts to answer. Two fundamental questions exist in empathy research: 1) how do we understand what those around us are thinking and feeling; and 2) what leads one to respond to another?

These two key questions pose an interesting conundrum for empathy researchers. On one hand, they lend themselves to independent investigation, that is, researchers are capable of addressing one without the other (Batson, 2009). On the other hand, the two questions are undeniably related. Research that has adopted a psychophysiological approach to empathy has primarily focused on exploring the first question (Decety & Jackson, 2004; Gallese, Keysers, & Rizzolatti, 2004; Jackson, Meltzoff, & Decety, 2005). Alternately, in addressing the second question, researchers have focused on the factors that motivate a response (Dovidio, 1991; Eisenberg & Fabes). Undoubtedly, understanding empathy will require investigation of both these questions; however, the focus of this review is on exploring how we understand what those around us are thinking and feeling.

2.2.2 The perception-action model (PAM) of empathy

The PAM of empathy is one explanation of how we interact with those around us (Preston & de Waal, 2002). The PAM of empathy is based upon the perception-action model of motor behaviour, which states that the perception of an action (e.g. seeing a ball get picked up) and the action itself (e.g. grasping the ball), share neural substrates (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Lipps, 1903; Rizzolatti, Fadiga, Fogassi, & Gallese, 1996). Preston and de Waal (2002) extended this theory into the affective domain, as a mechanism by which those around us are understood. Just as in the motor theory, the PAM of empathy states that when witness to another person's state, the perceiver will spontaneously activate the neural representations associated with the personal experience of that emotional state (Goubert et al., 2005; Keysers & Gazzola, 2006). Understanding how the PAM of empathy encompasses empathy and its related phenomena is integral to understanding how this model can be used to explain shared affective states (see Figure 2.1).

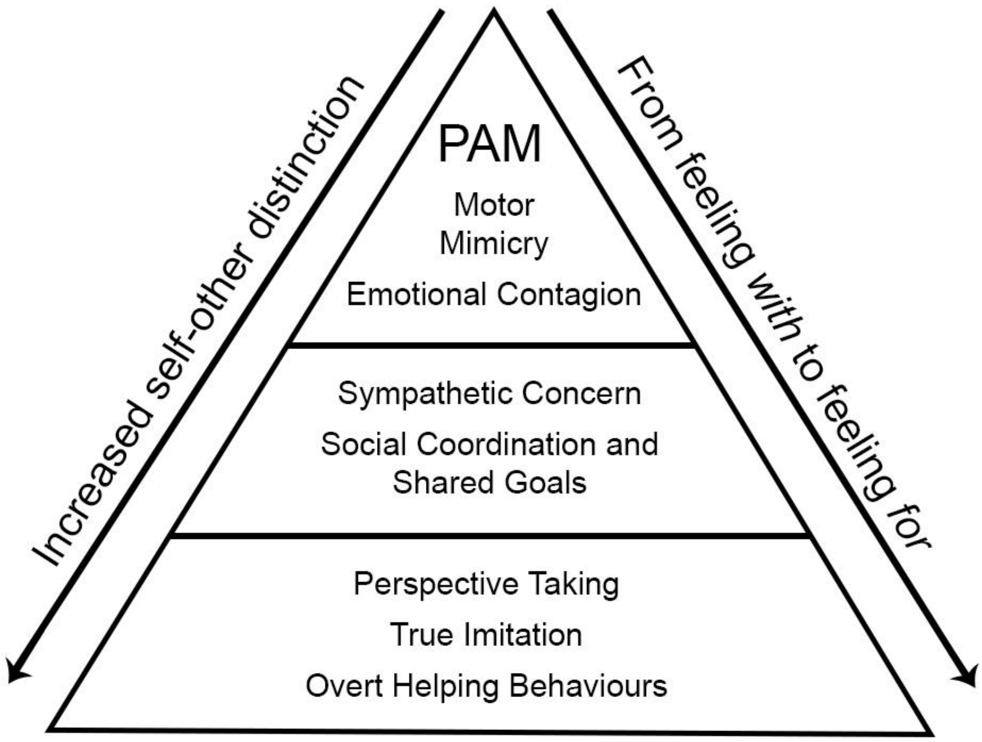

Figure 2.1. The perception-action model of empathy, and the distinction from the automatic nature of feeling 'with' another, to the conscious ability to feel 'for' another.

In the PAM of empathy, phenomena such as motor mimicry, imitation, and emotional contagion are all antecedents to empathic behaviour. In this sense, empathy is an evolved function that is supported by automatic representations of shared affective states (Goubert et al., 2005; Preston & de Waal, 2002). A key specification is that this process occurs automatically, or without cognitive effort. Although cognition is an integral component of the later stages of empathy (i.e. helping behaviours), conscious awareness is not required for core components such as mimicry and contagion. As a result, the PAM of empathy is typically used as a framework for psychophysiological studies.

2.2.3 The measurement of empathy

Empathy is typically measured using two methods: behavioural self-report scales and psychophysiology. Self-report measures typically ask (either directly or indirectly) for a participant to respond to a particular stimulus—usually in an attempt to gage the attitudes or feelings related to the stimulus (Paulhus & Vazire, 2009). Conversely, psychophysiological methods study the physiological signals underlying the reported psychological processes (Cacioppo, Tassinary, & Berntson, 2007; Larsen et al., 2008). Empathy research has traditionally been dominated by self-report measures, and investigation using psychophysiological techniques has, by comparison, only recently gained popularity (Neumann & Westbury, 2011; Paulhus & Vazire, 2009). Exploring the two key limitations of the self-report approach will provide a justification for why psychophysiology is increasingly becoming the preferred approach to investigate empathy.

The first limitation to self-report measures is by no means a new criticism. The objectivity of self-report measures has been questioned since the development of psychological assessment (Paulhus & Vazire, 2009). Self-report measures require trust in the participant to respond truthfully, which does not always occur. This problem is of particular relevance to empathy research as empathic responses are likely to be exaggerated because it is socially desirable to help others, and thus respondents might seek to conform with perceived social norms (Mauss & Robinson, 2009). An example of this social desirability is evident in a study conducted by Kämpfe, Penzhorn, Schikora, Dünzl, and Schneidenbach (2009) with delinquent or incarcerated participants. It was concluded that delinquent participants were higher in cognitive empathy than non-delinquent controls when assessed using a self-report measure. However, an implicit association empathy test (an indirect measure of empathy) indicated higher empathy in the non-delinquent controls compared to delinquent participants. Critically, there was a significant weak correlation between self-report empathy and social desirability in the delinquent sample, but not the control sample. As such, self-report empathy is susceptible to biased responses evidenced via social desirability. However, a further and perhaps more serious limitation of self-report measures stems from when a participant believes they are responding accurately and truthfully, but in fact they are not.

Self-report measures require cognition. It is this cognition that allows for the collection of information-rich data that is obtained from self-report measures (Paulhus & Vazire, 2009). However, as was identified using the PAM, the core components of empathy, such as mimicry and contagion, are processed unconsciously. Thus, even if participants believe they are reporting honestly, there may be a discrepancy between unconscious processes and cognitive awareness. For example, Preis, Kröner-Herwig, Schmidt-Samoa, Dechent, and Barke (2015) used both behavioural and psychophysiological measures to index empathy responses to pain images, and found that although self-report pain ratings remained constant over repeated presentations, neurological responses decreased over repeated exposure. In other words, psychophysiological measures showed habituation to the stimuli, but self-report measures did not (Preis et al., 2015). Thus, a participant may believe they are reporting consistently and accurately, however, psychophysiological measures are sensitive to these non-conscious processes and the corresponding data indicate otherwise. Therefore, it is proposed that future empathy research should adopt a complementary approach, as physiological and self-report measures need not be mutually exclusive. Rather, self-report measures should be used to assess the convergent validity of psychophysiological results.

When exploring the role of the central nervous system in empathy, the neuroimaging technique, functional magnetic resonance imaging (fMRI) has been used to map the brain structures associated with empathy (Decety & Lamm, 2006). Typically, fMRI is used in empathy research to investigate the shared neural overlap between the emotional state of another and the firsthand experience of emotion (Cheng, Chen, Lin, Chou, & Decety, 2010; Jackson, Brunet, Meltzoff, & Decety, 2006; Lamm, Decety, & Singer, 2011; Preis et al., 2015). Moreover, some fMRI research has demonstrated that there is not one neural network for sharing emotions, rather there are distinct empathy circuits for pain (Singer et al., 2004), disgust (Wicker et al., 2003), other basic emotions (Killgore & Yurgelun-Todd, 2004) and complex emotions, such as social exclusion (Eisenberger, Lieberman, & Williams, 2003). One limitation of fMRI is that although it has high spatial resolution (capable of indexing changes at submillimeter level), the temporal resolution is low (500-1000 ms) due to the relatively slow metabolic processes it is measuring (Goense, Bohraus, & Logothetis, 2016; Neumann & Westbury, 2011). Thus, although fMRI is capable of indexing where a particular response occurs in the brain with precision, it is not capable of detecting fast transient responses to emotional stimuli (Fan & Han, 2008; Pegna, Landis, & Khateb, 2008). To measure these responses requires a direct measure of electrical activity, which can be indexed using electroencephalography (EEG).

Two different EEG components have been used to measure the time-related processes involved in affective sharing: cortical wave patterns (Perry, Bentin, Bartal, Lamm, & Decety, 2010) and specific event-related potentials (ERPs), which are an index of cortical responses to a specific event (Neumann & Westbury, 2011). Increasingly, the N170 ERP component has been linked to facial expression processing (Hinojosa, Mercado, & Carretié, 2015), while the N200 component has been linked to empathy (Balconi & Canavesio, 2016). Thus, EEG can be used to index the changes in neural activity that are associated with shared affective states and emotional contagion (Pineda & Hecht, 2009).

2.2.4 Catching emotions

Emotional contagion is widely referred to as the "catching" of another's emotion (Batson, 2009; Hatfield, Bensman, Thornton, & Rapson, 2014; Hatfield, Rapson, & Le, 2009; Kret, 2015; Shamay-Tsoory, 2011). Focusing on the ability to "feel themselves into" another's emotion, emotional contagion is a critical component of understanding human behaviour (Hatfield et al., 2009). Prior to the conceptualisation of emotional contagion, the congruence of shared emotions was attributed to empathy (Davis, 1983). However, reviews indicate that empathy is a complex, overarching phenomenon, and emotional contagion consists of more primitive components (Hatfield, Cacioppo, & Rapson, 1994). Moreover, Hatfield et al. (1994) define primitive emotional contagion as the tendency to mimic another's affective state, whether through facial expressions, postures, behaviours, or neural networks—emotional contagion is the mechanism that allows for emotional convergence. Furthermore, it has been clarified that emotional contagion exists in three stages: mimicry, feedback, and the contagion of emotion (Hatfield et al., 2014; Hatfield et al., 2009).

Feeling sad when you see a sad person is a common experience. This contention is commonly supported by neuroscience research, wherein neural circuits are proposed to facilitate the sharing of emotion (Gallese, 2001; Gallese, Eagle, & Migone, 2007; Kaplan & Iacoboni, 2006; Keysers & Gazzola, 2006). Activation of several brain regions, such as anterior cingulate cortex (ACC) and bilateral anterior insula (AI), has been demonstrated during both the observation and the firsthand experience of pain using fMRI (Botvinick et al., 2005; de Vignemont & Singer, 2006; Singer et al., 2004). Oberman and Ramachandran (2009) contended that in order for an emotion to become an embodied representation, it must be converted from the visual system to the limbic system (i.e., the system commonly associated with the experience of emotion). In addition, different areas within the limbic system are activated for different emotions, For example, the ACC (Critchley et al., 2005; Jackson et al., 2005) is activated when experiencing the noxious qualities of pain, and the insula (Calder, Keane, Manes, Antoun, & Young, 2000; Wicker et al., 2003) is activated when feeling disgust. Therefore, shared circuits provide a neural basis for how affective states are shared. However, shared states only offer information about how we are able to comprehend those around us. Thus, a shift in focus from the role of the central nervous system in comprehending empathy, to the role of the peripheral nervous system in communicating empathy is required.

2.2.5 Imitating others

The observation that people mimic one another is by no means new (Hatfield et al., 2009). Smith (1759/1976) was one of the first to conceptualise mimicry as an automatic component of social interaction. Since this original proposition, research has provided physiological (Dimberg, Thunberg, & Elmehed, 2000; Dimberg, Thunberg, & Grunedal, 2002; Levenson & Ruef, 1992), behavioural (Chartrand & Bargh, 1999; van Baaren, Holland, Kawakami, & van Knippenberg, 2004; Van Baaren, Maddux, Chartrand, de Bouter, & van Knippenberg, 2003), and neurological (Kaplan & Iacoboni, 2006) evidence to corroborate this theory. This phenomenon, known as the "chameleon effect" or "matched motor hypothesis", encompasses the way that people subconsciously adapt their postures, mannerisms, and facial expressions to match a social environment. Facial expressions are an intuitive method through which to investigate empathy given their automatic responsiveness to emotional states (Dimberg & Öhman, 1996).

Mimicry is automatic in the sense that the mimicker does not need to be consciously aware of the process, or even the stimulus, that elicits the response (Chartrand & Bargh, 1999; Chartrand, Maddux, & Lakin, 2005). For example, Dimberg et al. (2000) demonstrated that congruent facial mimicry responses were elicited even when the emotional expressions were masked by a neutral stimulus, and thus the observer was unaware of the emotional stimulus. Therefore, the mechanisms facilitating facial mimicry are a low-level process, not dependent on conscious decision making or even explicit recognition. Through investigating the facial muscles implicated in the production of facial expressions, a greater understanding of the processes underlying affective sharing will be obtained.

Facial electromyography (EMG) is a robust and commonly used method of measuring activity in the facial muscles (Dimberg, 1982; Dimberg et al., 2000; Dimberg et al., 2002; Sonnby-Borgstrom, 2002). In a typical facial mimicry experiment, flat electrodes are placed over a participant's facial muscles and they are then presented with emotional faces. Subtle changes in the contraction of the muscles is detected as increased electrical activity (van Baaren et al., 2009). Specific muscles tend to contract in making particular emotional expressions. For example, activity in the zygomaticus major muscle is an index of positive and affiliative emotions—particularly smiling (Achaibou, Pourtois, Schwartz, & Vuilleumier, 2008; Duchenne de Boulogne, 1990; Rymarczyk, Biele, Grabowska, & Majczynski, 2011; Sonnby-Borgstrom, 2002). Thus, the zygomaticus major muscle draws the corners of the mouth upwards towards the ears, creating a smile (Bentsianov & Blitzer, 2004; Duchenne de Boulogne, 1990). Therefore, in a mimicry experiment if one observes increased activity in the zygomaticus major muscle in response to being presented with a happy face this would indicate mimicry of the portrayed emotion. Similarly, activation of the corrugator supercilii muscle is represented by the furrowing of the inner brow (Cacioppo, Petty, Losch, & Kim, 1986; Duchenne de Boulogne, 1990). Thus, activation of the corrugator muscle is associated with negative emotions (Murata, Saito, Schug, Ogawa, & Kameda, 2016). Therefore, in accord with the PAM of empathy, mimicry serves to facilitate social bonds when an observer perceives another's emotional expression and activates the same expression themselves. Thus, the function of mimicry is rooted in one of the key components of empathy: demonstrating an understanding of how another feels.

The function of empathy is undeniably adaptive. There is consensus that mimicry serves to facilitate increased rapport (Lakin & Chartrand, 2003), affiliation (Bourgeois & Hess, 2008; Hess & Fischer, 2013), and pro-social behaviour (van Baaren et al., 2004). The effects of mimicry on person perception have been demonstrated to increase bidirectional liking (Chartrand & Bargh, 1999), and to strengthen the bond between two interaction partners (van Baaren et al., 2009). Moreover, mimicry has been termed a "social glue", responsible for facilitating social bonding (Lakin, Jefferis, Cheng, & Chartrand, 2003). Theoretically, if this mechanism were capable of bonding societies, the benefits would extend beyond interaction partners into the general public. van Baaren et al. (2004) demonstrated that mimicry increases helping behaviours not just for the mimicker, but also persons with which the mimicked interact with. Moreover, being mimicked increases subsequent altruistic behaviours in the form of charitable donations, compared to persons who were not mimicked. However, mimicry also serves to facilitate personal gain. Namely, mimicry can be used to convey romantic interest (Farley, 2014) or for monetary gain (Sims, Van Reekum, Johnstone, & Chakrabarti, 2012). Thus, mimicry is a pervasive component of social interaction.

Perhaps an even greater contribution to the understanding of human affective states stems from when mimicry is inhibited. Typical mimicry research paradigms investigate facial responses whilst participants witness emotional displays (Dimberg et al., 2000; Hess & Blairy, 2001). However, what might occur if this mimicry is inhibited? The facial feedback hypothesis states that one's ability to experience emotion is dependent on the ability to express emotion. Strack, Martin, and Stepper (1988) demonstrated this hypothesis; participants held a pen in their mouth to either inhibit (holding with lips) or facilitate (holding with teeth) smiling. Facilitating a smile increased the participant's funniness ratings of cartoons in comparison to the inhibitory group. In a similar vein, Neal and Chartrand (2011) recruited matched participants who had received either a Botox treatment (the temporary paralysis of facial muscles), or a Restylane injection (a dermal filler). They concluded that facial feedback was an important component of emotion classification, as participants injected with Botox were less accurate in classifying emotional expressions than the Restylane control group. Thus, facial mimicry serves not only to strengthen social bonds, but also plays a role in emotion recognition (Iacoboni, 2009).

Evidently, the processes of mimicry and emotional contagion are important components of facilitating social communication (Chartrand & Bargh, 1999) and conveying empathy (Hess, Philippot, & Blairy, 1999). Most of the research into shared affective states has investigated the neural components of contagion separately from motor mimicry. However, it is proposed that understanding how these phenomena come together to form the overarching perception-action model will provide a richer understanding of empathy. Recently, it has been proposed that mirror neurons could underlie this phenomenon (Rizzolatti & Craighero, 2004; Rizzolatti et al., 1996). Originally proposed as a mechanism for action imitation in monkeys, and now evidenced in humans (Wolf, Gales, Shane, & Shane, 2001), mirror neurons have been touted as the next great advance in psychology (Oberman & Ramachandran, 2009). With new conceptualisations such as "the empathic brain" and "the social brain", the future of empathy research is rooted in physiology wherein mirror neurons provide a basis for the way that we as humans experience empathy (Adolphs, 2009; de Vignemont & Singer, 2006; Dunbar & Shultz, 2007; Frith, 2007; Iacoboni, 2009; Keysers, 2011).

2.3 Mirror Neurons

2.3.1 What are mirror neurons?

Thus far, the concepts of mimicry and imitation have been explored; now, the neurological processes that are thought to underpin these responses will be explained. Mirror neurons are a special class of visuomotor neurons that fire in response to both the execution of an action, and the observation of another performing the same or a similar motor act (Gallese et al., 1996). Activation of our own motor system in response to observing another's actions is at the core of the mirror neuron system (Kaplan & Iacoboni, 2006), meaning that mirror neurons allow for the shared representation of actions. Prior to the discovery of mirror neurons, it was posited that the interesting component to understanding social interaction was that of mentalising; however, it has since been questioned whether understanding the actions of others actually requires mentalising (Keysers, 2011). First reported in the ventral premotor cortex area F5 of the Rhesus macaque, these neurons were discovered through single cell recordings, where a neuron fired whilst the monkey picked up a peanut, and also when the monkey watched the experimenter pick up a peanut (Rizzolatti et al., 1996). Since this original discovery, psychophysiological evidence has revealed that it is not limited to grasp actions, as mirror neurons respond to other complex hand-actions (Gallese et al., 1996) and also to mouth actions (Ferrari, Gallese, Rizzolatti, & Fogassi, 2003). To determine the purpose of these dual property neurons, researchers investigated whether responses were simply motor copy of the motor act, or whether they were responsive to the intention behind the action (de Lange, Spronk, Willems, Toni, & Bekkering, 2008; Iacoboni et al., 2005).

It is not enough to simply identify a motor movement; increasingly mirror neuron research is focusing on understanding the intention or goal that underpins these actions (Iacoboni et al., 2005; Kaplan & Iacoboni, 2006). Mirror neurons discriminate between different goals based on their type. There is a consensus that there are two types of mirror neurons: strictly congruent and broadly congruent. Strictly congruent mirror neurons represent one third of all mirror neurons, and only respond to the exact action triggered during execution—down to the most minute detail (Gallese et al., 1996; Rizzolatti et al., 1996). Conversely, broadly congruent mirror neurons also respond to actions that achieve a similar goal through different means (Thioux, Gazzola, & Keysers, 2008). However, most mirror neurons will respond to the grasping of an object, but not if the grasp is performed in the absence of the object (Thioux et al., 2008). Iacoboni et al. (2005) conducted the now famous 'teacup experiment' where participant's mirror neuron systems adequately discriminated between precision grips in differing contexts. Specifically, the greatest mirror neuron activation resulted from the precision grip of a teacup paired with a neat tea-party scene, as opposed to a teacup presented alone. de Lange et al. (2008) further explored goal-directed action by varying whether the participants were instructed to attend to the intention of the action, or the means by which the action was executed. It was concluded that the mirror neuron system processes the intentionality of the action irrespective of whether or not the participant was attending to the intention of the action. Thus, the mirror neuron system is unlikely to be a system involving simple motor simulation, and the processes that underlie this activation are likely to employ theories of associative learning and theory of mind.

How primates came to possess mirror neurons is likely a combination of innate traits (Meltzoff & Moore, 1977), and Hebbian learning (Heyes, 2010; Keysers & Gazzola, 2009; Keysers & Perrett, 2004). The argument that some element of the mirror neuron system is innate has stemmed from research investigating imitation in infants (Anisfeld, 1996; Meltzoff & Moore, 1977). Given the importance of mimicry and imitation in successful social cognition, neonates are the only organism to have a "hard wired" ability to mimic others, with tongue protrusion evidenced in studies with human infants (Anisfeld, 1996; Meltzoff & Moore, 1977) and monkeys (Ferrari et al., 2006). However, the repertoire of behaviours and processes thought to be facilitated by mirror neurons is expanding beyond that of simple motor actions (Enticott, Johnston, Herring, Hoy, & Fitzgerald, 2008; Fogassi, 2011; Gallese et al., 2007; Molnar-Szakacs & Overy, 2006), and as such Hebbian association learning is proposed to account for further development of the mirror neuron system (Heyes, 2010; Keysers & Gazzola, 2009).

Hebbian learning, first proposed by Hebb (1949), states that the repeated association between events will result in a learned association, or 'neurons that fire together wire together'. From the point of view of the infant, repeated observation of the infants' own movements will result in activation of the same neural pathways as when observing another make the same movement (Del Giudice, Manera, & Keysers, 2009). However, this neural plasticity is not limited to infants, with research by Lahav, Saltzman, and Schlaug (2007) demonstrating that prior to training non-musical adults did not have any activation when listening to piano notes; however, after a few lessons, presentation of the practiced musical piece activated the same network. This plasticity provides support for the 'neurons that fire together wire together' argument, and indicates the complexity of the mirror neuron system, with research extending beyond that of actions, to "action listening" systems (Lahav et al., 2007), social cognition (Keysers & Gazzola, 2006; Pineda & Hecht, 2009; Uddin, Iacoboni, Lange, & Keenan, 2007), and empathy (Baird, Scheffer, & Wilson, 2011; Gallese, 2001; Kaplan & Iacoboni, 2006).

2.3.2 The empathic brain what have we learned from neuroimaging?

A greater understanding of the human mirror neuron system stems from understanding the brain regions commonly activated through action recognition, theory of mind, and empathy. Mirroring mechanisms allow us to activate an understanding of the intentions of others in ourselves, which is a key component of empathy (Kaplan & Iacoboni, 2006). A complex network of the occipital, temporal, and parietal visual areas make up the

MNS. However, as single electrode research in humans is invasive and dangerous, most of the understanding about the human mirror system has stemmed from neurophysiology and neuroimaging research (see Mukamel, Ekstrom, Kaplan, Iacoboni, and Fried (2010) for an exception). As mirror neurons stem from sensorimotor experience, or the experience gained through social interaction, research has typically focused on the activation of the classical mirror neuron areas: the inferior frontal gyrus, inferior parietal lobule (Heyes, 2010; Rizzolatti & Craighero, 2004), and the insula and amygdala (Wicker et al., 2003) (see Table 2.1).

Table 2.1

Neural Correlates of the Mirror Neuron System from Action Observation to Empathy

MNS - Action	Facial Expressions	Theory of Mind	Empathy
IFG	IFG	IFG	Premotor IFG
STS	STS	STS (Rt)	STS (Rt)
IPL (Rt)	Parietal cortex	IPL (Rt)	IPL (Rt)
Occipital cortex	ACC	Occipital cortex	ACC
Sensorimotor cortex	Sensorimotor cortex	Sensorimotor cortex	Sensorimotor cortex
PMC	Insula	Medial PFC (incl. ACC), OFC, Precuneus, Somatosensory cortices, Amygdala	Ventromedial PFC (incl. OFC), Precuneus, Somatosensory cortices, Amygdala, Insula, Posterior Cingulate

Note. IFG = Inferior Frontal Gyrus, STS = Superior Temporal Sulcus, IPL = Inferior Parietal Lobule, PMC = Premotor Cortex, PFC = Prefrontal Cortex, ACC = Anterior Cingulate Cortex, OFC = Orbitofrontal Cortex. Rt = Right hemisphere.

The inferior frontal gyrus (IFG) is one of the classical mirror areas involved in human action mirroring research (Gazzola, Rizzolatti, Wicker, & Keysers, 2007; Thioux et al., 2008). As the hand and mouth regions in the somatotopic organisation of the mirror neuron system are closely related, the IFG has also been implicated with the observation and imitation of facial expressions (particularly BA 45; Carr, Iacoboni, Dubeau, Mazziotta, and Lenzi (2003)). Hennenlotter et al. (2005) found that right IFG was implicated in viewing and executing smiles. Furthermore, Jabbi and Keysers (2008) concluded that viewing facial expressions engaged brain regions associated with motor functions (particularly BA45); however, they also concluded that this motor representation may not result in the overt production of expressions. Thus, the viewing of facial expressions may lead to simulation of motor functions, suggesting a mirror like response, rather than overt production of the expression (i.e. mimicry). Conversely, van der Gaag, Minderaa, and Keysers (2007) argued that observation and execution of facial expressions activate a similar network of brain regions indicating that overt motor simulation is directly linked to emotional simulation. Enticott et al. (2008) further concluded that the automatic processing of emotional facial expressions facilitates understanding of another's affective state. However, determining the emotional state of others is often a deductive process (Keysers & Gazzola, 2009). Thus, the neural pathways activated through motor simulation likely facilitate the automatic nature of processing others' emotions and allow for deductive reasoning to occur. Despite the conflicting evidence on how the IFG is implicated in the processing of facial expressions, there is consensus that similar brain regions are activated in a mirror neuron like response during the observation and execution of facial expressions (Keysers & Gazzola, 2009; Leslie, Johnson-Frey, & Grafton, 2004).

Several other brain regions have been successfully linked to the extended mirror neuron system in neuroimaging studies, such as the anterior cingulate cortex (ACC) and the insula. Botvinick et al. (2005) were among the first to provide evidence that facial expressions of pain activate the same cortical areas as pain experienced first-hand. In addition, they further concluded that the ACC was linked to sadness, indicating that the structure involved in feeling an emotion, was also linked in sharing affective states. Singer et al. (2004) had a similar conclusion in that viewing facial expressions of pain was linked with affective, but not sensory components of pain. In an effort to link traditional self-report measures of empathy with the mirror neuron system, Hein and Singer (2008) found a correlation between activation of the ACC, and the empathic concern subscale of the interpersonal reactivity index (IRI). This further suggests that the ACC may be an important component in sharing affective states and understanding facial expressions. In a similar vein, the insula is a common neural mechanism between understanding emotions in others and feeling the same emotion ourselves (Wicker et al., 2003). In a study comparing stroke patients who experienced damage to the left insula region with healthy controls, Wicker et al. (2003) demonstrated that the stroke patients were impaired in recognising disgust. This finding suggests that shared neural circuits facilitate the recognition of emotional content and facial expressions.

In addition to the brain regions associated with mirror neurons, expertise and empathy modulate who and how people respond in a mirroring manner. As was evidenced in Hein and Singer (2008), individuals who rated higher on empathy measures featuring empathic concern also had greater mirror neuron activation. Conversely, Gazzola, Aziz-Zadeh, and Keysers (2006) argued that the empathic concern subscale did not predict activation of a mirror system, and instead suggested that the perspective taking component of empathy was correlated with stronger mirror neuron activation. As the perspective taking (PT) subscale is associated with the ability to understand the goals and motivations of another (Davis, 1980), the overlap of perspective taking and the goal-directed mirror neuron system is evident (Gazzola et al., 2006). Haslinger et al. (2005) conducted a neuroimaging study on pianists who watched other pianists play. They found that the mirror neuron system was activated more in the pianists as opposed to the non-pianist controls. A similar study by Cheng et al. (2007) further demonstrates that expertise modulates the mirroring response. When comparing mirror neuron activation in response to needles, acupuncture experts experienced decreased activation in the ACC to needles when compared with controls. However, the experts experienced greater activation in the prefrontal cortices and the somatosensory cortices, both regions associated with theory of mind. These results indicated that whilst controls readily “empathised” with the person receiving the needle, the acupuncturists were controlled in their responses, likely a result of their professional environment (Cheng et al., 2007). This finding suggests that mirroring responses are modulated by not only the goal or outcome of the action or expression perceived, but also by who is responding.

2.3.3 Beyond neuroimaging: Mirror neuron research with mu rhythm

An increasing number of studies are using changes in mu rhythm as an index of human mirror neuron activity (see Fox et al., 2016 for a recent review). Mu rhythm occurs within the alpha band (i.e. 8-13 Hz in adults) and has been shown to decrease in amplitude (or desynchronise) during both observation and execution of actions (Muthukumaraswamy, Johnson, & McNair, 2004). One of the first to observe this desynchronization was Gastaut and Bert (1954), who demonstrated that when subjects viewed moving stimuli and engaged in active movement themselves, activity over the central sites was suppressed.

Desynchronisation or suppression of the mu rhythm during action execution and observation of actions, as indexed by the central cortical sites, indicates that the mu rhythm may be an index of sensorimotor activity (Fox et al., 2016). In order to disentangle mu from alpha, research has focused on examining the alpha activity over the occipital regions to determine that the activation is not a result of neural activity spreading to the central sites (Pineda, 2005). Further critical evidence for mu rhythm as an index of mirror neurons stems from research that uses concurrent EEG-fMRI, which has shown an overlap in region specific activation (Arnstein, Cui, Keysers, Maurits, & Gazzola, 2011). Although EEG-mu mirror neuron research was traditionally focused on mirroring of voluntary actions (Cannon et al., 2014; Muthukumaraswamy et al., 2004; Woodruff, Martin, & Bilyk, 2011), research is increasingly extending the mirror to encompass empathy (Yang, Decety, Lee, Chen, & Cheng, 2009), and emotion recognition (Ensenberg, Perry, & Aviezer, 2017; Moore, Gorodnitsky, & Pineda, 2012; Moore & Franz, 2017; Perry et al., 2010; Perry, Troje, & Bentin, 2010).

To discern whether the mirror neuron system as indexed by mu suppression is an index for empathic responses, research has focused on empathy for pain. As pain is a prominent emotion state readily felt by one's self and empathized within observers, a correlation between self-report empathy and mirror neuron responses should occur. When looking at hands in painful situations (i.e. being cut by scissors, or closed in a door) mu suppression was significantly correlated with empathy (Yang et al., 2009). Similarly, Perry et al. (2010) explored how empathic responses to painful stimuli were mediated by the receiver of the inflicted pain. When participants were instructed to imagine how the person experiencing the painful stimuli felt, they concluded that mu suppression was elicited automatically for situations considered painful for oneself. Furthermore, empathy for pain was found even when participants were informed that the individual receiving the touch had a neurological disorder that meant they could not feel pain. This empathy for pain, which extends beyond the self, indicates that the mirror neuron system as indexed by mu could be the foundation for empathy and sharing of emotional states. Extending the mu suppression research beyond pronounced emotion specific states such as pain, to everyday social communication can be achieved by considering the EEG mu response to emotional faces.

Limited research has investigated the mu suppression response to facial expressions of emotion. Moore et al. (2012) conducted preliminary research on the modulation of mu to static emotional expressions and self-report empathy. A mu suppression response was observed for happy and disgust expressions relative to a control condition, regardless of whether the participants were actively instructed to empathise with the expresser. Similarly, in research using facial morph stimuli where the expression shifted from neutral to emotional, emotional expressions were associated with modulated alpha power over sensorimotor regions (Popov, Miller, Rockstroh, & Weisz, 2013). To further explore whether affective recognition is related to shared emotional circuits, research has focused on emotional classification (Moore & Franz, 2017; Pineda & Hecht, 2009). Pineda and Hecht (2009) conducted an emotional classification task using eye regions and found no evidence for a mirroring response in the mu rhythm. Conversely, Moore and Franz (2017) concluded there was a robust mu response to emotional faces during classification tasks, even after subtraction of an emotional word control task. Although this desynchronization provides support for the theory that shared neural circuits mediate facial emotion processing, it also indicates that whole face stimuli are required, particularly when the task is reliant on emotion categorization.

In addition to this research, which has demonstrated suppression of the mu rhythm in response to emotional expressions, other research has focused on suppression elicited in response to neutral faces (Karakale, Moore, & Kirk, 2019). A recent mu suppression study by Karakale et al. (2019) explored responses to dynamic expressions of emotion including happy, sad, and neutral facial expressions, and a non-biological motion control stimulus. Neural expressions elicited greater sensorimotor mirroring than sad facial expressions, and only neutral expressions differed significantly from the control stimulus. Furthermore, a recent pre-print by the same authors further confirmed this effect, where static neutral faces elicited greater suppression responses than happy and sad expressions (Karakale, Moore, McNair, & Kirk, 2019). These EEG results provide further support for an earlier magnetencephalography (MEG) study examining sensorimotor responses to dynamic faces (Popov et al., 2013). Popov et al. (2013) demonstrated the greatest sensorimotor engagement during the pre-recognition phase of emotion recognition in response to dynamic faces. Furthermore, this increased sensorimotor engagement was reversed once the expression was a clearly recognisable emotion. Together, these studies provide evidence that the role of the sensorimotor cortices is to decode emotional expressions which are more ambiguous in nature (Karakale et al., 2019).

Given the scarcity of research in this field, further research is needed to determine whether mu for facial expressions is an adequate index of mirror neuron activity. None of the previously reviewed studies have explored mu responses to faces beyond observation. Given that mirror neurons are built on the premise that observation and execution activate shared circuits (Gallese et al., 2007), and that execution conditions reliably elicit greater mirroring responses than observation conditions (Woodruff et al., 2011), further research investigating execution of facial expressions is necessary. Further research will need to employ a design that can disentangle sensorimotor activation resulting from motor muscle movements from mu responses. This research will offer new insight into the way that people process emotional facial stimuli. The field of neuroscience is providing the bridge between self-and-other in the sense that without any form of conscious effort on our part, the brain has helped us to become highly social and empathic animals.

2.4 Contributions of this Thesis

The overarching aim of this thesis is to determine why we care when others cry. At the end of Chapter 1, it was proposed that psychophysiology could be used to further validate existing self-report crying research. To date an exceptionally limited number of studies have explored the psychophysiological responses to tears, using techniques such as EEG, fMRI and EMG (Grainger, Vanman, Matters, & Henry, 2019; Hendriks, van Boxtel, & Vingerhoets, 2007; Riem, van Ijzendoorn, De Carli, Vingerhoets, & Bakermans-Kranenburg, 2017; Riem et al., 2017; Takahashi et al., 2015). Given that psychophysiology is capable of indexing empathic responses, these studies have provided valuable information to the crying field.

The first study to explore physiology and tears, to the best of our knowledge, was an ERP study conducted by Hendriks et al. (2007). In their study, Hendriks et al. (2007) explored whether the N170 ERP was sensitive to crying tearful displays. Although the emotional faces elicited larger ERPs than neutral expressions, they concluded that there were no systematic differences between the different types of emotional displays. Therefore, it was concluded that tearful displays are processed in the same way as other universal expressions of emotion—rapidly and without conscious awareness. However, a recent meta-analysis identified that facial signals with increased social relevance (i.e. fearful and angry faces in threat detection, and happy faces for social affiliation), elicit larger N170 amplitudes (Hinojosa et al., 2015). From an evolutionary perspective, tears are an important communicative signal that alert others to distress and elicit support from observers (Hasson, 2009). Therefore, it is intuitive that tearful displays should also be prioritised at the neural level. Thus, further research exploring whether tearful displays elicit significantly greater N170 responses than the same displays without tears is needed to identify what role tears play in the identification of emotion.

Takahashi et al. (2015) and Riem et al. (2017) explored neural responses to tears using fMRI. These studies demonstrated that tears influenced the amount of activation in regions associated with mentalising—otherwise known as cognitive empathy—such as the medial prefrontal cortex (mPFC) and the precuneus/posterior cingulate cortex (PCC). Given that mentalising is typically associated with the ability to understand how another is feeling (Perry & Shamay-Tsoory, 2013), tears are associated with increased activation in areas associated with inferring the extent of others' emotion. Additionally, increased activation to tearful faces was observed over the somatosensory cortices by Riem et al. (2017). Given that the somatosensory cortices are a part of the extended mirror neuron system (MNS), wherein observing another and experiencing oneself share overlapping neural circuits (Bastiaansen, Thioux, & Keysers, 2009), further exploring the MNS response to tearful expressions may be the key to understanding the communicative functions of emotional tears.

The most recent study to explore psychophysiological responses to emotional tears was conducted by Grainger et al. (2019), who examined mimicry responses to tearful expressions. Grainger et al. (2019) demonstrated that tearful sad displays did not significantly increase the amount of mimicry exhibited by participants as indexed by facial EMG. The authors concluded that while participants were showing mimicry that was consistent with typical mimicry responses to sad displays (i.e. increased corrugator activity relative to zygomatic activity), tears did not modulate mimicry responses. Thus, they concluded that their data support the matched motor hypothesis, wherein persons automatically mimic facial displays. However, these conclusions contrast with evidence demonstrating that mimicry responses are influenced by the affiliative nature of the interaction (Hess & Fischer, 2013). Therefore, future research needs to further explore whether tears modulate mimicry responses when paired with expressions other than sadness.

Therefore, the work conducted to date exploring the psychophysiological responses to tears is exceptionally limited, and a worthy avenue of further research. This thesis will aid in addressing the limitations raised throughout this discussion and provide new insight into the communicative functions of emotional tears. This chapter will conclude by outlining the contributions of each thesis chapter, and the overarching research questions guiding this thesis.

2.4.1 2.4.1 Chapter overview

Chapter 3 extends the behavioural research exploring what emotional tears signal to observers. Although it has been well demonstrated that tearful displays elicit social support from observers, there are two competing theories about what emotional tears signal—namely the tear effect (i.e. that tears signal sadness) and the general enhancement perspective (i.e. that tears intensify any emotion they are paired with). Therefore, Chapter 3 reports the results of two behavioural experiments that explored whether tears serve as a marker of sadness in the absence of context.

Chapter 4 details the results of the first psychophysiological study, wherein it was investigated whether tears are mimicked more than tear-free displays. This research followed on from the work by Grainger et al. (2019), and additionally explored responses to tearful displays other than sadness (i.e. happiness, anger, and neutral faces). Therefore, Chapter 4 reports the first of a series of studies that examined whether tears modulate the physiological responses to facial displays.

Chapter 5 seeks to further explore whether tears are processed at the early neural level. Following Hendriks et al. (2007), we explored the early N170 response to emotional tears, on expressions of happiness and sadness. This chapter demonstrates whether tearful displays were preferentially processed compared to tear-free counterparts.

Chapter 6 reports a mu suppression study investigating the MNS response to tears. This chapter outlines the results of one of the largest mu suppression studies to date and identifies several components that influence mu during the observation and execution of facial displays. This chapter jointly furthers our understanding of responses to emotional tears, and the role of mu in neural mirroring.

Chapter 7 is a perspective piece exploring the type of stimuli used in crying research. A large body of the communicative tear research has relied on posed tearful expressions, including Chapters 3 to 6. However, the recent movement towards the adoption of ecologically valid stimuli in emotion research is explored, and the implications for the crying field highlighted.

Chapter 8 is one of the first empirical investigations exploring the perceptions of genuineness in tearful displays. These tearful displays include the posed expressions used in this thesis, and a selection of genuine tearful displays recently adopted in tear research. The results of three experiments are discussed, and the implications for the crying field are considered.

Chapter 9 is the concluding chapter of this thesis, where the critical question *why we care when others cry* is revisited. We offer several possible answers to this fundamental question and outline the potential implications of this thesis and what research could explore moving forward. The thesis concludes with a summary of the communicative functions of adult emotional tears and highlights the importance that this understanding can afford to our empathic society as a whole.

2.4.2 2.4.2 Thesis aim

As identified the overarching aim of this thesis is to determine why we care when others cry. To do this, these three research questions were investigated:

1) Do tears serve as a signal of sadness in the absence of context (Chapter 3)?
2) Do tears modulate physiological responses to facial displays (Chapters 4, 5, and 6)?
3) Do tears increase the authenticity of facial displays (Chapters 7 and 8)?

Chapter 3: The Tear Effect: More than just a Marker of Sadness?

3.1 Chapter Overview

Chapter 3 extends the behavioural research exploring what emotional tears signal to observers. Although it has been well demonstrated that tearful displays elicit social support from observers, there are two competing theories about what emotional tears signal—namely the tear effect (i.e. that tears signal sadness) and the general enhancement perspective (i.e. that tears intensify any emotion they are paired with). Therefore, Chapter 3 reports the results of two behavioural experiments that explored whether tears serve as a marker of sadness in the absence of context.

3.2 Publication Status

Under review at Cognition and Emotion, revise and resubmit completed.

3.3 Author Contributions

Krivan - planned and created the experiments, collected the data, conducted the data analysis, wrote up the manuscript, and completed the revisions from the reviewers.

Caltabiano - provided supervision.

Cottrell - aided in experimental design and provided supervision.

Thomas - provided supervision, contributed to editing and review, and provided the funding for the experiments.

3.4 Manuscript

3.4.1 Abstract

The function of emotional tears is said to alert others to emotional distress and signal the need for support. Yet, tears are elicited in moments of extreme joy, in addition to despair. The majority of research has demonstrated support for the tear effect, wherein tears increase the perception of sadness. However, limited empirical work has been conducted exploring the general enhancement perspective, which posits that tears increase the intensity of an emotion. We report the results of two experiments, which investigated the influence of tears on the identification of sad, happy, and neutral expressions. Participants were exposed to facial stimuli, half of which featured tears and half did not. Experiment 1 investigated reaction time responses to these displays, to determine whether tears were a signal of sadness—in line with the tear effect. Experiment 2 sought to provide further support for the tear effect by examining the roles of intensity and valence in the identification of happy and sad tearful displays. Experiment 1 supported the tear effect, with impaired recognition of happy-tear faces, and enhanced recognition of neutral-tear faces, while classification of sad expressions was not influenced by tears. Experiment 2 further demonstrated that the presence of tears impairs recognition of a happy face. Furthermore, the presence of tears increases perceived intensity, whilst simultaneously increasing the perception of negative valence. Thus, we demonstrated support for both the tear effect and the general enhancement perspective, wherein tears serve as an intense marker of sadness in the absence of context.

Keywords: adult crying, emotion recognition, reaction time

3.4.2 Introduction

Emotional tears are a universally recognised emotional expression (Gračanin, Bylsma, & Vingerhoets, 2018). Predictably, it is this universality that has aided in the identification of the communicative function of emotional tears. Tears have previously been shown to signal sadness (Provine et al., 2009; Zeifman & Brown, 2011), which in turn reliably elicits help and support from observers (Balsters et al., 2013; Hendriks et al., 2008). In these studies, it is demonstrated that tearful expressions communicate distress through sadness and the need for support more effectively than identical tear-free displays. However, these studies have typically used negative or neutral displays—where there is a specific focus on the perception of sadness. Therefore, it is not overly surprising that tears signal sadness. For this reason, there are two related, but competing, theories about what tears signal. The first, *the tear effect* postulates that in the absence of social context, tears are perceived as an indicator of sadness (Provine et al., 2009). However, the second, *the general enhancement perspective*, asserts that tears intensify the emotions they are paired with—serving as a “secretory exclamation point” (Ito et al., 2019; Provine, 2012). Under the general enhancement perspective, tears would increase the intensity of perceived sadness, but also increase the intensity of perceived anger for angry displays. Conversely, under the tear effect, tears would increase the perception of sadness, regardless of the emotion they are paired with.

Of these two competing theories, there is undoubtedly greater support for the tear effect. Provine et al. (2009) proposed that tears facilitate the recognition of sadness. Participants rated static images of crying individuals and duplicate images with the tears removed. Tearful expressions were rated as significantly sadder in appearance than the tear-free duplicates. In addition, participants perceived the tear-free images as ambiguous in emotional valence (Provine et al., 2009). Similarly, Zeifman and Brown (2011) demonstrated that participants perceived faces with tears as sadder than faces without tears, regardless of target age. Moreover, the greatest effect of this increased sadness was observed for adult faces, rather than infant and child faces. Takahashi et al. (2015) further demonstrated the tear effect using sad and neutral expressions and concluded that the magnitude of the tear effect was greater for neutral expressions. Additional evidence for the tear effect was reported by Balsters et al. (2013), who found that reaction time responses to sad faces with tears were significantly faster than to sad tear-free faces. Interestingly, the images were presented briefly (i.e. 50 ms), and tears were a salient signal, which rapidly attracted attention (Balsters et al., 2013). Together, these studies show that tears signal and facilitate the recognition of sadness. However, in all these studies the response options were centred around sadness. For example, in the rating tasks participants were responding with how sad the faces seemed, and in the reaction time task the response options were sad or not sad. Given the response metrics, it is not surprising that tears were associated with sadness.

This focus on sadness ratings resulted in the development of the general enhancement perspective. Proposed by Ito et al. (2019), the general enhancement perspective posits that tears increase the intensity of all facial expressions. Reed et al. (2015) explored whether the presence of tears on dynamic posed prototypical displays of happiness, anger, sadness, fearful and neutral expressions increased emotion specific ratings, in addition to generalised intensity and valence ratings. Unsurprisingly, sadness specific ratings were greater for all emotions (except anger) for tearful displays, relative to tear-free expressions. However, tears also increased the generalised intensity ratings of neutral, happy, angry, and fearful displays, and in several instances' emotion specific ratings (e.g. anger rating increased for tearful angry, happy, and fearful expressions). These results indicate support for a general enhancement perspective, where tears increase the intensity of emotional displays, rather than just increasing sadness. Ito et al. (2019) further explored the perception of negative tearful displays under the general enhancement perspective, by asking participants to rate angry, fearful, sad, disgusted, and neutral tearful expressions on emotion specific rating scales. As in Reed et al. (2015), perceived intensity of sadness was increased when the faces featured tears. Interestingly, the only evidence observed for a general enhancement perspective stemmed from increased intensity of anger in disgusted expressions with tears. The authors further explored these ratings in multidimensional space, and the presence of tears resulted in a tighter clustering of all emotions around sadness (Ito et al., 2019). Thus, both studies concluded that there is a generalised sadness effect when tears are added to emotional displays.

However, tears are also elicited in response to positive emotions (Miceli & Castelfranchi, 2003). As previously stated, Reed et al. (2015) examined the effect of tears on expressions other than sadness. Interestingly, tearful Duchenne smiles were attributed greater generalised intensity, while tearful non-Duchenne smiles were attributed greater negative valence (Reed et al., 2015). This result further indicates that tears are an intense marker of sadness, and that recognising "tears of joy" likely stems from contextual information. This interpretation is consistent with the dimorphous expression literature, in that when tearful facial expressions are paired with positive scenarios they are perceived as positive emotions (Aragón, 2017; Aragón & Bargh, 2018; Aragón & Clark, 2018). Thus, tears serve as a marker of sadness in the absence of context, for both positive and negative emotional displays.

However, these conclusions stem largely from sadness specific emotion ratings (Ito et al., 2019; Reed et al., 2015). The virtue of emotion specific ratings is the ability to investigate whether the presence of tears enhances the intensity of specific emotional expressions (i.e. greater perceived anger for angry expressions). However, emotion specific ratings increase the number of comparisons per emotion. Furthermore, the inclusion of a specific rating of sadness biases results towards a significant tear effect. Interestingly, two studies using sadness specific ratings have demonstrated that tears do not increase the perception of sadness for sad displays, but do for other expressions of emotion (Reed et al., 2015; Reed et al., 2019). Therefore, future research exploring the tear effect and the general enhancement perspective should use generalised intensity and valence ratings, as in Reed et al. (2015). In addition, the inclusion of a subjective response measure—such as reaction time (e.g. Balsters et al. (2013)—will aid in determining the influence of tears on emotion classification.

Finally, it is yet to be determined whether the sex of the stimulus influences responses to tears. In studies exploring crying frequency, females have been found to cry more than males (Lombardo, Cretser, Lombardo, & Mathis, 1983; Lombardo, Cretser, & Roesch, 2001). Therefore, one might expect that crying behaviours would be perceived as more acceptable for female criers due to sex-role stereotypes. Cretser, Lombardo, Lombardo, and Mathis (1982) demonstrated that females perceived crying by both males and females as appropriate, whereas males were more likely to perceive female crying as appropriate relative to male crying. This 'double standard' in the perception of male criers likely stems from the sex-role association linking 'not-crying' to masculinity (i.e. holding back the tears). Since this early work, Fischer et al. (2013) demonstrated that the perception of emotionality and competence did not differ between males and females in relationship scenarios (i.e. a vignette describing crying in response to divorce). However, in employment contexts (i.e. a vignette describing crying after getting fired), males were perceived as more emotional and less competent relative to females. These effects demonstrated that the damaging effects of crying in the workplace were harsher for males relative to females. Recently, Stadel et al. (2019) demonstrated that although 'willingness to help' crying persons was strong across multiple gender dyad combinations, the effect was the lowest in a male-male dyad. Therefore, how the gender of the participant and the sex of the stimulus influences responses to emotional tears is yet to be determined.

The present study sought to determine whether tears signal sadness (i.e. in line with the tear effect) or whether they increase the intensity of emotion (i.e. the general enhancement perspective). Given that the majority of literature supports a tear effect, we predicted the presence of tears would increase the perception of sadness for both negative and positive displays. As incongruent facial features increase reaction time (Calvo, Fernández-Martín, & Nummenmaa, 2012), we hypothesised that the competing facial features of a smile and tears would impede responses to happy faces. Furthermore, we predicted that the opposite effect would occur in response to sad facial displays, in line with tears enhancing the perception of sadness. We also predicted that the presence of tears would decrease generalised intensity and valence for happy displays and increase intensity and negative valence for sad displays. Finally, we conducted exploratory analyses to determine whether sex of stimulus influenced participants responses and as such we did not have any directional hypotheses for these effects.

3.4.3 Experiment 1

3.4.3.1 Method

3.4.3.1.1 Participants

The sample consisted of 35 undergraduate students (23 females, M_{age} = 26.1 years, SD_{age} = 10.5). All participants reported having normal or corrected-to-normal vision. Two participants who failed to follow experimental instructions were excluded from analysis, leaving a final sample of 33 participants. Ethical approval was obtained from the James Cook University Human Research Ethics committee and participants received course credit for their participation. All participants provided written informed consent in accord with the Declaration of Helsinki.

We determined sample size following the results of Balsters et al. (2013), who had a sample size of 30 participants and achieved an effect size of eta squared of .284. Using power analysis software G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) we calculated a power analysis for repeated measures, within factors. As the Balsters et al. (2013) study reported a large effect size, we opted for a conservative effect size of a partial eta squared value of .06, given that there was no reported literature for responses to happy-tear stimuli. The power analysis called for a total of 27 participants, and as such we recruited 35 participants to allow for participant attrition.

3.4.3.1.2 Stimuli

Stimuli were happy, sad, and neutral faces selected from the Karolinska Directed Emotional Faces database (KDEF; Lundqvist et al., 1998). Each face was cropped using an ellipsis tool to remove hair, clothing, and ears, ensuring only the face was visible and only facial features could be used to determine emotional expressions. Tears were digitally added to each of the faces (see Figure 3.1 for an example of the tear stimuli) using online photo editing software (http://funny.pho.to/tears-effect/). The dimensions for the cropped KDEF faces were 298 x 374 pixels.

A separate sample of participants ($N = 22$, $M_{age} = 24.6$ years, $SD_{age} = 9.5$) rated a subsample of the KDEF faces (192 images) using visual analogue scales. Pilot images were rated on emotional expression intensity (i.e. how happy is this face?), which ranged from 0 (*not at all*) to 1 (*very much so*); and generalised valence (i.e. what was the valence of this expression?) ranging from 0 (*negative*) to 1 (*positive*). The 5 male and 5 female stimuli that were best matched across intensity and valence were selected for the experiment proper (see Table 3.1). The experiment proper used 10 unique facial identities, wherein each identity included a happy, sad and a neutral expression, both with and without tears, resulting in a total of 60 experimental trials.

Table 3.1

Mean (SDs) Pilot Intensity and Valence Ratings for the 10 Facial Identities

		No Tears			Tears		
		Happy	Sad	Neutral	Happy	Sad	Neutral
Intensity	Female	.89 (10)	.79 (.14)	-	.82 (.10)	.86 (.12)	-
	Male	.92 (.08)	.76 (.15)	-	.87 (.11)	.86 (.13)	-
Valence	Female	.89 (.13)	.17 (.13)	.37 (.16)	.78 (.18)	.13 (13)	.20 (.13)
	Male	.89 (.11)	.16 (.13)	.43 (.08)	.80 (19)	.16 (.15)	.23 (.13)

Note. Intensity ratings reflect emotion specific intensity (i.e. how happy is this face?), and valence ranged from 0 (negative) to 1 (positive). There were no intensity ratings for neutral expressions.

3.4.3.1.3 Procedure

The experiment was conducted in a sound attenuated room on a 23.5” monitor with a 120 Hz refresh rate, using a NVIDIA GeForce 970 graphics card. PsychoPy software (version 1.84.2) was used to present the stimuli. All facial images were presented in full colour against a black background. Participants were seated in a chair approximately 60 cm from the monitor.

Each trial began with the presentation of a fixation cross for 500 ms, followed immediately by the target image for a maximum of 1800 ms. Half the participants were instructed to press the extreme left button for happy faces and the extreme right button for sad faces, with the instructions being reversed for the remaining half of participants. Thus, the task was a two-alternative forced choice, and participants were required to categorise faces as either happy or sad. All participants were informed that their reaction times were being recorded and they should make fast, but accurate judgments. The maximum time window for responses was 1800 ms, after which the participant would see a “too slow” message prior to the beginning of the next trial (see Figure 3.1). Stimuli were presented in a different quasi-random order for each participant, with the restriction that the same face with and without tears were never presented consecutively. Participants were given two practice trials to familiarize themselves with the task, followed by 60 test trials. The task took approximately five minutes to complete. Prior to this task, participants completed an additional unrelated task which is not reported here. Following completion, participants were debriefed and thanked for their participation.

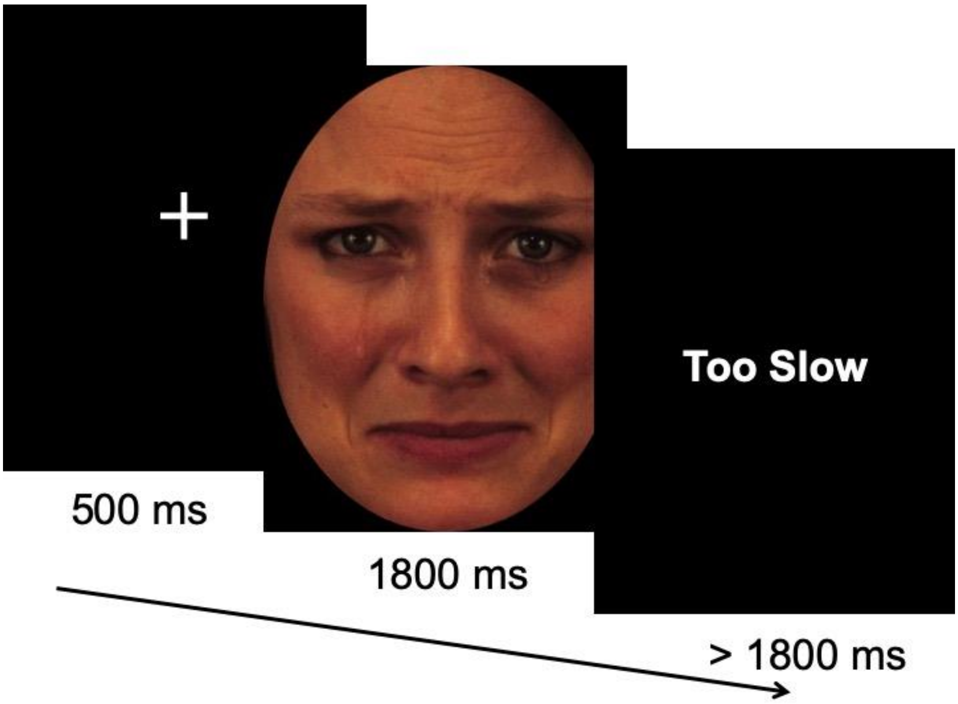

Figure 3.1. Example RT trial procedure. The “Too Slow” message was only presented if the participant failed to respond within 1800 ms. The KDEF image presented here is F01SAS, which has been edited to include tears.

3.4.3.2 Results

Accuracy scores were subjected to a 2 (emotion: happy, sad) by 2 (tears: no tears, tears) repeated-measures ANOVA. Incorrect responses, and outliers greater or less than 3 *SD* from the mean of each participant in the raw data (1.46%) were removed prior to reaction time analyses. Trimmed reaction time scores were subjected to a 2 (emotion: happy, sad) by 2 (tears: no tears, tears) by 2 (stimulus sex: female, male) repeated-measures ANOVA. All post hoc follow-up comparisons were Bonferroni-corrected. As participant gender was not found to influence reaction time, $F(1,31) = .084$, $p = .774$, $\eta_p^2 = .003$, it was not considered in further analyses.

3.4.3.2.1 Accuracy

Emotions were classified with high accuracy (see Table 3.2). Trials with incorrect responses (4.24%) and missing responses (0.38%) were pooled as errors for the accuracy analysis.

Table 3.2

Mean (SD's) Classification Accuracy and Reaction Time across Emotion Categories.

	No Tears		Tears	
Stimulus	Accuracy (%)	Reaction Time (ms)	Accuracy (%)	Reaction Time (ms)
Happy	96.06 (7.48)	683.18 (189.97)	89.70 (12.37)	718.90 (215.53)
Sad	97.57 (5.61)	714.64 (193.39)	98.18 (5.28)	689.74 (154.72)

Note. Accuracy scores are percentage correct out of 100.

The repeated-measures ANOVA revealed a significant main effect of emotion, $F(1, 32) = 13.200$, $p < .001$, $\eta_p^2 = .292$, where sad faces were classified with significantly greater accuracy than happy faces. There was also a significant main effect of tears, $F(1, 32) = 6.475$, $p = .016$, $\eta_p^2 = .168$, where tear-free faces were classified with significantly greater accuracy than tearful faces. There was a significant interaction between tears and emotion, $F(1, 32) = 9.004$, $p = .005$, $\eta_p^2 = .220$ (see Figure 3.2a). For happy faces, accuracy was significantly lower when tears were present on a happy face, $t(32)= 3.285$, $p = .002$, $d = .572$. There was no difference in classification accuracy between sad and sad-tear faces $t(32)= -0.494$, $p = .625$, $d = -.086$.

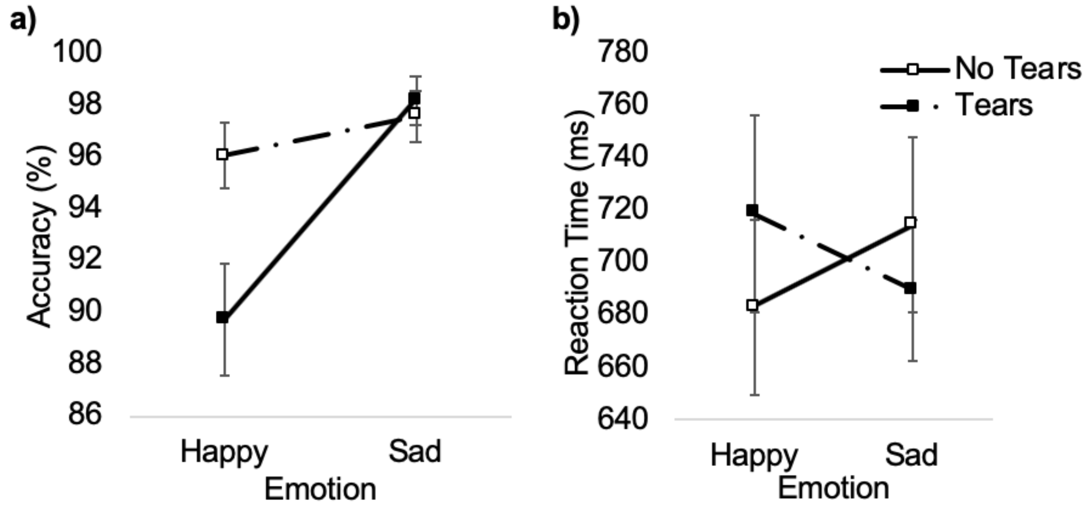

Figure 3.2. Mean scores for each emotion condition for the a) accuracy and b) response time data. Error bars are SEM.

3.4.3.2.2 Reaction time

The repeated-measures ANOVA showed no significant main effects of tears, $F(1, 32) =.103$, $p = .750$, $\eta_p^2=.003$; emotion, $F(1, 32) = .020$, $p = .888$, $\eta_p^2=.001$; or stimulus sex, $F(1, 32) = 3.491$, $p = .071$, $\eta_p^2=.098$. However, there was a significant interaction between tears and emotion, $F(1, 32) = 8.497$, $p = .006$, $\eta_p^2=.210$ (see Figure 3.2b). Happy faces were responded to faster than happy faces with tears, $t(32)= -2.287$, $p = .029$, $d = -.398$; however, this result was not significant after Bonferroni correction. There was no difference in reaction time between the sad and sad-tear expressions, $t(32)= 1.527$, $p = .137$, $d = .266$. No other interactions were significant, *F's* < .854, *p's* > .362.

3.4.3.2.3 Neutral face analyses

Finally, the neutral faces were analysed separately, to determine whether neutral faces with and without tears were more perceptually similar to happy or sad faces. Overall, neutral and neutral-tear expressions were predominantly classified as sad ($M = 90.45\%$); thus, we treated "sad" as the correct response in the accuracy analysis. Participants were more likely to classify a neutral face as sad when it included tears (*M* = 95.15%, *SD* = 7.55), compared to neutral faces without tears (*M* = 85.76%, *SD* = 18.88), $t(32)$= -2.886, p = .002, d = -.502. Interestingly, reaction time to classify a face as sad was not significantly faster for neutral faces with tears (*M* = 749.7ms, *SD* = 37.67), compared to neutral faces without tears (*M* = 781.7ms, *SD* = 40.83), $t(32)$= 1.312, p = .119, d = .228. This finding demonstrates that although neutral faces are more likely to be classified as sad when they feature tears, tears do not significantly improve the time taken to classify a neutral face as sad.

3.4.3.2.4 Discussion

The presence of tears modulated both accuracy and reaction time; however, this effect was dependent on type of emotion. Our results indicate that tears significantly influence the perception of happy and neutral faces, but not sad faces. Largely, the results of our first experiment support the tear effect hypothesis, where the addition of tears to emotional images makes images seem sadder.

This increased perception of sadness is particularly prominent when investigating the differences between happy expressions and happy expressions with tears. Moreover, the presence of tears on a happy face significantly increased reaction times and decreased classification accuracy, compared to happy tear-free faces. Given that incongruent facial features increase reaction times (Calvo et al., 2012), the competing features of a smile (i.e. a distinctive marker of happiness) and tears (i.e. a marker of sadness) impeded participants' ability to classify faces as happy. Additionally, participants were significantly more likely to misclassify a happy face as sad when it included tears. Together, these results indicate that the presence of tears on a happy face impedes responses. Thus, in line with the tear effect, tears are a signal of sadness and as such are incongruous with smiles.

Conversely, the addition of tears to sad facial displays did not significantly improve the classification of sad faces. Our results contradict the results reported by Balsters et al.

(2013), who found that the presence of tears on a sad face significantly sped up reaction time responses. However, examining the near identical high classification accuracy across both sad conditions indicates that participants did not require tears on a sad face to correctly classify the face as sad. Therefore, the presence of tears on a sad face does not substantially enhance the perception of sadness in relation to classification accuracy or reaction time in a forced choice reaction time task. This finding could partially be attributed to the signal value of the sad faces we used. The KDEF faces used in our experiment are classified with high accuracy (Calvo et al., 2016), whereas the more ecologically valid stimuli used in Provine et al. (2009) were perceived as ambiguous when the tears were removed. Furthermore, although Balsters et al. (2013) used the same KDEF stimuli as we did, they used a brief presentation time of 50 ms. Thus, in line with tears serving as a distinctive facial marker of sadness, tears make a face clearly identifiable as sad when presented briefly. Conversely, the extended display time of the stimuli in our experiment meant that participants had the time to accurately classify all emotional displays and, as such, the presence of tears was not as salient a marker.

Finally, for neutral expressions, participants were significantly more likely to classify a face as sad if it featured tears. This increased sadness is in line with prior research, which has demonstrated that tears are a clear marker of sadness that resolve the ambiguity associated with neutral expressions (Provine et al., 2009). However, participants were not faster at classifying a neutral face as sad when the face featured tears. When examining sadness ratings of neutral and emotional expressions, Reed et al. (2015), found that the tear effect was most pronounced for neutral faces. Therefore, it seems that although faces are perceived as sadder, and are classified as such, this increased perception of sadness does not improve reaction time. However, it must be cautioned that our study used a two-alternative forced choice response, where participants were required to choose happy or sad. As such, there was no neutral category. Therefore, future research could explore, using a three-choice paradigm, whether participants are still more likely to classify a neutral-tearful face as sad, when there is a neutral response.

Thus far we have demonstrated that the presence of tears on happy faces makes them less recognisable as happy; and the presence of tears on a sad face does not significantly alter responses. While these effects are consistent with prior research into the tear effect (Reed et al., 2019), they are confounded by the presence of tears, as tearful stimuli, by nature, change the perceived intensity of the image. Thus, the tear effect might not be about the presence of tears, but rather the intensity of the image. Wells, Gillespie, and Rotshtein (2016) found that intensity was linearly related to classification accuracy, in that the more intense the expression the greater the classification accuracy. Furthermore, intensity impacted upon response time in that more ambiguous emotional displays took longer to respond to than more intense displays. Therefore, to further explore what emotional tears convey, we will explore the way that intensity and valence influence classification accuracy and response time in Experiment 2.

3.4.4 Experiment 2

The results of Experiment 1 present interesting evidence in support of the tear effect, when happy, sad, and neutral faces are used as stimuli. However, in experiment 1 we conducted a dichotomous response task, and included a neutral face condition. Thus, for the neutral faces there was technically no correct answer. Furthermore, a recent review by Kauschke et al. (2019) highlighted that the inclusion of neutral faces in experiments can bias the results, given that posed neutral faces can be perceived as negative—rather than truly neutral. As was evidenced by our study, in a forced classification task, most participants selected ‘sad’ as the classification for neutral faces. Considering this evidence, we excluded the neutral face condition from the second experiment.

In our second experiment, participants were asked to complete a reaction time task and a rating task. We chose to also include a rating task to investigate the perceived intensity and valence of each image. We used generalised intensity and valence scales in an effort to avoid biasing our data towards a significant tear effect. As prior studies exploring the general enhancement perspective have used emotion specific ratings (i.e. how sad is this face?), it is not overly surprising that support was primarily demonstrated for the tear effect. The use of generalised intensity and valence will allow for a fairer investigation of whether there is greater support for the general enhancement or tear effect hypotheses.

We hypothesised that we would replicate the reaction time results of Experiment 1, where happy faces with tears were responded to more slowly than happy faces without tears. Additionally, in line with the tear effect, we anticipated that happy-tear faces would reduce perceived intensity and valence relative to happy faces without tears, whereas sad faces featuring tears would increase perceived intensity and valence relative to sad faces without tears.

3.4.4.1 Method

3.4.4.1.1 Participants

The sample consisted of 48 undergraduate students (32 females, M_{age} = 23 years, SD_{age} = 4.14 years). All participants reported having normal or corrected-to-normal vision. We excluded three participants from the analyses; one because they failed to follow experimental instructions and two for achieving below 70% accuracy, leaving a final sample of 45 participants. Participants were awarded $15AUD as compensation for their time. All participants gave written informed consent in adherence with the Declaration of Helsinki, and all experimental protocols were approved by the Monash University Human Research Ethics Committee.

3.4.4.1.2 Stimuli

We conducted a new pilot study, to obtain generalised intensity and valence ratings for the face stimuli. This pilot was made up of 17 participants (13 females; M_{age} = 33.5 years, SD_{age} = 12.55). We asked participants "how intense was the emotion depicted" and the scale ranged from 0 (*not at all*) to 1 (*extremely intense*). The valence scale was the same as the original pilot, and asked, "what valence was the emotion depicted?" and the scale ranged from 0 (*negative*) to 1 (*positive*). For Experiment 2, we selected 20 facial identities (10 female). Each facial identity expressed happy and sad emotions, and we created a digital duplicate, which included tears, using the same photo-editor software as in Experiment 1. Table 3.3 displays the generalised intensity and valence ratings for the 10 male and 10 female faces selected for Experiment 2.

Table 3.3

Mean (SDs) Pilot Generalised Intensity and Valence ratings for the 20 Facial Identities

		No Tears		Tears	
		Happy	Sad	Happy	Sad
Intensity	Female	.54 (.24)	.60 (.17)	.61 (.17)	.66 (.15)
	Male	.59 (.21)	.59 (.13)	.63 (.18)	.65 (.12)
Valence	Female	.79 (.12)	.25 (.08)	.70 (.18)	.21 (.09)
	Male	.78 (.11)	.26 (.07)	.70 (20)	.22 (.09)

Note. Higher intensity ratings reflect greater perceived intensity, and valence ranged from 0 (negative) to 1 (positive).

3.4.4.1.3 Procedure

Reaction time task. Stimuli were presented electronically using E-Prime 3.0 Professional software (Psychology Software Tools, Pittsburgh, PA). The reaction time task began with a set of 12 practice trials to familiarize participants with the procedure. All trials began with the presentation of a fixation cross for 500 ms, followed immediately by the presentation of the target image. The target image remained on the screen until participants made a response. Half of the participants were instructed to press the 'left' key to identify happy expressions, and the ‘right’ key to identify sad expressions, with the buttons on the Chronos Response Box reversed for the remaining participants. Participants were shown each target image four times in the reaction time task. This phase of the experiment took approximately 10 minutes to complete.

Rating task. The rating task began with a series of six practice trials. All trials began with the presentation of a fixation cross for 500 ms, which was followed by the presentation of a target image for 3 seconds. Participants were instructed to rate the image they had just seen on two visual analogue scales. Participants were first asked “what was the intensity of the emotion depicted” and the scale ranged from 0 (*not at all*) to 1 (*extremely*). Next participants were asked “what was the valence of the emotion depicted” and the scale ranged from 0 (*negative*) to 1 (*positive*). There was no time limit on the rating component of the task. All images were rated twice. This phase of the experiment took approximately 20 minutes to complete. After the completion of both tasks’ participants were debriefed and thanked for their participation. The analyses, with the exception of the exploratory sex effects, were pre-registered prior to data collection (https://aspredicted.org/blind.php?x=cb79zz).

3.4.4.2 Results

Data were subjected to 2 (emotion: happy, sad) by 2 (tears: no tears, tears) by 2 (stimulus sex: female, male) repeated-measures ANOVAs. When follow-up post-hoc analyses were conducted, we applied a Bonferroni correction. Table 3.4 denotes the descriptive statistics for the reaction time and rating tasks, collapsed across stimulus sex. As in Experiment 1, participant gender was not found to influence reaction time, $F(1,43) = .456$, $p = .503$, $\eta_p^2 = .010$, or the intensity, $F(1,43) = 1.132$, $p = .293$, $\eta_p^2 = .026$; or valence, $F(1,43) = 2.396$, $p = .129$, $\eta_p^2 = .053$; rating data and, as such, it will not be considered further.

Table 3.4

Mean (SDs) for Each Emotion Condition for the Reaction Time and Rating Tasks in Experiment 2.

	Reaction Time Task		Rating Task	
	Accuracy (%)	Reaction Time (ms)	Intensity	Valence
Happy	96.03 (2.79)	737.43 (224.80)	.62 (.19)	.77 (.10)
Sad	96.97 (3.22)	750.76 (193.78)	.56 (.17)	.24 (.07)
Happy-tear	92.08 (7.52)	818.04 (313.86)	.66 (.16)	.72 (.14)
Sad-tear	97.56 (2.88)	758.90 (208.91)	.66 (.16)	.18 (.07)

Note. Intensity scores range from 0-1, higher scores = greater intensity. Valence scores range from 0-1 with scores closer to 0 reflecting negative valence, and scores closer to 1 indicating positive valence.

3.4.4.2.1 Reaction time task

Accuracy. The repeated-measures ANOVA revealed a significant main effect of emotion, $F(1,44) = 20.994$, $p < .001$, $\eta_p^2 = .323$, as participants were more accurate at classifying sad expressions ($M = 97.26$, $SE = .539$), compared to happy expressions ($M = 94.06$, $SE = .539$). There was also a significant main effect of tears, $F(1,44) = 10.734$, $p = .002$, $\eta_p^2 = .196$, where tear-free expressions ($M = 96.50$, $SE = .483$) were classified correctly more often than tearful expressions ($M = 94.82$, $SE = .483$). Additionally, there was a significant tears by emotion interaction, $F(1,44) = 12.228$, $p = .001$, $\eta_p^2 = .217$ (see Figure 3.3a). Happy faces were classified with significantly greater accuracy than happy-tear faces, $t(44)= 3.791$, $p < .001$, $d = .565$. There was no significant difference in classification accuracy for the sad and the sad-tear faces, $t(32)= -1.099$, $p = .278$, $d = -.164$.

Figure 3.3. Mean scores for each emotion condition for a) accuracy and b) reaction time. Error bars are SEM.

Reaction time. Errors (4.34% of responses) and outliers greater or less than 3 *SD* from the mean of each participant (1.68% of responses) were removed prior to analysis. The repeated-measures ANOVA revealed there was no significant main effect of emotion, $F(1,44) = 2.015$, $p = .163$, $\eta_p^2 = .044$, or stimulus sex, $F(1,44) = .310$, $p = .580$, $\eta_p^2 = .007$. However, there was a significant main effect of tears, $F(1,44) = 14.399$, $p < .001$, $\eta_p^2 = .247$, where tear-free expressions ($M = 744.08$ ms, $SE = 34.606$) were responded to faster than tear expressions ($M = 788.70$ ms, $SE = 34.606$). This main effect was qualified by a significant emotion by tears interaction, $F(1,44) = 22.389$, $p < .001$, $\eta_p^2 = .337$ (see Figure 3.3b). Follow-up analyses revealed that happy expressions without tears were responded to significantly faster than the same happy expression with tears, $t(44) = -4.538$, $p < .001$, $d = .676$. Conversely, there was no significant difference in reaction time between the sad, and sad-tear faces, $t(44) = -.915$, $p = .365$, $d = -.136$.

There was also a significant emotion by stimulus sex interaction, $F(1{,}44) = 5.786$, p = .020, $\eta_p^2 = .116$. Follow-up analyses were not significant; however, a trend towards significance revealed that female happy faces were responded to faster than male happy faces, t(44)= -1.928, p = .060, d = -.287; while sad male faces were responded to faster than sad female faces, t(44)= 1.914, p = .062, d = .285.

3.4.4.2.2 Rating task

Intensity ratings. The repeated-measures ANOVA for the intensity rating data revealed a significant main effect of tears, $F(1{,}44) = 56.760$, p < .001, $\eta_p^2 = .563$, where tearful expressions (M = .660, SE = .023) were perceived as significantly more intense than tear-free expressions (M = .586, SE = .023). There was also a significant interaction between tears and emotion, $F(1{,}44) = 17.185$, p < .001, $\eta_p^2 = .281$ (see Figure 3.4). Specifically, sad-tear faces were perceived as significantly more intense than sad faces, t(44)= 9.409, p < .001, d = 1.403 Similarly, happy-tear faces were perceived as significantly more intense than happy faces, t(44)= -3.048, p = .004, d = .454.

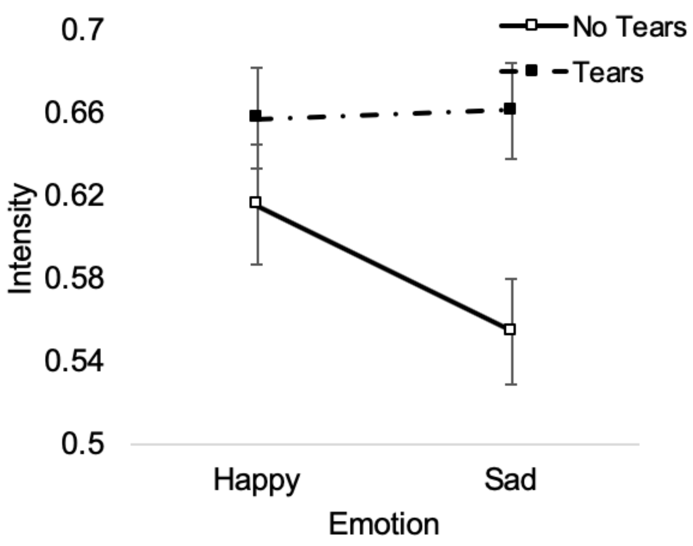

Figure 3.4. Interaction between tears and emotion for the intensity ratings. Error bars are SEM.

Additionally, there was a significant main effect of stimulus sex, $F(1,44) = 5.014$, $p = .030$, $\eta_p^2 = .102$; and significant stimulus sex by tears, $F(1,44) = 7.759$, $p = .008$, $\eta_p^2 = .150$; and stimulus sex by emotion interactions, $F(1,44) = 24.953$, $p < .001$, $\eta_p^2 = .362$. The main effect revealed that male faces ($M = .629$, $SE = .023$) were perceived as more intense than female faces ($M = .617$, $SE = .023$). The stimulus sex by emotion interaction stemmed from an increased intensity attributed to male happy expressions, relative female happy expressions $t(44)= 6.781$, $p < .001$, $d = 1.011$ (see Figure 3.5a). Similarly, the stimulus sex by tear interaction was the result of the main effect of tears, wherein there was a significant difference between tear and tear-free expressions for the female faces, $t(44)= 7.789$, $p < .001$, $d = 1.161$; and the male faces $t(44)= 6.272$, $p < .001$, $d = .935$ (see Figure 3.5b). In the tear-free condition, male faces were perceived as more intense than female faces, $t(44)= 2.953$, $p = .005$, $d = .440$; however, this effect was not present for the tearful expressions, $t(44)= .374$, $p = .710$, $d = .056$.

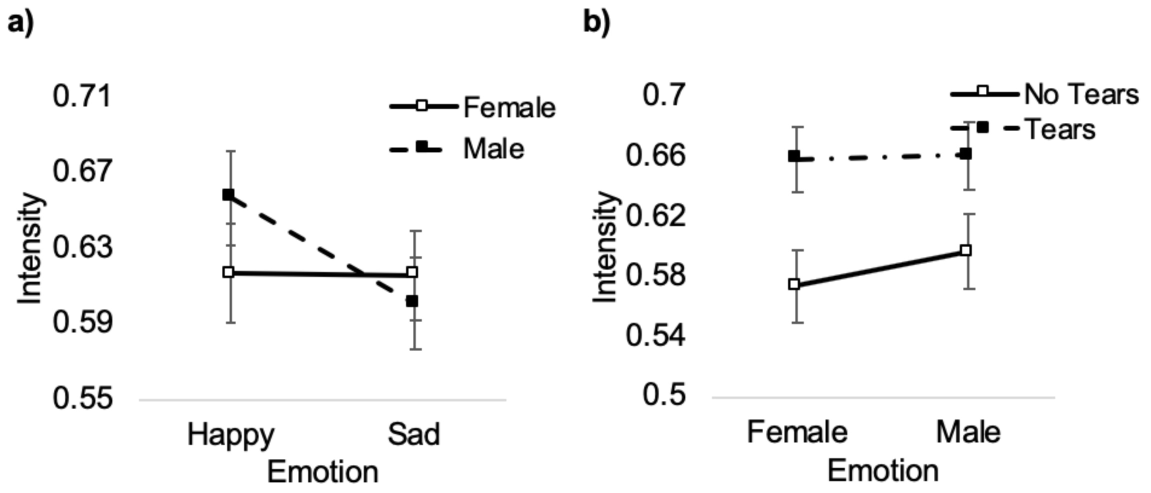

Figure 3.5. a) Interaction between emotion and stimulus sex; and b) interaction between tears and stimulus sex for the intensity ratings. Error bars are SEM.

Valence ratings. The repeated-measures ANOVA for the valence rating data revealed a significant main effect of emotion, $F(1,44) = 685.758, p < .001, \eta_p^2 = .940$, where happy expressions ($M = .745, SE = .013$) were attributed greater emotional valence than sad expressions ($M = .212, SE = .013$). However, this result is not overly interesting given the bipolar nature of the valence dimension. There was also a significant main effect of tears, $F(1,44) = 39.366, p < .001, \eta_p^2 = .472$, where tearful expressions ($M = .450, SE = .009$) increased the perception of negative valence relative to tear-free expressions ($M = .507, SE = .009$). In addition, there was a main effect of stimulus sex, $F(1,44) = 8.045$ $p = .007, \eta_p^2 = .155$, where male faces ($M = .484, SE = .009$) were attributed greater valence than female faces ($M = .474, SE = .009$). There were no significant interaction effects for the valence rating scores, F's < 4.024, p's > .051.

3.4.4.3 Discussion

Our main objective was to replicate the tear effect from Experiment 1 using a larger sample of stimulus faces, and to examine how tears modulate perceptions of intensity and valence on happy and sad faces. Our results demonstrate that tears increase the time taken to classify a face as happy and reduce classification accuracy, whereas reaction time responses to sad faces are largely not influenced by the presence of tears. Furthermore, these results support the idea that tears serve as a marker of sadness (Provine et al., 2009), as the presence of incongruent facial features, such as tears and a smile, increase reaction times to happy-tear faces. Conversely, our rating data demonstrate support for both the tear effect, and the general enhancement hypotheses.

Interestingly, while classification accuracy and reaction time to sad faces are not influenced by the presence of tears, intensity and valence ratings are. In addition to tears serving as a marker of sadness, tears increase the perceived intensity of happy and sad expressions. Furthermore, the presence of tears on facial displays decreased valence ratings (i.e. made ratings more negative). Thus, while tears make all faces seem more intense, their presence on a face makes a positive expression less positive, and a negative expression more negative.

Finally, the exploratory sex of stimulus analyses revealed that sex of stimulus largely did not change the way that participants responded to emotional tears. Moreover, the only significant stimulus sex by tear interaction was driven by the main effect of tears, wherein tearful expressions were perceived as more intense than tear-free expressions for male and female faces. Therefore, when examining reaction time, generalised intensity, and valence ratings, stimulus sex largely does not change the way that participants respond to tearful facial displays.

3.4.5 General Discussion

These studies demonstrate the most support for the tear effect, wherein tears—in the absence of context—symbolise sadness. In Experiment 1, tearful expressions impaired recognition of happy faces, and enhanced recognition of neutral faces, but made no difference to sad expressions. In Experiment 2, the presence of tears on a happy face once again impaired recognition, and there were no differences in recognition between sad and sad-tear expressions. Similarly, in ratings of valence, the addition of tears to a happy face made happy faces seem less positive, and negative faces seem more negative. However, when examining the intensity rating data, we demonstrated support for the general enhancement perspective, wherein all tearful expressions were perceived as more intense than their tear-free counterparts.

In Experiment 1, we demonstrated that the presence of tears resolved the emotional ambiguity of neutral faces, where neutral faces were more likely to be classified as sad when they featured tears. This is in accord with research by Küster (2018) who demonstrated that tears make a neutral expression more readily recognisable as sad. However, we further identified that tears did not significantly improve reaction time to neutral expressions. This contradicts prior studies who have demonstrated that the tear effect is most pronounced for neutral displays (Provine et al., 2009; Reed et al., 2019). However, in those studies, participants were instructed to rate the sadness of the tearful displays. Thus, tears may increase the perception of sadness, however this perception does not improve the time taken to classify a neutral face as sad.

Furthermore, tearful sad expressions were not responded to significantly faster or more accurately than sad faces without tears. This finding directly contrasts Balsters et al. (2013), who reported that sad-tear faces were responded to significantly faster than sad faces without tears. However, Balsters et al. (2013) presented their stimuli briefly (i.e., 50 ms). Thus, it seems that the tear effect is more pronounced for sad faces when presentation durations are shorter. In our experiments, the sad facial expressions both with and without tears were responded to rapidly and accurately, indicating that participants did not require the presence of tears to identify a face as sad. This could indicate the occurrence of a ceiling effect, where the sad faces we used were already clearly recognisable as sad (Calvo et al., 2016), thus we were unable to see an improvement in the classification of the sad-tear faces. The potential for a ceiling effect for sad and sad-tearful displays is in accord with existing research investigating blended facial displays. Calvo, Gutiérrez-García, and Del Líbano (2018) demonstrated that distinctiveness is an important factor when distinguishing truly happy smiles from blended displays. Moreover, the more distinctive the eye region (i.e., angry eyes with smiling mouth), the less likely the display would be judged as happy. However, for truly happy faces (i.e. happy eyes and smiling mouth) the distinctiveness of the mouth region meant that the eye region offered no further improvement to recognition accuracy. Although we used a different paradigm than Calvo et al. (2018), given the high classification accuracy for sad and sad-tear images in our experiments, it seems that the presence of tears offered no further improvement for classification accuracy in a dichotomous response task. Thus, it is possible that the tear effect would be more pronounced for sad faces when using a multiple response category paradigm.

Previous research into the tear effect and the general enhancement perspective has favoured comparison of tearful facial expressions with other negative emotions (Ito et al., 2019), while the influence of tears on happy displays has been largely neglected (Reed et al., 2015). In the present study, we sought to extend the understanding of how tearful happy expressions are perceived. Our results support prior work indicating that tears on happy faces enhance the perception of sadness (Reed et al., 2015). These findings are consistent with the idea that incongruous facial features result in slower reaction times for happy facial displays (Calvo et al., 2012). This result further indicates that tears are a distinctive marker of sadness, and that recognising “tears of joy” likely stems from contextual information. This interpretation is consistent with the dimorphous expression literature, in that when tearful facial expressions are paired with positive scenarios they are perceived as positive emotions

(Aragón, 2017; Aragón & Bargh, 2018; Aragón & Clark, 2018). Thus, tears when paired with a happy expression in the absence of context impair one's ability to classify a face as happy.

The rating data further supports the conclusions drawn from the reaction time results. Surprisingly, we demonstrated support for both the tear effect and the general enhancement perspective. Moreover, the presence of tears on both happy and sad faces resulted in greater perceived intensity. This result supports the general enhancement perspective posed by Ito et al. (2019), who demonstrated that tears made negative expressions more intensely sad, and Reed et al. (2015) who demonstrated that Duchenne smiles were perceived as more intense when they featured tears. Wells et al. (2016) showed that less intense (and as such more ambiguous) facial displays resulted in longer reaction times. However, in our studies, responses were slowest for happy-tear expressions despite these faces being intense. This contradictory finding is clearer when considering the valence rating data. The presence of tears on sad expressions increased perceived negative valence and decreased perceived positive valence for happy expressions. Thus, tears make expressions seem more negative. This reduced positive valence could arguably make a typically distinctive happy face more ambiguous. The increased ambiguity associated with happy-tear faces is a contributor to the slower reaction time. As such, we provide further support for Wells et al. (2016); however, conclude that valence is a larger contributor to reaction time than intensity, at least when considering tearful displays.

Finally, we conducted exploratory analyses examining whether sex of the stimulus influenced the way that persons respond to tears. Across the two experiments, we largely demonstrated that sex of stimulus did not change participants responses to tearful displays. This null result contradicts other studies which have demonstrated that females receive more favourable responses than males (Cretser et al., 1982; Fischer et al., 2013; Stadel et al., 2019). However, the discrepancy in findings could be attributed to two factors. Firstly, Cretser et al.

(1982) and Stadel et al. (2019) demonstrated their effects when exploring the relationship between sex of stimulus and gender of participant. Moreover, male participants were more likely to hold a 'double standard' where male-male dyads are responded to less favourably. We did not observe participant gender effects in our study, which could have contributed to our differential results. Secondly, in the prior research crier perception was typically explored via ratings of 'need for support', emotionality, competence, and appropriateness. Thus, it may be that these factors are more influenced by the sex of the stimulus than generalised intensity and valence ratings and reaction time measures are. These exploratory sex effects were not the primary interest of the paper, and we acknowledge that studying sex differences is a difficult undertaking. Further research could repeat our experiments over a series of studies with a balanced sample of male and female participants to elucidate whether the effects reported in prior literature extend to generalised rating and reaction time measures.

A few limitations should be considered when interpreting our results. Firstly, in our study we were expressly interested in exploring whether tears on happy and sad facial expressions demonstrated support for the tear effect, or the general enhancement perspective. This approach resulted in an overarching focus on the perception of sadness—despite our efforts to use unbiased response metrics. However, tears do not only signal sadness to observers, as other studies have identified that tears signal powerlessness, appeasement, and the need for social support (Hendriks et al., 2008; Miceli & Castelfranchi, 2003). Therefore, further studies could extend the studies reported herein to explore whether the perception of tearful displays mediates the responses to crying persons. Furthermore, we used posed standardised facial displays and digitally added tears. This approach allowed for rigorous control over the experimental stimuli and the subsequent ability to draw conclusions about the influence of tears. However, tears are touted as an honest expression of emotion and associated with sincerity (Picó et al., 2020; Vingerhoets, 2013; Zeifman & Brown, 2011).

Thus, it is yet to be determined whether the use of posed artificial tears influences participant responses (Krivan & Thomas, 2020). Further research could use authentic tearful stimuli, with increased ecological validity, to further explore responses to crying faces.

Our experiments showed that, in the absence of context, tears are a reliable marker of sadness. Specifically, this marker of sadness is most pronounced for facial displays that are not already being interpreted as a sad expression (i.e. happy and neutral displays). The pairing of a distinctive marker of sadness (i.e. tears), with a distinctive marker of joy (i.e. smiles) results in reduced classification accuracy and slower reaction time to happy expressions. Furthermore, while the addition of tears makes both positive and negative emotions more negatively valenced, tears make both facial expressions seem more intense. Thus, tearful displays are associated with being a marker of negative emotion while eliciting greater intensity ratings from observers. Overall, our results demonstrate support for both the general enhancement perspective and the tear effect whereby tears intensify expressions and in the absence of context, signal sadness.

Chapter 4: Unconscious Mimicry of Tearful Expressions

4.1 Chapter Overview

Chapter 3 demonstrated that tears serve as a signal of sadness in the absence of context. These experiments were a necessary step to determine how tears influenced happy and sad tearful displays in the absence of context. In the present chapter, I will expand this behavioural research into the psychophysiological domain, to explore whether the presence of tears on facial displays modulates mimicry responses. As facial mimicry is related to empathy and the sharing of affective states, I believed that tears should increase the amount of mimicry exhibited in response to a face. In Chapter 3, it was concluded that stimulus sex did not change responses that participants had to tearful displays. In light of this evidence, I have not explored any stimulus-related sex effects in the following data chapters. I believe this approach is well justified given the scarcity of research exploring physiological responses to tears; and the problems with multiple comparisons in psychophysiological research (Luck, 2014). However, I acknowledge, that the potential for sex differences cannot be ruled out completely, and as such where appropriate I have provided considered recommendations for further research.

4.2 Publication Status

Manuscript in preparation for submission.

4.3 Author Contributions

Krivan – designed the experiment, created the experimental paradigm, collected the data, processed the psychophysiological data, conducted the statistical analyses, and drafted the manuscript.

Cottrell – aided in designing the experiment and provided supervision.

Thomas – aided in revision of drafts and provided supervision.

4.4 Manuscript

4.4.1 Abstract

Facial mimicry, or the unconscious matching of another's expression, is said to facilitate social communication and increase liking and affiliation. A wealth of research has demonstrated that happy expressions, and to a lesser extent sad expressions, are mimicked with a congruent facial display. However, tearful displays have not received this same attention. Emotional tears elicit increased support and empathy from observers in self report studies. Given that mimicry falls under the umbrella of empathy, investigating mimicry responses to tearful displays provides the ability to explore empathic responses to tears that occur outside conscious awareness. It was predicted that tearful displays would elicit increased mimicry relative to tear-free displays. Two experimental tasks were conducted, one where tearful and tear-free stimuli were presented subliminally using forwards and backwards masking, and the second where the stimuli were presented to conscious awareness for an extended period. The study failed to demonstrate support for the hypothesis that mimicry is increased in response to tearful displays. Rather, a trend towards decreased mimicry in the masked trials was demonstrated, which was not present during the supraliminal trials. Therefore, persons, for the most part, do not mimic tearful displays. We conclude with a discussion about why it may not be adaptive to mimic tearful displays.

Keywords: facial mimicry, emotional tears, adult crying, EMG

4.4.2 Introduction

When viewing another's facial expressions of emotion, people unconsciously match, or imitate the sender's expression. Known as facial mimicry, this matching is typically an automatic, rapid facial reaction, which is difficult to suppress (Dimberg et al., 2000; Dimberg et al., 2002). A specific type of facial mimicry, termed emotional mimicry, occurs when someone mimics the emotional expression of another as a means of sharing the emotion with the other person (Hess & Fischer, 2014). As emotions convey our feelings and intentions (Hess et al., 1999), reciprocating these emotional signals aids in communicating to the sender that their emotions have been understood. As such, mimicry has been said to foster affiliative behaviours (Hess & Fischer, 2013) and increase liking amongst conversational partners (Hess et al., 1999; Van Der Schalk et al., 2011).

There are two competing theories to explain how mimicry occurs. The first suggests mimicry is an automatic and reflexive pure motor copy, and the second argues for an affiliative account wherein mimicry is influenced by situational context. The idea of automatic mimicry as a pure motor copy stems from a perception-behaviour model (Chartrand & Bargh, 1999). Dubbed the 'chameleon effect' or the 'matched motor hypothesis', simply witnessing another's expression is enough to result in the automatic, passive process whereby the same expression is performed by oneself (Chartrand & Bargh, 1999; Hess & Fischer, 2014). Thus, motor-matching follows the same concept of mirror neurons, where the same neurons are activated during the observation and execution of an action, and the perception-behaviour link occurs as a learned process without awareness or intention (Hess & Fischer, 2014; Iacoboni, 2005). To this end, facial mimicry through the lens of motor-matching is a spontaneous, direct imitation of the emotional display (Hess & Fischer, 2014), regardless of the type of emotion, or the familiarity of the sender (Chartrand et al., 2005).

By contrast, the affective account argues the exact opposite—that mimicry is more than pure motor copy. Moreover, whether mimicry occurs, and the magnitude of the mimicry response is dependent on a variety of factors pertaining to the appropriateness of the response in social scenarios (Kirkham, Hayes, Pawling, & Tipper, 2015). Mimicry is influenced by the relationship between the two individuals (Häfner & IJzerman, 2011), and enhanced when the exchange is positive or communal (Likowski, Mühlberger, Seibt, Pauli, & Weyers, 2008).

Furthermore, mimicry is dependent on the type of emotion displayed (Bourgeois & Hess, 2008), and the context in which it is encountered (Seibt et al., 2013). Finally, mimicry is also influenced by individual differences, such as empathy (Sonnby-Borgstrom, 2002) and the mood state of the person reciprocating the display (Moody, McIntosh, Mann, & Weisser, 2007). Although the two accounts are inconsistent in relation to the process by which mimicry occurs, there is consensus that mimicry fosters affiliation and social cohesion (Hess & Fischer, 2014; Hess et al., 1999), serving as a kind of 'social glue' (Lakin et al., 2003).

Where mimicry is facilitated by affiliation, mimicry increases empathy amongst conversational partners and is a means of sharing another's perspective (Hess & Fischer, 2013; Seibt et al., 2013). Typically, mimicry has been investigated by examining congruent facial reactions to happy and sad displays (Hess & Fischer, 2013). For example, a congruent response to a happy face would be activation of the *Zygomaticus Major* (ZMaj)—the muscle responsible for drawing the muscle upwards into a smile (Duchenne 1862/1990). By contrast, a congruent response to a sad expression is characterized by activation of the *Corrugator Supercilii* (CS)—the muscle responsible for drawing the brows together (Dimberg, 1982). As such, exhibiting a congruent response to a conversational partner is a means of communicating empathy and understanding (Häfner & IJzerman, 2011). A series of studies have demonstrated that happy and sad stimuli presented in an affiliative (or even neutral) context are mimicked more than the same stimuli in a negative context (Likowski et al., 2008; Likowski, Mühlberger, Seibt, Pauli, & Weyers, 2011). Similarly, mimicry is congruent and facilitated amongst communal exchange partners (Häfner & IJzerman, 2011) and in-group members (Bourgeois & Hess, 2008). Evidently, mimicking affiliative emotions has an increased evolutionary value in increasing social coordination (Lakin et al., 2003). However, not all emotions are affiliative (Bourgeois & Hess, 2008; Seibt et al., 2013), and as such the way that we respond to these displays of emotion is reactive (Hess & Fischer, 2013).

A reactive emotional response can be congruent, such as frowning at a negative stimulus (Hess & Fischer, 2014) or incongruent, such as smiling at the disappointment of another (Seibt et al., 2013). The former is a simple reactive response, where one frowns at a picture of a negative stimulus (e.g., angry face, a snake; Seibt et al., 2013). The latter, known as counter-mimicry, is typically elicited in competitive relationships, whereby smiling in response to a competitor's disappointment can be a marker of schadenfreude—pleasure derived from another's misfortune (Likowski et al., 2008). Further evidence for reactive responses is demonstrated when mimicry does not occur. Due to the signal value, some emotions are not mimicked when the context is known (Bourgeois & Hess, 2008; Hinsz & Tomhave, 1991). For example, anger displays are not affiliative (Knutson, 1996), and if mimicked, they are likely to result in escalated conflict. As such, non-affiliative displays are not mimicked or they elicit incongruent muscle responses (Likowski et al., 2011).

The research exploring mimicry responses to sad facial displays has yielded inconsistent results. Some studies have demonstrated that there is increased CS activity in response to a sad faces—in line with a reactive response (Harrison, Morgan, & Critchley, 2010; Hess & Blairy, 2001; Lundqvist & Dimberg, 1995). However, other studies have emphasised that sadness displays are more likely to be mimicked if expressed by a close partner, or in-group members—in accord with the affiliative account (Bourgeois & Hess, 2008; Häfner & IJzerman, 2011). This mediation of mimicry in response to sad displays likely stems from the signal value of sad faces and the social cost associated with comforting a sad person (Bavelas et al., 1986; Bourgeois & Hess, 2008). Evidence for this conclusion stems from research wherein mimicry is reduced when the social cost to the observer is high (Johnston, 2002). Under this perspective, mimicry of strangers would not be adaptive given the increased social cost, whereas mimicry of personally relevant individuals could be means of strengthening social bonds.

In addition to the mixed conclusions demonstrated in sadness mimicry research, there are also some methodological limitations. Moreover, most studies have used the CS to index sadness mimicry, despite Duchenne (1862/ 1990), the forefather of facial muscle research, identifying the *Depressor Angulis Oris* muscle (i.e., the muscle responsible for drawing the lips downward) with the expression of sadness. A potential limitation associated with using the CS to index both sadness and anger, is that anger expressions are characterised by the brows being lowered, whereas in sadness displays the brows are lowered while the inner brow is raised (Critchley et al., 2005; Ekman & Friesen, 1978; Ekman & Rosenberg, 2005). As both of these actions activate the CS (Nicanor & Mohammed, 2001), it is difficult to determine whether participants are mimicking the display or frowning at the stimulus. Soussignan et al. (2013) addressed this limitation by indexing sadness mimicry using the depressor and demonstrated significantly enhanced depressor activity during the viewing of sad displays. Therefore, sadness mimicry, as indexed by a muscle uniquely associated with sadness, occurs in the both in the absence of context and with unfamiliar individuals.

To date, most research investigating mimicry of sadness has focused on sad expressions without tears. Tears, a highly distinctive and uniquely human phenomenon, reliably elicit help and support from observers (Balsters et al., 2013; Hendriks, Croon, & Vingerhoets, 2008). Furthermore, tears are thought to be affiliative in that they promote social bonding (Vingerhoets et al., 2016), serve to reduce aggression from observers (Hasson, 2009), and foster approach behaviours relative to avoidance (Gračanin et al., 2018). However, most of this research has been self-report, which requires honest responses. This reliance on honesty is an important limitation to the pro-social responses elicited in tear research; as it is socially desirable to help others, respondents might seek to conform with perceived social norms (Mauss & Robinson, 2009), leading to demand characteristics. As facial mimicry is associated with empathy, investigating mimicry responses to tearful displays would allow for psychophysiological validation of existing self-report research.

A recent study by Grainger et al. (2019) failed to find any differences in EMG activity between sad faces with tears and sad faces without tears. As such, the authors concluded that their results offered support for the motor copy hypothesis, in that tearful displays are not distinct from tear-free sadness, and as such do not elicit increased empathy as evidenced by mimicry. However, their experiment can be extended in two ways. Firstly, although tearful displays are associated with the expression of sadness, tears are also elicited in response to joy and frustration (Miceli & Castelfranchi, 2003). For most negative scenarios that elicit tears, there is a corresponding positive scenario (e.g., separation and reunion) (Vingerhoets & Bylsma, 2015). Therefore, perhaps the type of crying expressed by an individual modulates mimicry. Secondly, Grainger et al. (2019) used the CS to index sadness mimicry. However, Duchenne (1862/1990) associated the *Zygomaticus Minor* (ZMin) with weeping. Therefore, mimicry of tearful displays might only be indexed by the muscle associated with the expression—the ZMin. As such, the present study will address these limitations by indexing mimicry using the CS in accord with existing research (Bourgeois & Hess, 2008; Grainger et al., 2019; Häfner & IJzerman, 2011) and using the ZMin as a specific index of weeping mimicry. Secondly, the present study included tearful displays associated with joy and frustration by adding tears to angry and happy expressions.

The present study aimed to investigate whether tears modulate mimicry responses. Tearful expressions were presented both supraliminally (i.e., to conscious awareness) and subliminally using forward and backward masking. In accord with tears being a salient distress signal, it was predicted tears would be attended without conscious awareness, wherein masked tearful displays would elicit larger mimicry responses than tear-free displays. Additionally, as tearful expressions are typically associated with pro-social responses and empathy, it was predicted that supraliminal tearful emotional expressions would elicit significantly greater mimicry than the same images without tears—regardless of the type of tearing display (i.e. happy-tears, sad-tears, or angry-tears).

4.4.3 Method

4.4.3.1 Participants

The total sample consisted of 35 undergraduate students (23 females, M_{age} = 26.1, SD_{age} = 10.5 years). All participants reported having normal or corrected-to-normal vision. Participants self-reported being right-handed, and participants with facial hair were prohibited from participation. Ethical approval was obtained from the James Cook University Human Research Ethics committee, and participants gave written informed consent in accord with the Declaration of Helsinki.

4.4.3.2 Stimuli

Stimuli were happy, angry, sad, and neutral faces from the Karolinska Directed Emotional Faces database (KDEF; Lundqvist et al., 1998). Each face was cropped using an ellipsis tool to remove hair, clothing, and ears to ensure the face only contained the elements necessary for determining emotional expressions. Tears were digitally added to the images (running from the eyes down the cheeks) to each of the faces using online photo editor software (http://funny.pho.to/tears-effect/).

The stimuli were selected from a larger pool of images, which were pilot tested using an independent group of 22 participants (20 females, *Mage* = 24.6, *SDage* = 9.5 years). Pilot participants rated the images using visual analogue scales on emotional expression intensity, and valence of expression. For the emotional intensity images, the scales ranged from 0 (not at all) to 1 (extremely) for happy, sad, and angry expressions. The valence scale ranged from 0 (negative) to 1 (positive). The five best matched male and female faces across stimulus categories were selected for the main study (see Table 4.1 for a summary of the pilot results).

Therefore, 10 unique facial identities were used, and each display included a tear and a tear-free version, resulting in a total of 80 stimuli.

Table 4.1

Mean (SDs) Pilot Intensity and Valence Ratings for the 10 Facial Identities

	Intensity		Valence	
	Female	Male	Female	Male
No Tears				
Happy	.89 (10)	.92 (.08)	.89 (.13)	.89 (.11)
Sad	.79 (.14)	.79 (.15)	.17 (.13)	.16 (.13)
Angry	.84 (.12)	.85 (.13)	.10 (.11)	.09 (.10)
Neutral	-	-	.37 (.16)	.43 (.08)
Tears				
Happy	.82 (.10)	.87 (.11)	.78 (.18)	.80 (.19)
Sad	.86 (.12)	.86 (.13)	.13 (.13)	.16 (.15)
Angry	.84 (.13)	.84 (.16)	.09 (.10)	.08 (.09)
Neutral	-	-	.20 (.13)	.23 (.13)

Note. Intensity ratings reflect emotion specific intensity (i.e. how happy is this face?), and valence ranged from 0 (negative) to 1 (positive). There were no intensity ratings for neutral expressions.

4.4.3.3 Procedure

The experiment was conducted in a sound attenuated electromagnetically shielded room on a 23.5-inch monitor with a 120 Hz refresh rate, using a NVIDIA GeForce 970 graphics card. PsychoPy software (version 1.84.2) was used to present the stimuli. All facial images were presented in full colour against a black background. The experiment began with the placement of the EMG electrodes, and participants were seated in a chair approximately 60 cm from the monitor. The experiment began with 16 practice trials to allow time for the EMG electrodes to stabilise and to familiarise the participant with visual analogue rating scales, which asked: 1) how happy is this face? 2) how sad is this face? and 3) how angry is this face? All visual analogue scales included the same scale range and anchors as described in the pilot study. The experiment was conducted in two phases: Phase 1 involved masked face priming, and Phase 2 involved supraliminal emotional faces followed by emotional neutral faces. Participants always completed the tasks in this order to avoid viewing the emotional faces prior to the masked paradigm.

4.4.3.3.1 Phase 1: Masked trials

Each trial followed the same experimental sequence. The trial structure can be seen in Figure 4.1, where each trial began with the presentation of a fixation cross. Following the fixation cross, a forward mask of a scrambled face was presented for 500 ms. This face was followed by presentation of the target emotional face stimuli for 30 ms. The use of 30 ms as a threshold was chosen as it has been used successfully in other masked priming studies. The target face was immediately replaced with a backwards mask of the same individual depicting a neutral expression for 5000 ms. During the presentation of the neutral expression, participants completed a gender judgement task (i.e. was the face male or female) to ensure participants maintained attention during the trials. Finally, trials were concluded with an inter-stimulus interval that varied between 5 and 11 seconds to ensure participants were not primed to expect a trial, and to also give the electrodes time to stabilize after each motor response.

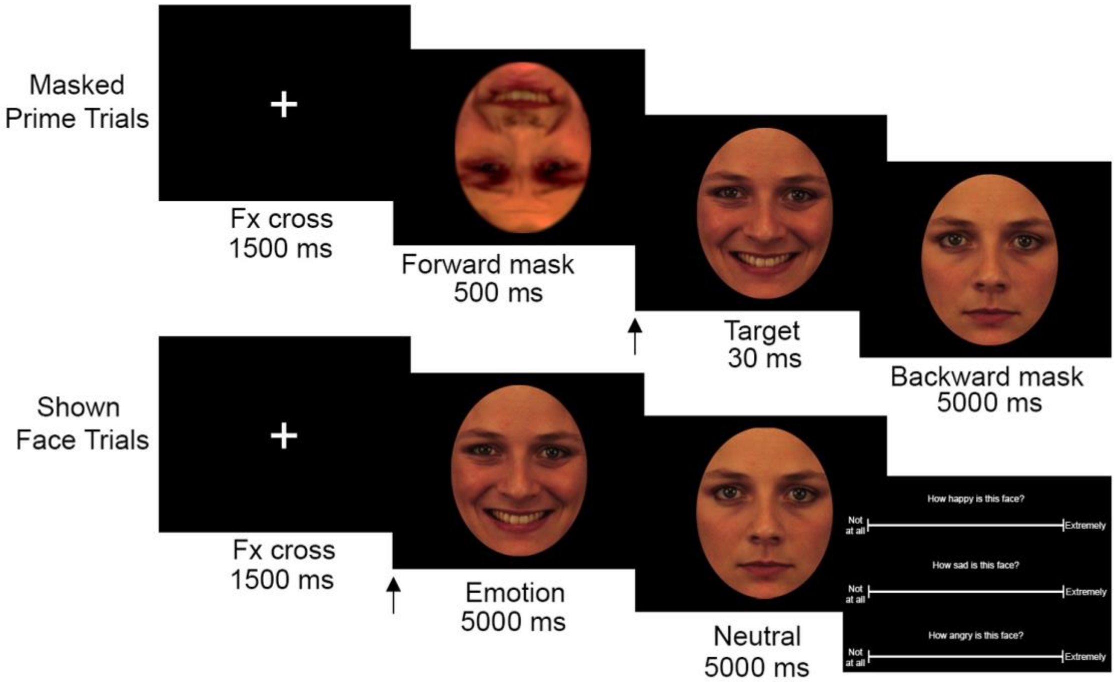

Figure 4.1. Example trial structure for the masked prime and supraliminal face trials. Arrows denote onset of the target stimulus for each trial. KDEF stimulus is AF01.

4.4.3.3.2 Phase 2: Shown face trials

As in Phase 1, each trial began with the presentation of a fixation cross. Next, an emotional face was presented for 5000 ms, followed by a neutral face of the same identity for 5000 ms. The activity of interest during this task was the EMG response to the emotional face presentation (as denoted by the arrows in Figure 4.1). Participants were instructed to rate the neutral expressions using the three emotional visual analogue scales described earlier. This technique ensured that participants were attending to the task, but minimised attention on the emotional expression. On trials where the emotional expression was a neutral face or a neutral face with tears, the second neutral face was of a different identity so as not to emphasise the addition of the tears. Participants completed the visual analogue scales at their own pace and were unable to move to the next trial without completing each of the scales.

Lastly, participants completed an unrelated five-minute reaction time task where they made rapid responses to each facial expression (see Chapter 3 for the results of this experiment). After completion of the experiment, participants were debriefed and questioned about the purpose of the study to determine whether the target emotional stimulus was perceived in Phase 1 (masked priming task). None of the participants reported seeing any target stimuli during the masked priming task.

4.4.3.4 EMG recording and analysis

EMG was recorded using a Biosemi Active-Two amplifier system, using six active electrodes corresponding to three bipolar montages. Prior to electrode placement, the participant's skin was prepared using an alcohol wipe, and was lightly abraded using electrode paste. The electrodes were affixed (using disposable electrode collars) to the left side of the participant's face, over the CS, ZMaj, and ZMin muscle regions. Two additional electrodes, the common mode sense (CMS) and driven right leg (DRL), were used as reference and ground electrodes, respectively, which is in accord with the Biosemi electrode placement manual (https://www.biosemi.com). The EMG signal was continuously recorded at 2048 Hz, with a 0.1-417 Hz band pass filter. All pre-processing steps were performed using BrainVision Analyzer 2.0 software (Brain Products, Munich, Germany). EMG data was band-pass filtered (20-500 Hz, 12 dB/oct) with a 50 Hz notch filter to correct for powerline noise. These selected recording and filtering techniques are in accord with the published guidelines for EMG research (Luca, 1997; van Boxtel, 2001).

Continuous EMG was then segmented in epochs from -2000 to 2000 ms after stimulus onset for each emotional expression. Epochs were subjected to a rectified moving average with a 125 ms time constant. Epochs of interest were the 2000 ms after stimulus onset.

For the masked prime trials (Phase 1), this 2000 ms epoch was baseline corrected using the final 500 ms of the fixation cross presentation[2]. To ensure participants were not moving during the presentation of the forward mask (which could confound activity during the presentation of the target stimulus), these trials were scanned for artifacts and trials with amplitudes ±10 µV were removed. The baseline corrected epochs were scanned for artifacts and trials with amplitudes ±30 µV were removed. This amplitude cut off was chosen in accord with published research that details that EMG activation beyond 30 µV is associated with overt motor movement (Korb, Grandjean, & Scherer, 2010).

For the supraliminal face trials (Phase 2), the epoch of interest (2000 ms following stimulus onset) was baseline corrected using the final 500 ms of the fixation cross presentation. The same artifact rejection criteria used for the epochs of interest in Phase 1 were applied here. At least 70% of the data was required for participants to be included in the analysis (N = 34). All trials from the same condition were averaged. Data was exported separately for the masked and supraliminal face trials for the 2000 ms time period following stimulus onset for each of the emotion categories.

4.4.3.5 Data analysis

Data exclusions. To ensure participants maintained attention during the masked prime task, participants were asked to identify the gender of the neutral backwards-mask face. Three participants were excluded as they failed to follow experimental procedure during the task, and a further two participants were removed due to excessive error rates (< 70% accuracy). The remaining 30 participants responded with high classification accuracy (M = 77.7%, SD = 3.34). One additional participant was excluded due to having excessive artifacts in the EMG data (failure to retain 70% of trials). Participants who did not meet retention criteria for the behavioural data were excluded from the psychophysiological masked trial

[2]This equated to the time period from -1000 ms to -500 ms prior to stimulus onset.

data analysis. As participants could not complete Phase 2 without completing the rating scales, all participants (except for one participant with excessive EMG artifacts) were retained for the emotional supraliminal face analysis (*N* = 34).

Data analyses. A series of repeated-measures ANOVAs were conducted to explore each hypothesis of interest. First, the data during the masked prime trials (Phase 1) was explored to examine whether different emotions elicited significant corresponding muscle activity at the pre-attentive level. Second, the degree of mimicry elicited in response to the supraliminal face stimuli was examined. Separate analyses were conducted for each muscle group of interest; for the zygomaticus muscles, 2 (muscle: ZMaj, ZMin) by 4 (emotion: happy, sad, angry, neutral) by 2 (tears: no tears, tears) repeated-measures ANOVAs were conducted. For the CS, 4 (emotion: happy, sad, angry, neutral) by 2 (tears: no tears, tears) repeated-measures ANOVAs were conducted. All violations of sphericity were corrected using Greenhouse-Geisser corrections. All analyses used a set alpha level of .05, however all follow-up comparisons were Bonferroni-corrected.

4.4.4 Results

4.4.4.1 Physiological responses to masked primes

4.4.4.1.1 ZMaj and ZMin

A 2 x 4 x 2 repeated-measures ANOVA was conducted to investigate whether prime emotions elicited corresponding muscle activity at the pre-attentive level. The main effect of muscle approached significance as the ZMaj muscle (*M* = -.104, *SE* = .032) was more relaxed than the ZMin muscle (*M* = -.072, *SE* = .032), $F(1, 28) = 3.100$, $p = .089$, $\eta_p^2 = .100$. No other main effects or interactions were significant, all *F*'s < 1.339, *p*'s > .270. The data for the mimicry responses to masked primes is demonstrated in Table 4.2.

Table 4.2

Mean (SDs) Mimicry Responses for the Masked Trials by Emotion and Muscle.

		Happy	Angry	Sad	Neutral
Corrugator (CS)	No Tear	.162 (.490)	.169 (.589)	.188 (.394)	.140 (.460)
	Tear	.134 (.417)	.139 (.474)	.071 (.546)	.022 (.362)
Zygomaticus Major (ZMaj)	No Tear	-.064 (.315)	-.040 (.418)	-.132 (.395)	-.157 (.338)
	Tear	-.093 (.367)	-.112 (.333)	-.048 (.228)	-.186 (.455)
Zygomaticus Minor (ZMin)	No Tear	-.038 (.320)	-.028 (.325)	-.093 (.354)	-.129 (.236)
	Tear	-.090 (.335)	-.017 (.309)	-.005 (.294)	-.178 (.452)

4.4.4.1.2 CS

A 4 x 2 repeated-measures ANOVA was conducted to examine the influence of prime emotion at the pre-attentive level. While no main effects or interactions were significant, the main effect of tears approached significance, $F(1, 28) = 3.211$, $p = .084$, $\eta_p^2 = .103$; tearful expressions ($M = .092$, $SE = .071$) elicited less mimicry than tear-free expressions ($M = .165$, $SE = .071$).

4.4.4.2 Physiological responses to supraliminal faces

4.4.4.2.1 ZMaj and ZMin

The supraliminal face mimicry at the zygomaticus muscles exhibited a similar pattern of response as the masked prime analyses wherein no main effects or interactions were significant, all *F*'s < 1.288, *p*'s > .265. The data for the mimicry elicited by each muscle for each emotion during the supraliminal face trials is presented in Table 4.3.

Table 4.3

Mean (SD) Mimicry Responses by Muscle and Emotion for the Supraliminal Trials.

		Happy	**Angry**	**Sad**	**Neutral**
Corrugator (CS)	No Tear	-.112 (.673)	.232 (.561)	.265 (.612)	.124 (.574)
	Tear	-.177 (1.07)	.346 (.527)	.182 (.501)	.194 (.642)
Zygomaticus Major (ZMaj)	No Tear	-.057 (.812)	0 (.519)	-.063 (.471)	.059 (.540)
	Tear	.094 (.353)	-.017 (.823)	.152 (.653)	-.028 (.548)
Zygomaticus Minor (ZMin)	No Tear	-.052 (.813)	-.003 (.428)	-.088 (.430)	.044 (.505)
	Tear	.063 (.270)	.039 (.685)	.092 (.522)	.031 (.639)

4.4.4.2.2 CS.

For the CS, there was a significant main effect of emotion, $F(1.744, 57.565) = 4.683$, $p = .017$, $\eta_p^2 = .124$. No comparisons were significant after Bonferroni correction; however, the main effect stemmed from larger CS activation for angry expressions relative to happy expressions, $t(29) = 2.788$, $p = .052$, $d = .496$. There were no significant differences between all other expressions: anger-sad, $t(29)= 1.164$, $p = 1.00$; anger-neutral, $t(29) = 1.344$, $p = 1.00$; happy-neutral, $t(29) = -2.390$, $p = .136$; happy-sad, $t(29) = -2.205$, $p = .207$; or neutral-sad, $t(29)= -.559$, $p = 1.00$. Additionally, the main effect of tears, $F(1, 28) = .023$, $p = .881$, $\eta_p^2 = .001$; and tears by emotion interaction, $F(2.128, 70.226) = .617$, $p = .552$, $\eta_p^2 = .018$; were not significant.

4.4.5 Discussion

This study aimed to determine whether tears exhibited on happy, sad, angry, and neutral expressions influence subconscious facial mimicry. Largely, we demonstrated that the presence of tears on facial expressions of emotion do not modulate the facial muscle responses one has to an emotional expression. While tears did not influence mimicry during the supraliminal emotional face condition, mimicry responses approached significance in the masked prime condition. This result was evidenced by a trend towards reduced corrugator mimicry following tearful expressions. Additionally, the electrodes placed over ZMaj and

ZMin indexed the same muscular activity, and as such it was not possible to observe any significant differences over the ZMin for tearful displays. Collectively, these findings indicate that the tearful expressions used in our experiment do not modulate early facial mimicry.

While it was not possible to demonstrate that tearful expressions modulated physiological responses to facial displays presented to conscious awareness, this finding was in accord with an existing EMG study exploring mimicry of tears (Grainger et al., 2019). Grainger et al. (2019) found that while corrugator activity was elevated in response to sad displays, tears did not influence EMG responses when examining expressions of sadness. Therefore, they concluded that their study provided evidence for the motor matching hypothesis as the participants matched the target stimuli's sad expression (i.e. furrowed brow to a sad stimulus). The motor matching account posits that mimicry occurs as pure motor copy (Hess & Fischer, 2013), and as such the results of Grainger et al. (2019) indicate that tearful displays do not significantly change one's perception of sadness. Therefore, individuals mimic sad and sad-tearful displays in the same way. Conversely, in our experiment, when emotional expressions were presented unconsciously, using a masking paradigm, there was a trend towards reduced corrugator activity following tearful expressions. This finding indicates that participants frowned less following a masked tearful display, which does not support a pure motor copy account, given that tears seemed to reduce participants' frowning response. Thus, this reduced response to tearful expressions fits with the affective mimicry account, wherein different expressions mediate mimicry based on their signal value (Bourgeois & Hess, 2008; Seibt et al., 2013). Moreover, this result could indicate that: 1) tearful expressions elicit reduced congruent mimicry relative to tear-free expressions; or 2) that tearful expressions reduce the negative reactivity typically observed to negative displays.

The first possible conclusion demonstrates that a reduced frowning response to tearful displays—in line with a motor mimicry account—is indicative of reduced mimicry for tearful displays. Emotional mimicry fosters affiliation between interaction partners, and allows for the sharing of another's perspective (Hess & Fischer, 2013). In this way, the reduced frowning response to tearful faces may signal a desire to not engage in affiliative behaviours and serves as an indicator to avoid further interaction. However, this account seems unlikely, given that tearful expressions typically foster approach behaviours rather than avoidance (Gračanin et al., 2018), and encourage empathic and helping responses from observers (Hendriks & Vingerhoets, 2006; Hendriks et al., 2008). Therefore, the second possible explanation, wherein reduced frowning is indicative of reduced negativity and aggression towards tearful displays is more plausible. Moreover, the reduction of the CS in response to tearful expressions would indicate that if the frowning response elicited from sad displays is a marker of a negative response to a stimulus, then tears reduce this negativity. Given that tears serve to foster support and reduce aggression in observers (Hasson, 2009), this reduced CS response to tearful displays could be a biological example of the signal value of tears. As such, tears reduce reactive responses towards negative displays.

A possible explanation for the lack of mimicry responses to supraliminal emotional expressions observed by Grainger et al. (2019) and herein is that mimicry of tearful displays may not be adaptive. Firstly, sad facial expressions are affiliative, and as such should result in congruent responses (Knutson, 1996). However, responding to a sad display comes at a high cost for the observer (Bavelas et al., 1986; Bourgeois & Hess, 2008) and when social cost is increased, mimicry is typically decreased (Johnston, 2002). Mimicry signals empathy and understanding and, as such, fosters a link between interaction partners. However, the mimicry of tearful displays could result in continued crying (Bourgeois & Hess, 2008; Häfner & IJzerman, 2011). Although most self-report research has demonstrated favourable helping responses to tearful displays (Hendriks et al., 2008; Lockwood et al., 2013), these helping responses are typically expressed via down-regulation (Aragón & Clark, 2018). In this way, the goal of the perceiver is to calm down the tearful individual and aid them in regaining control over their emotions. Under this perspective, mimicry of tearful displays would be counterproductive. Finally, previous studies that have evidenced sadness mimicry, have demonstrated that mimicry of sadness is restricted to in-group members (Bourgeois & Hess, 2008) and close partners (Häfner & IJzerman, 2011). Thus, it is recommended that future investigations of tearful mimicry use personally relevant stimuli to explore whether the relationship between the expresser and the observer influences mimicry responses. This increased personal relevance would aid in determining whether mimicry of tears is reactive or serves to foster affiliation, as the absence of mimicry amongst close partners would indicate that mimicry of tearful expressions is not an adaptive response.

One final implication that warrants discussion is the electrode locations used to index mimicry of sad facial displays. Firstly, the CS is used to index mimicry of both sadness and anger (Hofelich & Preston, 2012; Likowski et al., 2012; Lundqvist, 1995; Lundqvist & Dimberg, 1995). Although some studies have demonstrated increased CS activation for sad displays (Lundqvist, 1995; Lundqvist & Dimberg, 1995), others have demonstrated increased CS activation for angry displays (Likowski et al., 2012). However, in expressions of sadness the eyebrows are pulled together and upward, whereas anger is expressed by the eyebrows pulled together and lowered. Importantly, both actions would be indexed by increased CS activity (Nicanor & Mohammed, 2001). Therefore, the key to disentangling whether mimicry is a result of pure motor copy or a reactive response could lie in changing the muscles used to index sadness. This approach is in accord with seminal research by Duchenne (1862/ 1990), who argued that the muscle associated with sadness is the depressor anguli oris—the muscle responsible for drawing the lips downward. Soussignan et al. (2013) adopted this approach and found increased depressor lip activity in response to sad expressions. Thus, the depressor muscle could be a worthy indicator of sadness mimicry that warrants future investigation.

A similar approach to Soussignan et al. (2013) was adopted in the present study, wherein the muscle that Duchenne associated with weeping—the ZMin—was used to index mimicry of tearful expressions. However, it was not possible to distinguish mimicry responses elicited from the ZMin from the ZMaj. This finding was not entirely unexpected, as earlier research has demonstrated that both happy and disgust expressions activate the levator labii muscle (i.e., the muscle responsible for drawing lip upwards—a common marker for disgust) (Lundqvist, 1995; Lundqvist & Dimberg, 1995). The authors concluded that the levator was contaminated by cross talk resulting from zygomaticus activation in response to happy expressions (Lundqvist, 1995; Lundqvist & Dimberg, 1995). As the ZMin lies between the levator and the ZMaj, it is likely indexing the activity of the larger ZMaj. Therefore, although Duchenne associated the ZMin with weeping, it is not a reliable muscle to use in further experimental studies. As such, it is recommended that future studies adopt the use of the depressor to index mimicry of tearful displays.

It is acknowledged that this study has some limitations. Firstly, a sample of posed prototypical facial displays was used and these images were digitally modified to include tears. While the use of prototypical posed displays is in accord with existing research, there is evidence that the type of facial expressions used influences mimicry. Namely, some studies have demonstrated that genuine expressions elicit greater mimicry than posed displays (Krumhuber, Likowski, & Weyers, 2014). This idea has a relevance for tearful displays, given that posed crying has negative connotations (e.g. crocodile tears). Therefore, further research using genuine stimuli may aid in determining whether mimicry of tearful displays occurs. Secondly, no contextual information was provided. As existing research has found that contextual information can mediate whether emotional faces are mimicked (Hess &

Fischer, 2013), the use of context in future experimental paradigms may aid in determining whether tearful displays elicit increased responses when an individual knows why the expressor is crying. This recommendation has relevance when exploring mimicry of tearful joy. In the absence of context, tearful joy is more ambiguous than tear-free smiles (Krivan, Caltabiano, Cottrell, & Thomas, 2020). However, when the context is known (i.e. tearful faces paired with victorious scenarios), tearful joy is readily interpreted as positive (Aragón, 2017; Aragón & Clark, 2018), with some believing that tearful joy is the most intense expression of positive emotion (Aragón & Bargh, 2018; Fernández-Dols & Ruiz-Belda, 1995). This paradigm would allow for the exploration of whether tearful joy displays are mimicked with corresponding zygomaticus activity when the context is known.

Finally, in this study stimulus sex was not considered, as the use of a single sex stimulus would reduce the generalisability of results, and a sample of five expressions is insufficient to accurately index EMG responses. While there are no consistent patterns for gender effects in facial mimicry research (Seibt, Mühlberger, Likowski, & Weyers, 2015), the potential for a gender difference for responses to tearful displays cannot be ruled out. Early crying research demonstrated that there was a significant sex difference in responses to tearful displays (Lombardo et al., 1983; Lombardo et al., 2001). However, most recent research has not demonstrated this effect (see Vingerhoets & Bylsma, 2015 for a review). In saying this, Stadel et al. (2019) demonstrated that self-report 'willingness to help' responses to tearful displays were more common among mixed dyads, than male-male dyads. As such, further studies investigating tearful displays should explore whether mimicry is dependent on the gender of the interactional dyad.

In summary, the present study has demonstrated that tearful displays are not mimicked in a unique way to tear-free expressions. However, a trend towards reduced mimicry of tearful displays when presented in a masked prime paradigm has been demonstrated. This reduction of corrugator activity in response to tearful displays may indicate a reduction in aggressive or negative responses to tearful displays or indicate the desire to disengage from further contact. These conflicting interpretations have highlighted the importance for future studies to explore sadness mimicry responses to personally relevant faces, and the use of muscles other than the CS to index sadness (Soussignan et al., 2013). Overall, the inconclusive results of the present study contribute to the body of literature, which has demonstrated mixed evidence for mimicry of sad facial displays. However, several experimental advancements have been suggested herein, to disentangle whether mimicry of sad facial displays is not adaptive and as such does not occur, or whether mimicry is limited to personally relevant individuals. Therefore, further exploring mimicry responses to tearful displays will aid not only in understanding the communicative functions of tears, but also the communicative functions of affiliative expressions as a whole.

Chapter 5: Early Neural Processing of Tearful Faces

5.1 Chapter Overview

Chapter 4 discussed one of the first EMG studies to explore mimicry responses to tearful displays. The results of the study were inconclusive; however, it seemed that participants did not mimic tearful displays differently than tear-free expressions. It was concluded that mimicry of a tearful expression may not be adaptive—particularly if the observer's goal is to downregulate the crier. However, this null result does not mean that tears are not shared at the psychophysiological level. Rather, although we do not mimic tearful displays, which would encourage continued expression, it is yet to be determined whether tearful displays are preferentially processed relative to other tear-free displays. This chapter explores this theory by indexing early neural responses to emotional faces. I predicted, in line with tears being a salient social signal, that tearful displays would elicit larger early neural responses compared to tear-free expressions.

5.2 Publication Status

In preparation for submission.

5.3 Author Contributions

Krivan – conceptualised the experiment, created the stimuli, programmed the experimental procedure, collected the data, pre-processed the EEG data, conducted the statistical analyses and drafted manuscripts.

Cottrell – aided in conceptualisation and provided supervision.

Thomas – provided supervision and aided in manuscript revision.

5.4 Manuscript

5.4.1 Abstract

Facial expressions are a critical component of social communication. Expressions of joy are readily shared, whereas expressions of sadness are costly to respond to. Despite this fact, research employing self-report methodologies has identified that tears aid in signalling distress and elicit greater caregiving responses compared to other tear-free expressions. Understanding whether these differences also modulate face-specific, event-related potential (ERP) waveforms will aid in determining whether tears are preferentially processed at the neural level. Fifty-two participants completed an emotional discrimination task of faces depicting happy, sad, and neutral expressions both with and without tears. The face specific N170 ERP was sensitive to the emotional content of the images. Specifically, tearful sadness elicited significantly larger responses than sad faces without tears, while the inverse result was observed for happy expressions. Therefore, emotional stimuli requiring rapid interpretation are preferentially processed at the early neural level. This early neural processing provides a biological basis for the increased behavioural responses typically observed in response to sad tearful stimuli.

Keywords: Tears, N170, Social Communication, EEG, Adult Crying

5.4.2 Introduction

The preferential processing of emotionally relevant stimuli is necessary for adaptive social behaviour (Batty & Taylor, 2003). One method by which emotionally relevant information is conveyed to others is via the face. As such, facial expressions are a means of communicating one's affective state rapidly, without words. Therefore, it has been argued that the ability to decode facial expressions is an automatic process (Batty & Taylor, 2003; Rellecke, Sommer, & Schacht, 2012), and that this automaticity is fostered by face specific neural circuits (Hadjikhani et al., 2009; Haxby et al., 2000, 2002). This notion stems from neuroimaging research wherein increased hemodynamic activity for facial stimuli is observed in cortical regions such as the lateral fusiform gyrus (or fusiform face area; FFA), superior temporal sulcus (STS), and inferior occipital gyri. In addition to this core facial processing network, is an extended subcortical system for the recognition of emotion which encapsulates the amygdala, insula, and limbic system (Hadjikhani et al., 2009; Haxby et al., 2000). As such, the ability to rapidly interpret facial expressions is facilitated by a specific face processing network.

In addition to exploring the physical structures associated with face processing, an increasing body of research is interested in the temporal, or time-related, processes indexed via electroencephalography (EEG). EEG is a recording technique that indexes the synchronised firing of electrical potentials on the surface of the scalp (Brenner et al., 2014). EEG is capable of indexing activity at the millisecond level, and as such is the preferred technique for indexing rapid neural changes to facial stimuli. The most reliable index of facial perception afforded by scalp EEG is the N170 event-related potential (ERP) (Joyce & Rossion, 2005). Widely associated with facial processing, the N170 is enhanced in response to facial stimuli relative to non-face objects (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Sadeh, Zhdanov, Podlipsky, Hendler, & Yovel, 2008). The N170 is typically maximal at occipitotemporal electrode sites and is present approximately 170 ms after stimulus onset. The N170 response is generated from face specific regions—identified via neuroimaging—notably the FFA and STG (Horovitz, Rossion, Skudlarski, & Gore, 2004). As a result, most of the N170 literature has focused on determining *what* facial information the N170 is capable of indexing. There are two broad competing theories; 1) that the N170 represents structural encoding of facial recognition—where specialised processing such as identity and emotion are interpreted later, and 2) that the N170 is sensitive to changes in emotional expression.

Early theories posited that the N170 was responsible for the structural encoding of facial expressions (Bentin et al., 1996; Bentin & Deouell, 2000; Eimer, 2000, 2000). Following Bruce and Young's (1986) facial recognition model, structural encoding is the featural and configural representation of a face. This primary structural encoding phase provides the necessary information for determining facial expression and identity. This link between the N170 and structural encoding was established through a series of experiments by Bentin et al. (1996). Moreover, the N170 was largest in response to human facial expressions, and sensitive to facial configuration and features (Bentin et al., 1996). Further evidence for the link between the N170 and structural encoding was bolstered by research showing that the N170 was not modulated by facial familiarity (Bentin & Deouell, 2000; Eimer, 2000) or emotional expression (Eimer, Holmes, & McGlone, 2003; Holmes, Winston, & Eimer, 2005). That is to say, no modulation of early N170 components was observed; however, later ERP components were found to be modulated by familiarity and emotionality of the stimulus (Eimer, 2000; Eimer et al., 2003). As a result, the N170 was associated with the detection of facial stimuli, as opposed to identification, and as such reflected the neural mechanisms underlying the Bruce and Young (1986) facial recognition model.

While early research primarily showed that the N170 was sensitive to structural components of faces, there is ongoing contention as to whether the N170 is sensitive to emotional content (Kralj Novak, Smailović, Sluban, & Mozetič, 2015; Krombholz, Schaefer, & Boucsein, 2007; Weiß, Gutzeit, Rodrigues, Mussel, & Hewig, 2019; Weiß, Mussel, & Hewig, 2019). A wealth of research has been conducted examining whether facial expressions of emotion modulate neural responses relative to neutral expressions (Bediou, Eimer, d'Amato, Hauk, & Calder, 2009; Blau et al., 2007; Brennan, Harris, & Williams, 2014; Del Zotto & Pegna, 2015; Guillermo, Wilhelm, Sommer, & Hildebrandt, 2017; Jetha, Zheng, Goldberg, Segalowitz, & Schmidt, 2013). However, this field has yielded mixed results, given that some studies report increased emotion effects relative to neutral stimuli (Bediou et al., 2009; Blau et al., 2007; Del Zotto & Pegna, 2015), whereas others fail to find this effect (Brennan et al., 2014; He et al., 2012). Further contention stems from conflicting evidence regarding the type of emotion that modulates the N170 response; where some argue that negative emotions elicit larger N170 amplitudes (Brenner et al., 2014; Jetha et al., 2013), and others argue for positive displays (Chen et al., 2014; Rossignol et al., 2012). A recent meta-analysis identified that the N170 was modulated by emotional content, with anger, fear, and happy expressions exhibiting the largest N170 amplitudes (Hinojosa et al., 2015). Conversely, sad and disgust expressions were not found to modulate the N170. Thus, the authors concluded that modulation of the N170 is dependent on the communicative function of emotional expressions – wherein emotions such as happy, angry, and fear are all particularly salient signals that are interpreted rapidly relative to sadness and disgust.

Anger, fear, and happy expressions are elicited in social exchanges requiring rapid interpretation and are typically attributed greater social relevance than disgust and sadness expressions (Hinojosa et al., 2015). This social relevance stems from the fact that anger and fear expressions signal danger, and thus rapid interpretation and response is critical to evolutionarily adaptive behaviour (Tipples et al., 2002). This increased response to threatening and aversive stimuli is termed the 'threat hypothesis', which falls under the umbrella of a 'negativity bias' (Hajcak et al., 2011; Ito et al., 1998; Öhman et al., 2001). The processing of negative stimuli is said to engage the "low-road" subcortical pathway via the amygdala, which facilitates rapid responses to threat (LeDoux, 2007; Liddell et al., 2005; Liddell et al., 2004). As anger and fear both signal potential danger and threat, neural processes have evolved to ensure their rapid interpretation. However, happy expressions, while not threatening, also facilitate N170 responses (Chen et al., 2014; Mühlberger et al., 2009; Tortosa, Lupiáñez, & Ruz, 2013). Moreover, happy expressions have an increased social relevance as smiles are rapidly exchanged to foster affiliative pro-social behaviours (Nummenmaa & Calvo, 2015). By contrast, sad and disgust expressions do not modulate the N170 response (Hinojosa et al., 2015); however, the number of studies including sad or disgust expressions is much more limited. Furthermore, research exploring sad and disgust expressions is conflicted as some has demonstrated increased N170 amplitude responses for these emotions relative to neutral expressions (Caharel, Courtay, Bernard, Lalonde, & Rebaï, 2005; Lynn & Salisbury, 2008; Rossignol et al., 2012; Turetsky et al., 2007; Zhao & Li, 2006), whereas others failed to observe this effect (Brennan et al., 2014; Chen et al., 2014; He et al., 2012). Thus, there is insufficient evidence to conclude that the N170 is solely modulated by social relevance, as a result of the limited research exploring sadness and disgust.

As a result of this conflicting evidence, there has been a rise in literature arguing that the N170 is not modulated by specific emotions, but rather the intensity or arousal of the emotional display (Almeida et al., 2016; Sprengelmeyer & Jentzsch, 2006; Turetsky et al., 2007; Wang et al., 2013). Sprengelmeyer and Jentzsch (2006) were the first to demonstrate this effect, in an experiment where angry, fearful and happy displays were presented at 50%, 100%, and 150% intensity. There were no significant differences between emotion categories; however, as intensity increased, so did N170 amplitudes. Since this seminal research, there is a consensus that intensity is linearly related to N170 amplitude, wherein higher intensity expressions elicit larger N170 amplitudes (Almeida et al., 2016; Wang et al., 2013). However, it must be noted that although Almeida et al. (2016) primarily demonstrated that the N170 was modulated by the arousal of the stimulus, they also concluded expressions of fear retain some priority in neural processing as a result of their evolutionary value. Thus, the role of intensity and emotion in modulating the N170 response is yet to be determined. As such, further research is needed to disentangle the role of intensity from that of emotional expression.

The limitations of previous experiments can be addressed by using stimuli that have been largely neglected in emotion research—tears. Tearful facial expressions of emotion are an inborn biological signal designed to elicit help and support from others (Balsters et al., 2013; Hendriks et al., 2008). Additionally, behavioural research has demonstrated that tears are a signal of sadness, which foster approach behaviours relative to avoidance (Gračanin et al., 2018). The *tear effect* proposes that in the absence of context a tearful expression will be perceived as sad (Provine et al., 2009). Thus, tears are a distinctive marker of sadness, which serve as a salient distress signal. However, it is yet to be determined whether these increased behavioural responses have a biological basis. Thus far only one study has investigated N170 responses to sad crying faces (Hendriks et al., 2007). Although tearful displays elicited larger N170 amplitudes relative to neutral expressions, they were not significantly different from other basic emotional displays (Hendriks et al., 2007). However, Hendriks et al. (2007) compared sad crying faces with other tear-free expressions. Yet, tears are not only elicited in response to sadness; tears are also elicited in response to joy (Miceli & Castelfranchi, 2003).

The existing research investigating responses to happy-tear expressions is exceptionally limited. In the absence of context, happy tearful displays are associated with increased sadness and increased negative valence (Reed et al., 2015). Thus, tearful happy expressions reduce the distinctiveness of a typically happy face. As happy expressions modulate the N170 response (Chen et al., 2014; Rellecke et al., 2012), the inclusion of both tearful and tear-free stimuli allowed us to investigate how tears modulate the N170 based on the type of emotion they were paired with. Furthermore, tears are an ideal candidate for investigating the competing social relevance and intensity hypotheses. Moreover, recent research has demonstrated that tears increase the overall intensity of a stimulus, regardless of whether it is positively or negatively valenced (Krivan et al., 2020; Reed et al., 2015). Thus, tearful stimuli are more intense overall; however, happy faces without tears and sad faces with tears are particularly distinctive, which increases their social relevance. Therefore, the addition of tears to happy and sad stimuli makes it possible to disentangle the influence of tears on structurally identical faces, while maintaining their emotional relevance.

Therefore, the aim of the present study was to determine whether the N170 is modulated by emotional facial expressions. Given that existing research is mixed as to whether emotional faces elicit larger N170 amplitudes than neutral expressions, a neutral control condition was included. In addition, although happy faces elicit increased N170 amplitudes relative to neutral expressions, sad faces do not (Hinojosa et al., 2015). Thus, both happy and sad stimuli, with and without tears, were included to explore the influence of tears on early neural responses to faces. Firstly, it was hypothesised that emotional expressions would elicit larger overall N170 amplitudes relative to neutral expressions—demonstrating that the N170 is sensitive to emotional content. It was further predicted that if the N170 is modulated by socially relevant emotional expressions, increased responses for happy faces without tears (i.e. a distinctive marker of happiness) and sad expressions with tears (i.e. a distinctive marker of sadness) would be observed.

5.4.3 Method

5.4.3.1 Participants

The sample consisted of 75 undergraduate students (47 females, M_{age} = 25.15, SD_{age} = 8.52 years). Exclusion criteria included left-handed individuals, a prior diagnosis of neurological disorders, hairstyles that were incompatible with the electrode cap (i.e. Mohawks, dreadlocks), and stimulant use in the two hours prior to the experiment. All participants reported having normal or corrected-to-normal vision and identified as right-handed (M = 79.23, SD = 17.99) (Oldfield, 1971). All participants gave written informed consent, in accord with the Declaration of Helsinki, and were compensated with course credit. Ethical approval was obtained from the James Cook University Human Research Ethics committee.

5.4.3.2 Stimuli

Stimuli were 10 male and 10 female identities, each portraying happy, sad, and neutral expressions, which were taken from the Karolinska Directed Emotional Faces database (KDEF; Lundqvist, Flykt, & Öhman, 1998). Each face was cropped (298 x 374 px) using an ellipsis tool to remove hair, clothing, and ears to ensure the face only contained the elements necessary for determining emotional expressions. Tears were digitally added to the happy and sad images, with online editor software (http://funny.pho.to/tears-effect/), to create the tearful stimuli.

The stimuli were piloted using an independent sample of 17 participants. Pilot participants rated the images using generalised intensity and valence visual analogue scales. Participants were asked, "how intense was the emotion depicted" and the scale ranged from 0 (*not at all*) to 1 (*extremely intense*). The valence scale asked, "what valence was the emotion depicted?" and the scale ranged from 0 (*negative*) to 1 (*positive*). We selected 20 identities (10 female) for inclusion in the experiment proper, based on ability to match across gender in terms of intensity and valence ratings (see Table 5.1).

Table 5.1

Mean (SDs) Pilot Generalised Intensity and Valence Ratings for the 20 Facial Identities

		No Tears		Tears	
		Happy	Sad	Happy	Sad
Intensity	Female	.54 (.24)	.60 (.17)	.61 (.17)	.66 (.15)
	Male	.59 (.21)	.59 (.13)	.63 (.18)	.65 (.12)
Valence	Female	.79 (.12)	.25 (.08)	.70 (.18)	.21 (.09)
	Male	.78 (.11)	.26 (.07)	.70 (20)	.22 (.09)

Note. Higher intensity ratings reflect greater perceived intensity, and valence ranged from 0 (negative) to 1 (positive).

5.4.3.3 Procedure

The experiment was conducted in a sound attenuated electromagnetically shielded room on a 24-inch Dell monitor with a 60 Hz refresh rate. PsychoPy software (version 1.91.1) was used to present the stimuli. All facial images were presented in full colour against a black background.

Each trial followed the same experimental sequence. Participants received instructions for a delayed match-to-sample task on emotion, where two images were presented sequentially, and the participants had to report via button press whether the emotions of the first and second image were the same or different. Prior to the testing phase, 10 practice trials, using unique faces that were not presented during the actual trials, were given to familiarise participants with the procedure. Participants were asked to make fast, but accurate, judgments and indicated they understood it was a reaction time task. An example trial structure is depicted in Figure 5.1. The intertrial fixation cross was randomly varied in blocks of 100 ms, between 2500 and 3500 ms, to avoid anticipatory responses. The image pairs were shown randomly, where every image was shown twice in the first face position, and on 50% of trials the emotions were the same. The response prompt was shown until a response was made, with a maximum response time of 2000 ms, after which participants were informed their response was too slow. The experiment was conducted in 5 blocks of 40 trials (~ 7 minutes), and each block was followed by a 30 second break. After participants completed this phase of the experiment, they were informed about a second experimental task; these data were analysed separately (see Chapter 6 for results). After participants completed both tasks, they were debriefed and thanked for their participation.

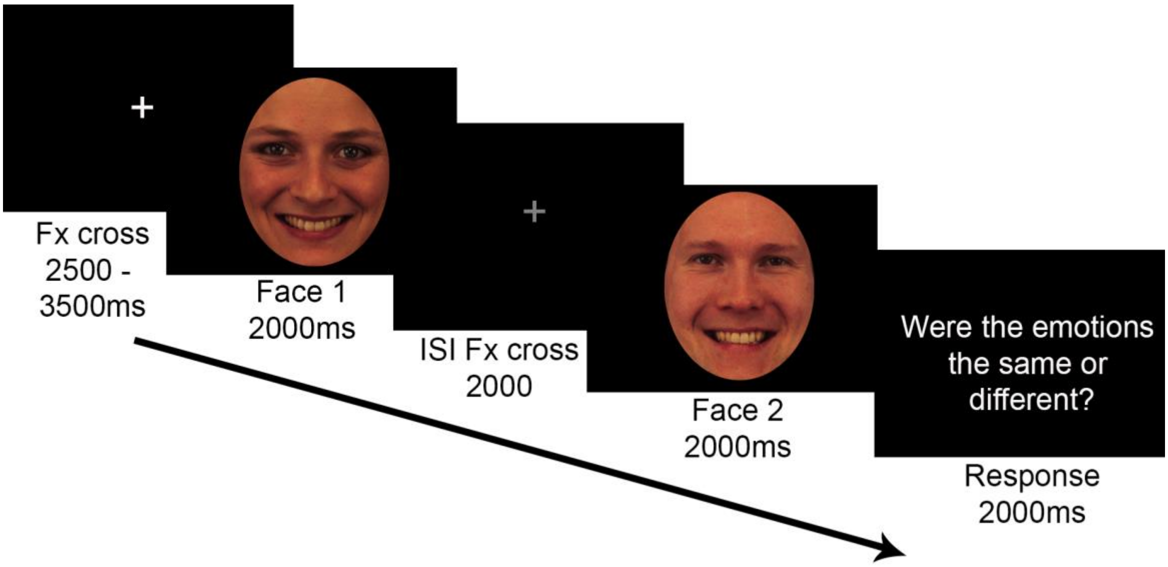

Figure 5.1. Example trial structure and KDEF stimuli used in the study. KDEF stimuli are F01HAS and M11HAS. The correct response for this trial was 'same'.

5.4.3.4 EEG recording and analysis

Electrical brain activity (EEG) was recorded using the BioSemi Active-Two system using a 32-channel headcap set out according to the international 10-20 system. Online recording was reference free. All electrode offsets were checked and below 25 in accordance with BioSemi guidelines. Eyeblinks were monitored using bipolar vertical EOG, with the electrodes attached to the infraorbital and supraorbital regions of the left eye. EEG and EOG were sampled using a 2048 Hz sampling rate.

All pre-processing steps were performed using the software BrainVision Analyzer 2.0 (Brain Products, Munich, Germany). EEG data was re-referenced to the average of all electrodes and high-pass filtered (0.5 Hz, 12 dB/oct) with a 50 Hz notch filter to correct for powerline noise. Eyeblink artifacts were corrected offline using a regression-based algorithm (Gratton, Coles, & Donchin, 1983). Continuous EEG was then segmented in epochs ranging from -100 to 700 ms after stimulus onset[3] for each emotion expression, and baseline corrected in the 100 ms period prior to stimulus onset. EEG epochs were removed from analyses if the epoch included amplitudes exceeding ±100 µV. Average ERPs were calculated for each type of facial expression corresponding to ~ 70 trials per participant for each of the emotion categories. Data were exported using local peak latency and mean area. The N170 mean amplitude between 175 and 255 ms was averaged, and the local point at which the peak occurred (±5 time points) was detected.

5.4.3.5 Data exclusions

Four participants from our initial sample were excluded due to technical recording problems. As at least 70% of each participant's data had to be retained to be included in analysis, a further 18 participants were excluded. One further participant, who failed to respond during the behavioural task, was removed, resulting in a final sample of 52 participants.

5.4.4 Results

5.4.4.1 Behavioural data

Classification accuracy for the image pairs was analysed to ensure participants- maintained attention throughout the task. Participants performed significantly above chance when identifying emotional expressions (see Table 5.2), with a mean accuracy of 85.57% (*SD* = 6.98). As the task relied on person perception, it is feasible that some participants perceived the tear and the tear-free emotions as different, despite having the same underlying emotion. As such, we did not exclude any of the EEG data based on behavioural accuracy, in order to maintain as much EEG data as possible.

[3] EEG triggers were sent after a stimulus was presented for a full frame, rather than at stimulus onset. As a result, our latency data is delayed by 16.67 ms (the time of one frame) from that of existing research which has demonstrated the N170 at ~170ms after onset.

Table 5.2

One Sample t-test Results of Accuracy Scores per Emotion Condition during the Discrimination Task.

	Mean	*SD*	*t*	*p*	*d*
Happy	89.28	8.30	34.11	<.001	4.730
Sad	82.12	9.44	24.54	<.001	3.403
Happy-tear	86.11	10.62	24.50	<.001	3.399
Sad-tear	84.81	8.46	29.68	<.001	3.116
Neutral (Control)	85.53	8.61	29.76	<.001	4.127

Note. Compared against chance level classification (50% accuracy).

5.4.4.2 ERP data

Grand-averaged ERP waveforms for face stimuli are shown in Figure 5.2. Based on visual inspection, responses were characterized by an early positive component (P1, peak around 150 ms after stimulus onset), followed by a negative wave (N170, peak around 200 ms after stimulus onset) bilaterally over occipitotemporal electrode sites (left hemisphere P7/ right hemisphere P8). Table 5.3 shows the mean amplitude and local peak latency of the N170 response for each of the emotion conditions.

Table 5.3

Mean Amplitudes and Local Peak Latencies (SD) of the N170, for each Emotion at the Left and Right Occipitotemporal Electrodes.

		Left Hemisphere (P7)		Right Hemisphere (P8)	
		Amplitude (μV)	Latency (ms)	Amplitude (μV)	Latency (ms)
Happy	No tears	-1.24 (2.78)	209.43 (16.12)	-2.45 (3.13)	207.29 (12.88)
	Tears	-1.47 (2.91)	206.12 (19.81)	-2.14 (3.06)	206.76 (12.48)
Sad	No tears	-1.54 (2.90)	210.52 (14.27)	-2.31 (3.23)	209.61 (14.36)
	Tears	-1.72 (2.79)	211.60 (14.65)	-2.71 (3.11)	211.20 (14.71)
Neutral	No tears	-1.19 (2.53)	210.72 (16.24)	-2.10 (3.12)	207.23 (12.89)

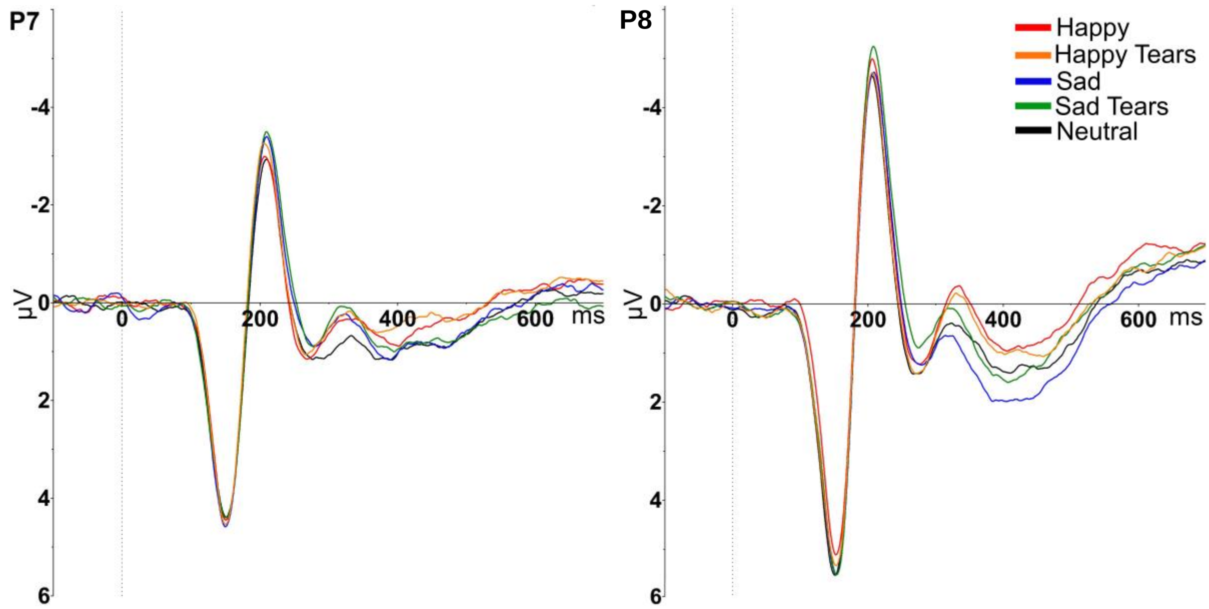

Figure 5.2. Grand-averaged ERPs as a function of facial expression, for left hemisphere electrode P7 (pictured on left), and right hemisphere electrode P8 (pictured on right). The waveforms were low pass filtered prior to plotting, with a half-amplitude cut-off of 30 Hz for clarity of ERP figures.

5.4.4.2.1 N170 mean amplitude

Separate planned contrasts were conducted to compare the neutral condition with the other emotional expression categories to determine the role of emotional content. Planned contrasts indicated the neutral condition elicited smaller negative mean amplitude responses relative to the emotional face conditions at both left hemisphere P7, $F(1,51) = 5.580$, $p = .022$, $\eta_p^2 = .099$; and right hemisphere P8, $F(1,51) = 5.285$, $p = .026$, $\eta_p^2 = .094$, electrode sites. Thus, the neutral condition was excluded from our follow-up analyses to better explore the electrode by emotion by tear effects at each electrode site.

A 2 (electrode: left hemisphere P7, right hemisphere P8), by 2 (tears: no tear, tears), by 2 (emotion: happy, sad) repeated-measures ANOVA was conducted to investigate the role of tears in modulating neural responses to emotional faces. A significant main effect of electrode was observed, with a significantly larger negative mean amplitude at the right occipitotemporal electrode (P8) compared to the left (P7), $F(1,51) = 5.387$, $p = .024$, $\eta_p^2 = .096$. There was also a significant main effect of emotion, $F(1,51) = 7.498$, $p = .008$, $\eta_p^2 = .128$, where sad expressions elicited larger negative mean amplitudes than happy expressions. Although remaining main effects and all 2-way interactions were non-significant, *F's* < 3.904, *p's* > .054; there was also a significant electrode by tears by emotion interaction, $F(1,51) = 5.001$, $p = .030$, $\eta_p^2 = .089$. To follow-up this interaction, separate 2 (tears: tear-free, tears) by 2 (emotion: happy, sad) repeated-measures ANOVAs were conducted at left hemisphere electrode site P7 and right hemisphere electrode site P8.

At left hemisphere electrode site P7, there was a main effect of emotion, with sad expressions eliciting a larger negative mean amplitude relative to happy expressions, $F(1,51) = 5.683$, $p = .021$, $\eta_p^2 = .100$. Both the main effect of tears, $F(1,51) = 3.534$, $p = .066$, $\eta_p^2 = .06$, and the interaction, $F(1,51) = .041$, $p = .840$, $\eta_p^2 = .001$, were non-significant.

At right hemisphere electrode site P8, there were no significant main effects of emotion, $F(1,51) = 3.585$, $p = .064$, $\eta_p^2 = .066$; or tears, $F(1,51) = .166$, $p = .686$, $\eta_p^2 = .003$. However, there was a significant tears by emotion interaction, $F(1,51) = 8.260$, $p = .006$, $\eta_p^2 = .139$. Follow-up Bonferroni-corrected paired samples *t*-tests revealed that sad tearful displays elicited significantly larger negative mean amplitudes compared to sad tear-free displays, $t(51) = 2.346$, $p = .023$, $d = .325$. There was no significant difference between happy tear-free and happy tearful displays, $t(51) = -1.993$, $p = .052$, $d = -.276$.

5.4.4.2.2 N170 peak latency.

To examine whether there were any latency effects, another 2 (electrode: left hemisphere P7, right hemisphere P8), by 2 (tears: no tear, tears), by 2 (emotion: happy, sad) repeated-measures ANOVA was conducted on the latency data. There was a significant main effect of emotion, $F(1,51) = 11.840$, $p = .001$, $\eta_p^2 = .188$, whereby happy expressions peaked earlier than sad expressions. No other main effects or interactions were significant, *F's* < 2.730, *p's* > .105.

5.4.5 Discussion

The findings demonstrated that the face specific N170 ERP is modulated by the emotional content depicted in facial displays. Early research identified that the N170 was involved in the structural encoding of faces (Bentin & Deouell, 2000; Eimer, 2000; Eimer et al., 2003; Holmes et al., 2005). Rather, we have shown that, overall, emotional expressions elicit larger N170 amplitudes relative to neutral expressions, which supports an increasing body of research in the field (Bediou et al., 2009; Blau et al., 2007; Mühlberger et al., 2009). Additionally, an increased modulation of the N170 to emotional faces was demonstrated at the occipitotemporal electrode sites, with significantly stronger activation observed over the right hemisphere (P8), in line with a right hemisphere dominance for emotional processing (Dimberg & Petterson, 2000; Gainotti, 2012). Finally, we demonstrated that the social relevance of the facial display, as opposed to the intensity of the stimulus, plays a greater role in N170 modulation.

Regardless of the type of emotion presented, emotional faces elicited increased negative N170 amplitudes relative to neutral displays. This increased amplitude response reveals that emotion processing occurs rapidly, in the same time frame as facial detection. This finding contradicts earlier studies, which concluded that the N170 ERP reflected the structural processing of faces (Bentin & Deouell, 2000; Eimer, 2000; Eimer et al., 2003; Holmes et al., 2005). Rather, it provides support for theoretical models, which state that while structural encoding occurs independently of expression identification, the two can occur simultaneously (Bruce & Young, 1986; Eimer & Holmes, 2007). Furthermore, the earlier studies that concluded that the N170 was sensitive to structural, as opposed to affective, content reached this conclusion because they failed to find significant modulation of emotion (Eimer et al., 2003; Holmes et al., 2005). However, more recent research has demonstrated N170 modulation using schematic emotional faces (i.e. line drawings of emotional expressions) and emojis (i.e. simple graphic symbols) with minor variability between emotional facial displays (Kralj Novak et al., 2015; Krombholz et al., 2007; Weiß et al., 2019; Weiß et al., 2019). Critically, Weiß et al. (2019) demonstrated that sad emojis, which were structurally identical to happy emojis with an inverted smile, elicited larger N170 amplitudes relative to happy and neutral displays. Thus, as in studies using human facial expressions (Blau et al., 2007; Caharel et al., 2005; Del Zotto & Pegna, 2015), a larger N170 amplitude is observed in response to negative schematic expressions and emojis relative to positive displays (Krombholz et al., 2007; Weiß et al., 2019; Weiß et al., 2019). Therefore, the N170 is modulated by the emotional content of a face, even in the absence of human-like structural features.

In addition to demonstrating an increased modulation of the N170 relative to neutral expressions, we demonstrated that this modulation was emotion dependent. Existing research has demonstrated that larger ERPs are elicited in response to facial expressions with greater social relevance (see Hinojosa et al. (2015) for a review). Specifically, existing research has shown that facial displays conveying threat-related information, such as fear and anger, elicit the largest N170 amplitudes (Blau et al., 2007; Jetha et al., 2013). This increased neural response to threatening facial expressions is in accord with neuroimaging studies identifying a preferential processing network, including the amygdala, for threatening visual stimuli (LeDoux, 2007; Liddell et al., 2005; Liddell et al., 2004). However, the meta-analysis by Hinojosa et al. (2015) also identified that happy facial expressions significantly modulate the N170 response. Moreover, although some studies have not demonstrated an amplitude difference between happy, angry, and fearful stimuli (Mühlberger et al., 2009; Rellecke et al., 2012; Tortosa et al., 2013), others have reported that happy expressions elicit larger potentials overall, when compared to negative displays (Chen et al., 2014; Rossignol et al., 2012). Therefore, the N170 is not modulated solely by threat-related information. Rather, the N170 is modulated by the social relevance of the stimuli, where certain emotional expressions, either positive or negative, require rapid social exchange.

To address the theory of social relevance, tearful expressions of sadness and joy were used. Tears provide a way to address the factor of social relevance, for both positive and negative emotions, while minimising the structural variation between emotional images. Our results provide the greatest support for the social relevance hypothesis, as sad tearful displays and happy tear-free displays elicited the largest potentials overall, relative to neutral expressions. This increased amplitude response to happy tear-free and sad tearful faces is in accord with previous behavioural research reflecting an advantage for salient stimuli (Krivan et al., 2020). Moreover, happy facial expressions are common in rapid social interactions, and the preferential processing observed in this study and existing research is potentially a result of their pro-social signal. Although sad tearful displays are negatively valenced, they reliably elicit support and empathic responses from observers (Balsters et al., 2013; Hendriks et al., 2008). Additionally, sad tearful displays foster approach behaviours (Gračanin et al., 2018) and facilitate the recognition of sadness (Ito et al., 2019; Provine et al., 2009). Thus, tears are a distinctive marker of sadness, akin to smiles being a distinctive marker of joy.

Our support for the social relevance hypothesis contradicts the argument that the N170 is modulated by the intensity or arousal of an image more so than it is by emotion (Almeida et al., 2016; Sprengelmeyer & Jentzsch, 2006; Wang et al., 2013). Sprengelmeyer and Jentzsch (2006) demonstrated that the more intense an emotional stimulus, the greater the N170 amplitude observed. Similarly, Almeida et al. (2016) demonstrated a linear relationship between increasing stimulus arousal and N170 amplitudes. However, the results from this study fail to support this theory. Specifically, our results demonstrated that sad-tear and happy tear-free images elicited significantly larger ERPs than their counterparts. One possible explanation for the discrepancy between the present findings and earlier intensity research is the way in which intensity was matched in the present study. Moreover, tearful expressions in the present study are more intense than tear-free expressions (Krivan et al., 2020). Therefore, if the intensity account was supported, a main effect of tears would have been observed, wherein tearful displays elicited greater N170 amplitudes relative to tear-free expressions. Rather, we have demonstrated the greatest support for the argument that the N170 is modulated by the communicative criteria of the display—wherein tearful sadness clearly communicates sadness, and happy tear-free expressions are a distinctive happy expression—and, as such, are the emotions that elicit larger N170 amplitudes. Therefore, intensity alone does not modulate the N170, and the greatest support is demonstrated for the social relevance account.

Furthermore, the interaction between tears and emotion at electrode P8 also contradicts previous N170 research, which has demonstrated a negativity bias. Moreover, a negativity bias for N170 amplitude at electrode P7 was observed, where sad faces elicited larger amplitudes overall when compared to happy expressions. As raised by Hajcak et al. (2011), this negativity bias is typically difficult to equate. However, the tear stimuli used herein increased overall perceptions of intensity, while maintaining the social relevance associated with happy and sad emotional displays. In addition, the inverse of a negativity bias was demonstrated when examining the latency effects observed at electrode P8, as happy expressions peaked earlier than sad displays. However, it is important to note that the existing N170 latency literature is mixed, with some studies demonstrating no latency differences between facial stimuli (Blau et al., 2007; Guillermo et al., 2017; Herrmann et al., 2002; Krombholz et al., 2007), and others demonstrating a negative bias (Del Zotto & Pegna, 2015) or a positive advantage (Batty & Taylor, 2003). Thus, there is insufficient evidence to draw strong conclusions regarding N170 latency modulation from the existing literature. Nonetheless, the slight processing advantage for positive emotional displays exhibited in our study might reflect a neural basis for the happy face advantage, which has been widely observed in behavioural studies (Calvo et al., 2016; Leppänen et al., 2003; Palermo & Coltheart, 2004), or it might relate to the complexity associated with decoding negative stimuli (Kuperman, Estes, Brysbaert, & Warriner, 2014; Taylor, 1991).

A limitation that must be addressed is the choice of referencing scheme used. The two most common referencing systems when examining the N170 are the common average and the mastoids (Hinojosa et al., 2015). The common average reference has been identified as the superior choice, given the mastoids proximity to the occipitotemporal electrodes (Rellecke, Sommer, & Schacht, 2013); as such, the common average is used more frequently (Hinojosa et al., 2015). However, computing a common average on a small electrode array (i.e. 32 electrodes) is not ideal (Dien, 1998). For this reason, the ERP data was re-analysed using the mastoid reference, and the pattern of results was consistent regardless of reference choice; albeit smaller N170 amplitudes were observed when a mastoid reference was used, which is consistent with prior research (Rellecke et al., 2013). As a result, it is proposed that the current conclusion that the emotional content of a facial expression modulates the N170 response more so than intensity is appropriate; however, further research using a larger electrode array is needed to provide confirmatory evidence.

Furthermore, we did not include an additional control condition wherein participants completed a task not associated with emotion recognition. Moreover, the current results contradict an earlier study that examined the way that crying modulates the N170 (Hendriks et al., 2007). Hendriks et al. (2007) demonstrated that crying faces were distinct from neutral expressions, although not fundamentally different from other basic emotions. However, their participants were instructed to complete a gender identification task, rather than an emotion-focused task. The role of directed emotional attention is contentious in determining the degree to which the N170 is modulated by emotion. Although some studies have demonstrated that N170 modulation only occurs when attention is focused on affective state (Eimer et al., 2003), others have demonstrated that emotional modulation occurs in the absence of conscious awareness (Del Zotto & Pegna, 2015; Pegna, Darque, Berrut, & Khateb, 2011; Pegna et al., 2008), and yields larger effect sizes when indirect tasks are used (Hinojosa et al., 2015). As such, it is unlikely that the current results stem solely from the choice of task; however, the results should be further validated by including a task wherein participants' attention is directed away from the emotional content of the face.

In conclusion, the present study has demonstrated that the N170 ERP is modulated by emotional content. Furthermore, this modulation is dependent on the type of emotional expression presented, in line with the social relevance hypothesis (Hinojosa et al., 2015). Moreover, although earlier studies primarily demonstrated this social relevance using fearful and angry displays (Blau et al., 2007; Jetha et al., 2013), we have supported this hypothesis using a novel tear paradigm. Enhanced N170 responses were observed at right occipitotemporal electrodes for happy faces without tears and sad faces with tears. This finding demonstrates that socially relevant stimuli—such as happy expressions, which foster affiliative behaviours, and tearful expressions, which signal distress—elicit larger neural responses relative to less salient emotional signals. Additionally, this increased neural response to tearful expressions provides a biological basis for the enhanced responses typically observed in behavioural research (Balsters et al., 2013; Hendriks et al., 2008; Hendriks & Vingerhoets, 2006). As a result, tears serve a clear communicative function, where the preferential processing of tearful expressions is demonstrated at the early neural level.

Chapter 6: I'll cry Instead: Mu Suppression Responses to Tearful Facial Expressions

6.1 Chapter Overview

Thus far in this thesis I have demonstrated that tears signal sadness in the absence of context, and that tearful displays are facilitated at the neural level. Collectively, the results thus far demonstrate a consistent picture that responses to tears have a biological basis. However, thus far I have predominantly focused on *what* tearful displays communicate, with a focus on sadness, intensity, and valence. However, numerous studies have demonstrated that tears also elicit support and empathy from observers (Hareli & Hess, 2012; van de Ven, Meijs, & Vingerhoets, 2017). It is yet to be determined whether empathic responses to tearful displays can be indexed using psychophysiology. Specifically, the purpose of this chapter is to explore the role of the mirror neuron system in responding to tearful faces. Mirror neurons were chosen to explore empathy and tears, as they are proposed to be the underlying neural mechanism for empathy in humans (Gallese, 2001).

6.2 Publication Status

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6.3 Author Contributions

Krivan – Conceptualization, Methodology, Software, Formal analysis, Investigation, Project administration, Resources, Software, Visualization, Writing: original draft, review & editing.[4]

Caltabiano – Supervision

Cottrell – Supervision, Conceptualization.

Thomas – Supervision, Writing: review & editing.

[4] These author contributions are according to the Neuropsychologica CRediT statement

6.4 Manuscript

6.4.1 Abstract

Tears are a facial expression of emotion that readily elicit empathic responses from observers. It is currently unknown whether these empathic responses to tears are influenced by specific neural substrates. The EEG mu rhythm is one method of investigating the human mirror neuron system, purported to underlie the sharing of affective states and a facilitator of social cognition. The purpose of this research was to explore the mu response to tearful expressions of emotion. Sixty-eight participants viewed happy and sad faces, both with and without tears, in addition to a neutral control condition. Participants first completed an emotion discrimination task, and then an imitation condition where they were required to mimic the displayed expression. Mu enhancement was found in response to the discrimination task, whilst suppression was demonstrated in response to the imitation condition. Examination of the suppression scores revealed that greater suppression was observed in response to happy-tear and sad tear-free expressions. Planned contrasts exploring suppression to neutral faces revealed no significant differences between emotional and neutral conditions. The mu response to neutral expressions resembled that of the happy-tear and the sad tear-free conditions, lending support to the idea that ambiguous emotional expressions require greater sensorimotor engagement. This study provides preliminary evidence for the role of the mirror neuron system in discerning tearful expressions of emotion in the absence of context.

Keywords: adult crying, mirror neurons, face perception, EEG, tears

6.4.2 Introduction

Tears are a facial expression of emotion which capture attention. When we witness another cry, their tears typically elicit strong emotion in ourselves. Tears are a universally recognised expression of emotion that readily elicit prosocial responses from observers

(Hareli & Hess, 2012; van de Ven et al., 2017). These prosocial responses are typically observed in experimental conditions through the use of self-report measures, where a tearful individual will elicit greater helping responses relative to the same individual without tears (Stadel et al., 2019; van de Ven et al., 2017; Vingerhoets et al., 2016; Zickfeld & Schubert, 2018). Despite the wealth of self-report research demonstrating this prosocial behaviour, we have a limited understanding of why tears elicit this response.

Why we care when others cry

The tear effect is a prominent argument for why we respond so strongly to another's crying. The tear effect proposes that individuals with tears are readily perceived as sadder than the same individual without tears (Provine et al., 2009). As such, the presence of tears on the face serves as a clear signal of sadness (Balsters et al., 2013). Thus, some have argued that adult emotional crying serves an evolutionary purpose—where the function of tears is to elicit helping responses (Balsters et al., 2013; Provine et al., 2009). Further evidence for the evolutionary role of tears stems from research exploring the physical properties of emotional tears (e.g. Frey, Desota-Johnson, Hoffman, and McCall (1981); Gelstein et al., (2011), but see also Gračanin, van Assen, Omrčen, Koraj, and Vingerhoets (2016)). Biologically, the presence of tears serves as an emotional handicap where the expresser experiences blurred vision and visibly signals distress, serving to reduce aggression in observers (Hasson, 2009). Given that adults typically cry around individuals who are close to them (Vingerhoets, van Geleuken, Van Tilburg, & Van Heck, 1997), tears serve as a signal for help from those who are witness to the emotional display (Vingerhoets et al., 2016; Zeifman & Brown, 2011). Recent self-report studies have further demonstrated that tears foster a sense of being moved, and feeling closely connected to an individual who is expressing this emotion (van de Ven et al., 2017; Vingerhoets et al., 2016; Zickfeld & Schubert, 2018). Thus, the role of tears appears to be that of a clear signal of sadness, designed to elicit support from observers through increased connectedness, likely facilitated by empathy.

Empathy is broadly defined as the ability to resonate or share the affective states of others (Hofelich & Preston, 2012). Such a broad account of empathy encompasses two overarching components including: empathic concern or 'I feel as you feel', and cognitive empathy 'I understand how you feel' (Seibt et al., 2015). Traditionally, empathy has been measured through the use of self-report inventories (Neumann, Chan, Boyle, Wang, & Westbury, 2015). Increasingly, researchers are adopting a psychophysiological approach to validate self-report measures (Larsen et al., 2008), which can be prone to bias and social desirability (Paulhus & Vazire, 2009). For the field of empathy research, this change in research focus was facilitated by the discovery of mirror neurons, which are believed to be the neurological basis of empathy (Gallese, 2001).

Mirror neurons

Mirror neurons are the proposed underlying neural mechanism for empathy in humans (Gallese, 2001). The role of mirror neurons as a facilitator of empathy stems from the simulation theory of action understanding (Gallese & Goldman, 1998). The simulation theory of action understanding posits that observing another individual performing an action will activate the observer's own motor system to facilitate understanding (Gallese & Goldman, 1998). Mirror neurons, first discovered through single electrode recording in the motor cortex of the Macaque monkey, are neurons that respond to both the observation and the execution of actions (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992). The discovery that the same neurons were involved in both perception and action strengthened the belief that there was a shared neural circuit for observation of another and experience by oneself (Keysers & Perrett, 2004). Critically, it was determined that some mirror neurons code not only for the occurrence of an action, but also the meaning of the action (Iacoboni et al., 2005). This finding indicates that the function of mirror neurons is to facilitate understanding of others (Oberman & Ramachandran, 2009). Only one study has demonstrated the presence of mirror neurons at the single cell level in humans (Mukamel et al., 2010); however, psychophysiological techniques such as electroencephalography (EEG) (Hogeveen, Chartrand, & Obhi, 2015; Keuken et al., 2011; Peled-Avron, Goldstein, Yellinek, Weissman-Fogel, & Shamay-Tsoory, 2017; Perry et al., 2010; Pineda & Hecht, 2009; Yang et al., 2009), and neuroimaging or functional magnetic resonance imaging (fMRI) (Calder et al., 2000; Kaplan & Iacoboni, 2006; Leslie et al., 2004; Saarela et al., 2006; Wicker et al., 2003) are increasingly being used to explore the functions of the human mirror neuron system.

Mu suppression

EEG has been used to explore mirroring by measuring the amount of desynchronization, or suppression, in the mu rhythm. The mu rhythm is typically characterised as 8-13Hz activity in the alpha band, and is typically maximal over sensorimotor electrode sites (Hobson & Bishop, 2016; Karakale et al., 2019; Moore et al., 2012; Schomer, 2007). As observation of biological action is a visual process, there has been concern as to whether the sensorimotor mu rhythm might be confounded by attentional alpha (Hobson & Bishop, 2017). To provide a control condition, mu suppression studies are increasingly analysing the same frequency bands at occipital electrode sites, which allows for examination of the role of attention to visual stimuli (Hobson & Bishop, 2016; Hoenen, Schain, & Pause, 2013; Karakale et al., 2019). Although suppression responses originally extended the research into action understanding (Muthukumaraswamy et al., 2004; Woodruff & Maaske, 2010; Woodruff et al., 2011), there has since been an expansion to encompass a greater understanding of the social mind and the mechanisms behind affective sharing.

Relationship with empathy

The relationship between mirror neurons and empathy has been predominantly explored through correlations with traditional self-report measures of empathy (Silas, Levy, Nielsen, Slade, & Holmes, 2010; Woodruff et al., 2011). The Interpersonal Reactivity Index (IRI; Davis, 1980) is typically used to examine the relationship between mirror neurons and empathy, as it has a specific perspective taking (PT) subscale, which targets cognitive empathy (Joyal, Neveu, Boukhalfi, Jackson, & Renaud, 2018; Woodruff et al., 2011). However, other studies have demonstrated that mu suppression is also related to the empathic concern (EC) and personal distress (PD) subscales (Cheng et al., 2008; DiGirolamo, Simon, Hubley, Kopulsky, & Gutsell, 2019; Perry et al., 2010). A negative correlation between self-report empathy (indexed by EC and PT subscales) and mu suppression is observed, demonstrating that as empathy increases, so does the amount of suppression (Woodruff et al., 2011). However, some studies have failed to find a relationship between suppression and self-reported empathy (DiGirolamo et al., 2019; Moore et al., 2012), or observed a relationship in the inverse direction of what is typically expected (Perry et al., 2010; Woodruff & Klein, 2013). Furthermore, where there are significant correlations reported in the literature, these are typically a moderate to small effect size (Hobson & Bishop, 2017). Thus, it remains unclear whether suppression scores are related to traditional self-report measures of empathy, and further research is required to investigate the relationship between these two measures.

Facial expressions

The sharing of affective states is a further extension of the role that mirror neurons play in empathic responding. Research using fMRI has demonstrated that the same regions are activated during the personal experience of emotion and witnessing another experience that same emotion for disgust (Wicker et al., 2003) and pain (Cheng, Yang, Lin, Lee, & Decety, 2008; Saarela et al., 2006; Singer et al., 2004). Furthermore, overlapping facial processing regions are activated when individuals are asked to infer emotions from another's face, and when performing a facial movement themselves (Gallese et al., 2007; Niedenthal et al., 2010). van der Gaag et al. (2007) concluded that increased mirroring responses to emotional faces were demonstrated in emotion processing regions (such as the inferior frontal operculum), whereas greater sensorimotor mirroring was demonstrated in response to neutral expressions. Thus, the research from fMRI studies is inconclusive, in that some studies have demonstrated increased activation in response to emotion, whereas other studies demonstrate increased responses to neutral expressions. Recently, this debate about the role of sensorimotor mirroring has been addressed using EEG and examination of the mu rhythm.

Mu suppression responses to facial expressions and affiliative displays have been demonstrated in human adults (Ensenberg et al., 2017; Karakale et al., 2019; Moore & Franz, 2017) and infants (Rayson, Bonaiuto, Ferrari, & Murray, 2016), as well as infant neonates (Ferrari et al., 2012; Vanderwert et al., 2015). Moore et al. (2012) concluded that although disgust facial expressions elicited a rapid increased mu suppression in the first 500 ms of viewing, happy facial expressions demonstrated a greater sustained suppressive response across time. This finding is in line with the emotion literature that details a happy face advantage when processing emotional facial displays (see Becker and Srinivasan (2014) for a recent review). Happy facial expressions are typically classified faster and with greater accuracy in emotion recognition tasks relative to other emotions (Calvo & Lundqvist, 2008; Leppänen & Hietanen, 2004). Furthermore, smiles are typically mimicked more than other expressions by conversational partners (Hess & Bourgeois, 2010). A common theory for this advantage is that happy faces signal affiliative intent and foster approach behaviours (Davidson, 1992; Stins et al., 2011; van Peer, Rotteveel, Spinhoven, Tollenaar, & Roelofs, 2010). Thus, as mirror neurons are proposed to be a method for sharing others' affective states, it is intuitive that there would be greater sharing of affiliative emotions. Research in neonatal rhesus monkeys has demonstrated that mu rhythm desynchronization is sensitive to affiliative facial gestures, providing evidence for the role of mirror neurons in determining social relevance (Vanderwert et al., 2015). Thus, the mu rhythm appears to be sensitive to emotional content depicted in facial displays, as well as the social relevance of the display.

While some studies have demonstrated that emotional faces typically elicit greater suppression responses (Moore et al., 2012; Moore & Franz, 2017), others have emphasised the role of the sensorimotor cortex in determining ambiguous displays (Karakale et al., 2019; van der Gaag et al., 2007). Karakale et al. (2019) in a study examining responses to observing dynamic facial displays concluded that neutral expressions elicited greater sensorimotor mirroring when compared to emotional expressions. Relatedly, a magnetoencephalography (MEG) study by Popov et al. (2013) demonstrated that sensorimotor suppression was maximal during the pre-recognition period for dynamic emotional expressions. Furthermore, once the expression reached a point where the emotion was recognisable, this pattern of responding was reversed. Together, these studies provide evidence that the role of mirror neurons in the sensorimotor cortices is to facilitate understanding of ambiguous expressions, as was observed in the fMRI study by van der Gaag et al. (2007).

Thus, it is yet to be determined what type of emotional faces elicit greater modulation of the mu rhythm. When considering the behavioural research to date exploring perceptions of tearful expressions, there is consistent evidence that tears serve as a clear marker of sadness (Balsters et al., 2013; Ito et al., 2019; Reed et al., 2015), and promote approach-related behaviours relative to avoidance (Gračanin et al., 2018). Thus, if the affiliative account of mirror neurons is correct, we would anticipate greater mu suppression responses to sad tearful expressions. However, limited empirical research has examined the way that tears are perceived on expressions of joy (Reed et al., 2015). In the absence of context, the presence of tears on a happy face is likely ambiguous, as it could signal 'tears of joy' or 'smiling through sadness'. Thus, in keeping with the affiliative account of mirror neurons, we would anticipate greater mu suppression responses to happy faces without tears, and sad faces with tears – both clear depictions of approach-related emotion. However, if the ambiguity account of mirror neurons is correct, we would expect the opposite pattern of results. To date, research investigating the modulation of the mu rhythm in response to facial expression has used observation-related tasks (Cooper, Simpson, Till, Simmons, & Puzzo, 2013; Gros, Panasiti, & Chakrabarti, 2015; Joyal et al., 2018; Moore & Franz, 2017). As the core premise of mirror neurons is that activation occurs during both observation and execution, our research seeks to fill this gap through the inclusion of both observation and execution related facial task conditions.

Current research

We aimed to determine whether the mu rhythm is sensitive to the presence of tears on facial expressions of emotion. In order to align with the key considerations for mu suppression research raised by Hobson and Bishop (2017) we used an execution condition to examine differences between production and perception; a within trial baseline; and examined alpha suppression at occipital electrode sites. Specifically, we hypothesised that mu suppression responses would be the most pronounced for the happy and sad-tear faces in accord with approach behaviours facilitating mirroring. Similarly, as compared to a neutral face control group, neutral faces would evoke the least suppression relative to other emotional faces. Finally, we predicted that mu suppression would correlate with self-reported empathy as assessed by the Interpersonal Reactivity Index (IRI).

6.4.3 Method

6.4.3.1 Participants

The total sample consisted of 74 undergraduate students (47 females, M_{age} = 25.32, SD_{age} = 8.53 years). Participants self-identified as right-handed, and handedness was assessed using an extension of the Oldfield Handedness Inventory (*M* = 79.48, *SD* = 18.15; Oldfield, 1971). All participants reported being healthy and free from neurological disorders, with normal or corrected-to-normal vision, and minimized the use of stimulants in the two hours prior to the experiment. All participants gave written informed consent, in accord with the Declaration of Helsinki and were compensated with course credit. Ethical approval was obtained from the James Cook University Human Research Ethics committee. We aimed to recruit a sample of 60 participants in accord with prior research that recommended this sample size for achieve adequately powered mu suppression research (Fox et al., 2016; Hobson & Bishop, 2016).

6.4.3.2 Materials

Stimuli consisted of 10 male and 10 female faces, which portrayed happy, sad, and neutral facial expressions, taken from the Karolinska Directed Emotional Faces database (KDEF; Lundqvist, Flykt, & Öhman, 1998). Each face was cropped using an ellipsis tool to remove hair, clothing, and ears to ensure the face only contained the elements necessary for determining emotional expression. Tears were digitally added to the happy and sad images, with online photo editor software (http://funny.pho.to/tears-effect/), to create the happy-tear and sad-tear stimuli.

The stimuli were selected from a larger pool of 192 images, which were piloted using an independent group of 22 participants (19 females, M_{age} = 24.6 years, SD_{age} = 9.49). Pilot participants rated the images using visual analogue scales on emotional expression intensity, and valence of the expression. The 10 best-matched male and female faces across stimulus categories were selected for the main study (see Table 6.1).

Table 6.1

Mean (SDs) Pilot Intensity and Valence ratings for the 20 Facial Identities

		No Tears			Tears	
		Happy	Sad	Neutral	Happy	Sad
Intensity	Female	.89 (.09)	.77 (.14)	-	.81 (.09)	.84 (.12)
	Male	.90 (.08)	.76 (.15)	-	.82 (.13)	.84 (.13)
Valence	Female	.87 (.13)	.17 (.12)	.41 (.12)	.77 (.18)	.14 (.12)
	Male	.87 (.12)	.17 (.13)	.43 (.09)	.75 (.20)	.16 (.14)

Note. Higher intensity ratings reflect greater perceived intensity (e.g. more intensely happy, or more intensely sad), and valence ranged from 0 (negative) to 1 (positive). Neutral faces did not have intensity ratings.

Empathy was assessed using the IRI (Davis, 1980). The IRI is comprised of 24 items made up of 4 subscales: perspective taking (PT), personal distress (PD), empathic concern (EC), and fantasy. Prior research exploring correlations between mirror neurons and self-report empathy have predominantly focused on the PT, EC, and PD subscales (Cheng et al., 2008; DiGirolamo et al., 2019; Joyal et al., 2018; Perry et al., 2010; Woodruff et al., 2011). Following prior research, we did not include the fantasy subscale in our analyses, due to its focus on fictional characters. The PT subscale is used to assess one's ability to share another's perspective; the EC subscale is used to assess feelings of concern for others, and the PD subscale is used to determine the degree of discomfort when witnessing another's negative experiences. Each subscale contains 7 items, and participants are instructed to respond via a Likert scale ranging from 0 (does not describe me very well) to 4 (describes me very well). Subscale scores can range from 0 to 28 with higher scores indicating greater PT and EC abilities, and lower scores indicate a reduced propensity for PD. Reliability analysis of the three subscales revealed that the Cronbach's alphas obtained in our study (PT: $\alpha = .79$; EC: $\alpha = .80$; PT: $\alpha = .78$) were comparable to the original norming study (PT: $\alpha = .71$-.75; EC: $\alpha = .68$-.73; PT: $\alpha = .75$-.77; Davis, 1980).

6.4.3.3 Procedure

The experiment was conducted in a sound attenuated electromagnetically shielded room on a 24-inch Dell monitor. PsychoPy software (version 1.91.1) was used to present the stimuli. All facial images were presented in full colour against a black background. The experiment was conducted in two parts to examine both discrimination and execution. The task design was an extension of van der Gaag et al. (2007) and as in their experiment, the tasks were always presented in the same order, the discrimination task followed by the execution task, to ensure that participants were not biased during the discrimination task.

6.4.3.3.1 Discrimination task

Each trial followed the same experimental sequence. Participants received instructions for a delayed match-to-sample task on emotion (see Figure 6.1a), where images were presented in pairs and participants had to report via button press whether the emotions of the first and second image were the same or different. Participants were asked to make fast but accurate judgments and it was confirmed they understood it was a reaction time task. Only neural activity during the presentation of the first image was considered here, as it forms the basis for understanding emotion comprehension, without the motor planning involved in preparing for the reaction time task. The trial sequence began with the presentation of a fixation cross, which varied in length of presentation time between 2500 and 3500ms (fixation varied in blocks of 200 ms; see Figure 6.1a). We implemented a variable fixation cross length to avoid participants' anticipating the presentation of an image. We utilised white fixation crosses to denote between trial fixation, and grey fixation crosses to denote between image pair fixation. Image pairs were shown randomly, with each image being shown twice in the first position. After the presentation of the inter-stimulus fixation cross, on 50% of trials the second image presented was a match (i.e. the same emotion) as the first image. Finally, a response prompt was shown until a response was made, or for 2000 ms;

participants who took longer than 2000 ms were informed that their response was too slow. Prior to the testing phase, 10 practice trials were administered to familiarise participants with the procedure. Faces used during the practice trials were different to those used in the experimental trials. The experiment was conducted in blocks of 40 trials (~ 7 minutes), and each trial was followed by a 30 second break. After the participants completed this phase of the experiment, they were informed about the execution task.

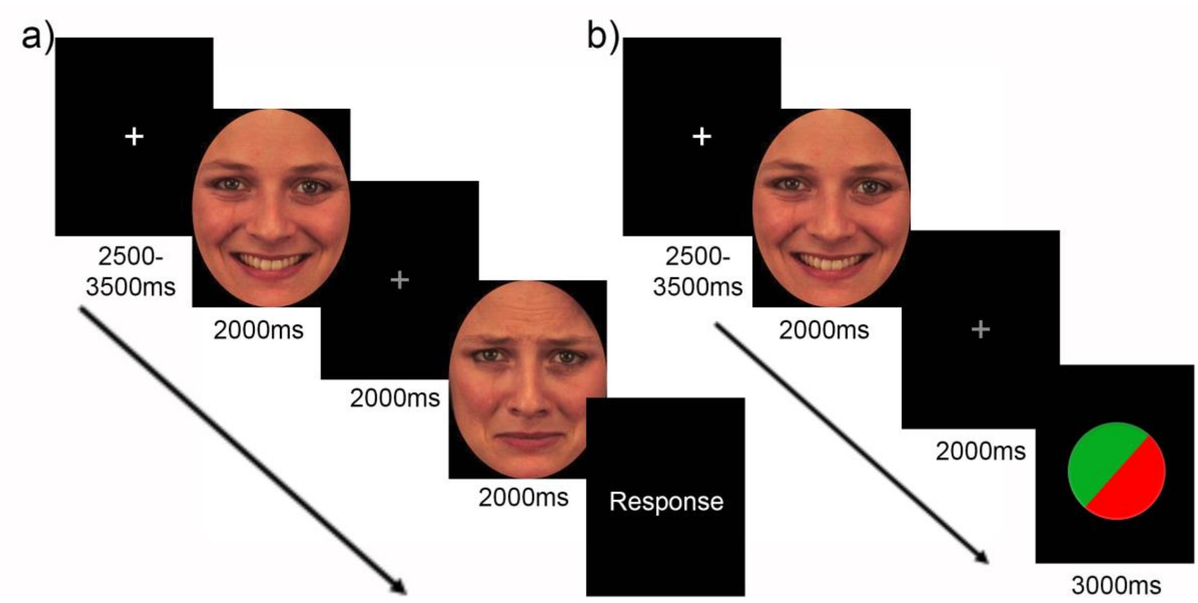

Figure 6.1. Experimental layout and timing of a) the discrimination task and b) the execution task. In the execution task the circle was completely green on go trials and completely red on no-go trials. KDEF stimulus in image is AF01.

6.4.3.3.2 Execution task

Participants were instructed that this task would follow a similar trial procedure to the previous task and would involve imitation of the emotional faces. The trials adopted an emotional go/no-go procedure, with participants instructed to reproduce the seen expression, or to inhibit all responses. Only the neural activity captured during the presentation of the image was analysed, as it allows for investigation of the neural responses associated with intention to imitate, without the motor movement artifact obtained during expression production. A go/no-go task was chosen to minimise mimicry during the presentation phase. Participants were instructed to keep a neutral expression during trials except for during the go phase. Trials began with a fixation cross, which was presented for between 2500 and 3500 ms (varied in blocks of 200 ms; see Figure 6.1b). Then, an emotional image was presented for 2000 ms, in randomised order. This image was followed by a grey fixation cross for 2000 ms, and then either a large green circle on go trials or a large red circle on no-go trials, which appeared for 3000 ms. As in the discrimination task, every image was shown twice, and 50% of the trials were go trials.

Once participants had completed both tasks, they completed the IRI. The IRI was always presented as the last component of the experiment to avoid priming participants about empathy. After participants had completed the experiment, we conducted a brief interview asking participants about what they thought the purpose of the study was, and how they believed they went in the tasks. After the interview, participants were debriefed and thanked for their participation.

6.4.3.4 EEG recording and analysis

EEG recording took place in an electromagnetically and acoustically shielded room. The EEG signal was recorded from 32 Ag/AgCl pin-type electrodes mounted in an elastic cap according to the international 10-20 system, with two additional electrodes placed behind each ear (i.e., mastoids). Eyeblinks were monitored using bipolar vertical EOG, with the electrodes attached to the infraorbital and supraorbital regions of the left eye. EEG and EOG were sampled using a Biosemi Active II system, with a 2048 Hz sampling rate.

All pre-processing steps were performed in Python using the MNE package (Gramfort et al., 2013). All pre-processing techniques were in accord with the technique outlined in Oberman, McCleery, Ramachandran, and Pineda (2007), and the script for analysing the data is available on Open Science Framework (https://osf.io/6c3eu/). Data was downsampled to 512 Hz, re-referenced to the average of the left and right mastoids. Next, the data was bandpass filtered between 0.1–30 Hz. The data was corrected for eyeblink artifacts using independent component analysis, which is included in the MNE package. The data was segmented into epochs ranging from 2000 ms pre-stimulus to 2000 ms post-stimulus, leading to epochs with time length $T = 4000$ ms. Next the data was inspected for artifacts at the central and occipital electrode sites of interest (i.e. C3, C4, O1, O2), and segments were rejected if the EEG signal varied with a Peak to Peak difference of 100µV. Participants were removed from the analysis if more than 60 trials were rejected (i.e. 30% of the 200 total trials), in either the discrimination (average trials removed: $M = 9.68$, $SD = 14.78$) or execution ($M = 9.89$, $SD = 17.03$) conditions. The number of trials removed did not differ between the two tasks, $t(74) = -.117$, $p = .907$. For each cleaned segment the integrated power in the 8–13Hz range was computed using a fast Fourier transform with a 1024 cosine window. Mu power was calculated at the central electrode sites by computing a ratio score where the mu power during stimulus presentation was divided by the mu power during the baseline (i.e. the fixation cross). A ratio was chosen to control for individual differences in scalp thickness. As ratio data are non-normal a log transform was applied. A log ratio of less than zero indicates suppression of mu power, whereas positive values indicate enhancement, and zero values reflect neither suppression nor enhancement. In addition, occipital electrodes O1 and O2 were analysed as an index of alpha activity.

6.4.4 Results

6.4.4.1 Data exclusions

Of the 74 participants recruited for this study, 1 participant was excluded for failing to follow task instructions, and a further 5 participants were excluded based on the EEG artifact rejection criteria. Additionally, one participant failed to complete the IRI and as such they were excluded from the correlational analyses.

6.4.4.2 Behavioural results

The percentage of correctly matched expressions during the discrimination task were analysed to ensure participants were maintaining attention and that the stimuli were perceived in a consistent manner. As indicated in Table 6.2, participants performed above chance when matching emotional expressions, with a mean accuracy of 86.08% (SD = 7.73). We conducted paired-samples t-tests to explore whether classification accuracy differed between the tear and tear-free conditions, based on each emotion. Tear-free happy faces were classified with greater accuracy than happy-tear faces, $t(67) = 3.468$, $p < .001$, $d = .421$, $BF_{10}=27.677$. Conversely, sad-tear faces were classified with significantly greater accuracy than sad faces without tears, $t(67) = 3.004$, $p = .004$, $d = .364$, $BF_{10}=7.880$. Collectively, these results demonstrate that happy faces without tears and sad-tear faces are easier to classify than their counterparts. As the task relied on the participants' perception about whether the face pairings were the same emotional expressions or different emotional expressions, we anticipated some participants would believe the happy-tear condition reflected either tears of joy or smiling through sadness, or that tearful sadness could be distinct from sadness without tears. Thus, we did not exclude any individual trials based on accuracy, to maintain as much EEG data as possible.

Table 6.2

One Sample t-test Results of Accuracy Scores per Emotion Condition during the Discrimination Task.

	Mean	*SD*	*t*	*p*	*d*	$Log(BF_{10})$
Happy	89.89	9.28	35.45	<.001	4.299	95.836
Sad	82.33	9.77	27.29	<.001	3.310	79.716
Happy-tear	87.10	11.52	26.59	<.001	3.224	78.132
Sad-tear	85.10	8.59	33.68	<.001	4.084	92.625
Neutral (Control)	85.99	8.93	33.25	<.001	4.084	91.835

Note. Compared against chance level classification (50% accuracy). We used $Log(BF_{10})$ Bayes factors for this table to aid interpretation of the large Bayes factors.

6.4.4.3 EEG results

Separate 2 (task: discrimination, execution) x 2 (hemisphere: left, right) x 2 (tears: tears, no tears) x 2 (emotion: happy, sad) repeated-measures ANOVAs were conducted at central and occipital sites to analyse the suppression index. At central electrodes we investigated whether the mu rhythm was significantly different from 0 using one sample *t*-tests. We also conducted planned contrasts using the neutral face control group to examine whether neutral faces elicited significantly less suppression than other emotion categories. Finally, we conducted correlations to explore the relationship between self-report empathy and mu suppression. All follow-up analyses were corrected using the Bonferroni adjustment for multiple comparisons. Bayes factors were calculated in JASP (2019). To classify the evidence for the Bayes factors we used the interpretation provided by Lee and Wagenmakers (2014). When exploring Bayesian interactions, we used the effects across matched models' analysis. The mean mu modulation for each emotion type at the central electrode sites for the discrimination, and execution tasks are shown in Table 6.3.

Table 6.3

Mean (SD) Mu Modulation at Central Electrodes for each Emotion.

	Happy	Sad	Happy-tear	Sad-tear	Neutral
Discrimination					
Left hemisphere	.068 (.376)	.075 (.357)	.039 (.403)	.026 (.401)	.076 (.401)
Right hemisphere	.105 (.370)	.133 (.377)	.119 (.410)	.074 (.397)	.129 (.390)
Averaged hemisphere	.087 (.343)	.104 (.343)	.079 (.376)	.050 (.368)	.103 (.364)
Execution					
Left hemisphere	-.092 (.343)	-.146 (.384)	-.158 (.391)	-.123 (.365)	-.191 (.311)
Right hemisphere	-.092 (.333)	-.124 (.356)	-.125 (.362)	-.120 (.388)	-.138 (.302)
Averaged hemisphere	-.092 (.311)	-.135 (.344)	-.141 (.352)	-.122 (.355)	-.165 (.276)

6.4.4.3.1 Central electrodes

As predicted, we found a significant main effect of task, $F(1,67) = 27.309$, $p < .001$, $\eta_p^2 = .290$, BF_{incl}=7.361e+31, with the execution task eliciting greater mu suppression compared to the discrimination task. Critically, a task by tears by emotion interaction was observed, $F(1,67) = 4.582$, $p = .036$, $\eta_p^2 = .064$, BF_{incl}=.628; see Figure 6.2 for a graphical depiction of this interaction.

Figure 6.2. The interaction effect between task, emotion, and tears at the central electrode sites (averaged C3 and C4). a) depicts the mu enhancement observed during the discrimination task, and b) depicts mu suppression observed during the execution task. Error bars are SEM.

To follow-up these interactions, separate ANOVAs were conducted for the discrimination and execution tasks. For the central electrode sites during the discrimination task, scores displayed mu enhancement, not suppression. Mu was significantly enhanced (i.e. significantly greater than 0) at right hemisphere C4, $t(67) = 2.609$, $p = .011$, $d = .316$, $BF_{10}=3.026$; but not left hemisphere C3, $t(67) = 1.350$, $p = .182$, $d = .164$, $BF_{10}=.316$. There were no significant main effects or interactions observed during the discrimination task, *F's* < 3.645, *p's* > .061. However. there was a marginally significant main effect of hemisphere, $F(1,67) = 3.622$, $p = .061$, $\eta_p^2 = .051$, $BF_{incl}=9.175$, where there was greater enhancement observed over right hemisphere electrode C4 ($M = .108$, $SE = .043$), compared to left hemisphere electrode C3 ($M = .052$, $SE = .043$). There was also a marginally significant main effect of tears, $F(1,67) = 3.645$, $p = .061$, $\eta_p^2 = .052$, $BF_{incl}=.383$, where tear-free expressions

(M = .095, SE = .041) elicited greater enhancement than tearful expressions (M = .064, SE = .041).

For the execution task, significant suppression was observed over the left C3, $t(67) = -3.724$, $p < .001$, $d = -.452$, BF_{10}=58.256 and right C4, $t(67) = -3.188$, $p = .002$, $d = -.387$, BF_{10}=12.776, hemisphere electrodes. There was a marginally significant emotion by tears interaction effect, $F(1,67) = 3.609$, $p = .062$, $\eta_p^2 = .051$, BF_{incl}=.653 (see Figure 2b). Although this finding was not significant, we conducted follow-up analyses to test for our emotion specific hypotheses. Follow-up paired *t*-tests revealed no significant differences in the amount of suppression elicited between the happy and happy-tear faces, $t(67) = 1.876$, $p = .065$, $d = .228$, BF_{10}=.695; or the sad or sad-tear faces, $t(67) = -.529$, $p = .598$, $d = -.064$, BF_{10}=.152. No other main effects or interactions were significant during the execution task, $F's < 1.574$, $p's > .214$.

Planned contrasts were conducted to compare the neutral face control condition to the four emotional expression conditions at each central electrode site. As prior analyses indicated that there was only enhancement during the observation task, we did not include this condition in follow-up analyses. For the execution task, as there were no hemisphere effects in prior analyses, we averaged across the left and right hemisphere electrodes. The neutral face condition was not significantly different from any of the emotional categories, $F(1,67) = .2.866$, $p = .095$, $\eta_p^2 = .041$. Rather, neutral faces seemed to elicit larger suppression relative to the emotional conditions (see Figure 3). To further investigate the contrast results, we conducted Bayesian hypothesis testing to determine the degree of similarity between the neutral control condition and the other emotion conditions. There was moderate support for the null hypothesis that there was no significant difference between the neutral condition and the tears-happy (BF_{01}=5.648) and sad tear-free conditions (BF_{01}=4.552). When comparing the neutral condition to the happy condition and the sad-tear condition, there was only anecdotal evidence for the null hypothesis (BF_{01}=.298, and BF_{01}=3.286, respectively).

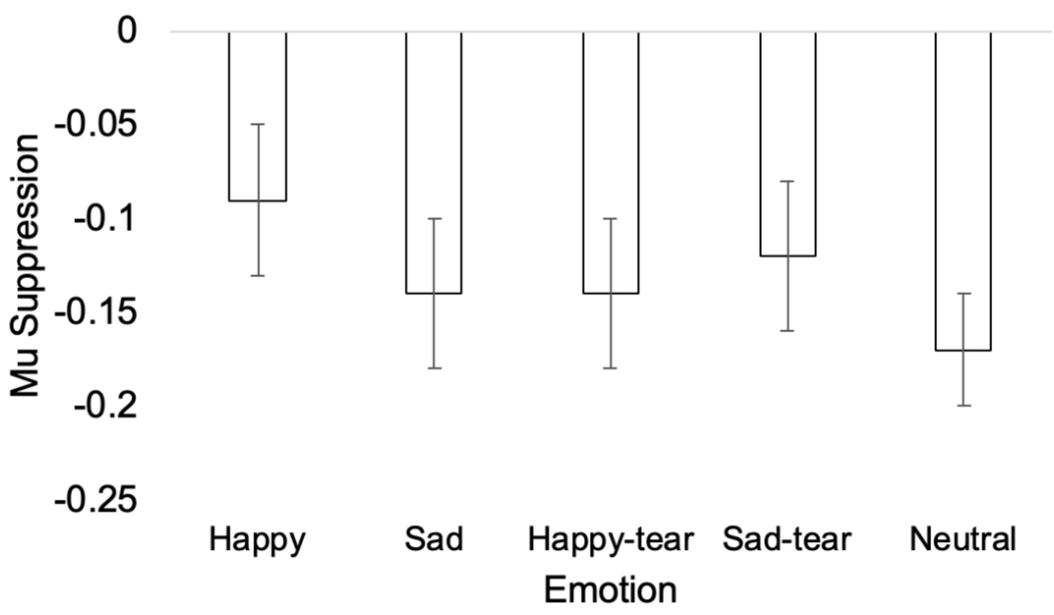

Figure 6.3. Planned contrast between the emotional faces and the neutral control condition during the execution task at central electrodes. Error bars are SEM.

6.4.4.3.2 Occipital electrodes

As mu suppression is calculated within the alpha band, occipital electrode sites were also investigated to ensure effects were not driven by attentional alpha. Critically, we observed no task related main effects or interactions, *F's* < 1.589, *p's* > .212. The repeated-measures ANOVA at occipital sites yielded a significant main effect of hemisphere, $F(1,67) = 6.254$, $p = .015$, $\eta_p^2 = .085$, BF_{incl}=76.205, where suppression was greater over the right hemisphere (*M* = -.396, *SE* = .051) compared to the left (*M* = -.332, *SE* = .051). There was also a significant hemisphere by tears interaction, $F(1,67) = 4.524$, $p = .037$, $\eta_p^2 = .063$, BF_{incl}=.117. To follow-up this interaction, we collapsed across task and emotion, and demonstrated that tearful faces did not yield increased suppression at left, $t(67) = -.382$, $p = .704$, $d = .046$, $BF_{10}=.143$ or right hemisphere electrode sites, $t(67) = -1.698$, $p = .094$, $d = -.206$, $BF_{10}=.518$.

6.4.4.4 Correlations between central electrodes and self-report empathy

Correlations were conducted to examine whether central electrode suppression was related to self-report empathy as assessed using the PT, EC, and PD subscales of the IRI. As in the contrast analyses, we limited our correlations to the execution condition and collapsed across hemisphere. There were no significant correlations between averaged mu suppression and the PT: $r(66) = .029$, $p = .818$, $BF_{01}=6.387$; EC: $r(66) = .141$, $p = .255$, $BF_{01}=3.477$; or the PD: $r(66) = .036$, $p = .772$, $BF_{01}=6.292$, subscales.

6.4.5 Discussion

The current study aimed to determine whether modulation of the mu rhythm is sensitive to the presence of tears on happy and sad expressions of emotion. Converse to what we predicted, we observed the greatest mu suppression in response to neutral, happy-tear, and sad tear-free expressions. This provides support for the ambiguity account proposed by Karakale et al. (2019), that ambiguous facial expressions require greater sensorimotor engagement to determine the meaning of the expression. Additionally, we demonstrated that task-related effects and interactions were only significant at central electrode sites. This finding indicates that the activity indexed at occipital electrode sites was not sensitive to task-related differences, providing support that sensorimotor mu is distinct from occipital alpha. Finally, we failed to observe any significant correlations between mu suppression and self-report empathy as indexed by the IRI.

Greater sensorimotor activation in response to ambiguous expressions has been noted in EEG (Karakale et al., 2019) and fMRI (van der Gaag et al., 2007) literature. To isolate the mu activity involved in motor planning, we conducted a stop-go-task where participants were instructed to either mimic a previously shown expression, or to inhibit all responses. During this execution task, we observed that happy-tearful faces elicited marginally greater suppression than happy faces. Conversely, though not statistically significant, sad tear-free faces elicited greater suppression than sad-tearful faces. Furthermore, both the happy-tearful and sad tear-free expressions elicited suppression levels that were similar to those observed in response to neutral expressions. Given that neutral expressions are ambiguous in emotional valence, our study provides further support for the conclusion that more ambiguous expressions require greater sensorimotor mirroring (Karakale et al., 2019; van der Gaag et al., 2007).

Further support for this conclusion is provided by the behavioural data. Moreover, participants were *less* accurate at classifying happy-tear faces compared to happy faces without tears. Conversely, participants were *more* accurate at classifying sad-tear faces relative to sad faces without tears. Collectively, these results demonstrate that happy faces without tears and sad-tear faces are easier to classify than their counterparts. Therefore, we believe that the reduced classification accuracy is indicative of more ambiguous stimuli. Further support for this conclusion can be found through previous behavioural studies, which have investigated the tear effect, where tears make an expression seem sadder than the same expression without tears (Ito et al., 2019; Provine et al., 2009; Reed et al., 2015), and serve to resolve the ambiguity of a face (Balsters et al., 2013). Furthermore, recent research has explored the tear effect on happy expressions of emotion and found that happy faces with tears are responded to slower and rated with lower positive valence as opposed to the same face without tears (Krivan et al., 2020). In this way, the incongruous features of a smile (i.e. a distinctive marker of happiness), paired with tears (i.e. a distinctive marker of sadness), increase the time taken to classify a happy face as happy (Calvo et al., 2012). Therefore, this increased response time taken to respond to happy expressions with tears, coupled with the reduction in positive valence, indicates that happy tearful expressions—in the absence of context—are more ambiguous than the same tear-free expressions.

Taken together, our results offer the most support for the ambiguity hypothesis, where more ambiguous emotional expressions require greater sensorimotor engagement. It should be noted however, that when examining our effect sizes and Bayes factors for comparisons between our emotion conditions, we typically only provided weak or anecdotal evidence for our results. Therefore, the effects that we are reporting are quite small, and as such the role of tears in influencing sensorimotor mirroring responses in static displays is small as well. However, in our study we used static, posed facial expressions of emotion, and added tears which were identical on all facial displays. Mirror neurons have primarily been explored through dynamic biological displays, where the same neurons are activated during observation and execution of actions (Gallese et al., 1996; Rizzolatti et al., 1996). Furthermore, several studies have demonstrated that mirror neurons are sensitive to the goal or the intent of the action performed (di Pellegrino et al., 1992; Iacoboni et al., 2005). Thus, our use of static facial stimuli and reliance on participants inferring facial movement, is possibly a contributor to our small effects.

The use of static stimuli and reliance on participants inferring facial movement is also a potential factor contributing to the enhancement effects observed during the discrimination task. Although our study is the first to explore mu suppression and the execution of facial expressions, several other studies have demonstrated mu suppression during observation of facial stimuli (Cooper et al., 2013; Ensenberg et al., 2017; Gros et al., 2015; Joyal et al., 2018; Karakale et al., 2019; Moore et al., 2012; Moore & Franz, 2017; Pineda & Hecht, 2009). Of these studies, the majority have used dynamic as opposed to static stimuli facial stimuli (see Pineda and Hecht (2009) and Moore et al. (2012) for static examples). Although some studies have demonstrated greater activity in the mirror neuron system during static displays as opposed to dynamic displays (Enticott et al., 2008), others have reported the opposite (Angelini et al., 2018; Buccino et al., 2001). Therefore, the role of sensorimotor mirroring in response to both static and dynamic facial displays requires further investigation. Furthermore, prior research has demonstrated that under some conditions mu is suppressed in response to faces, whereas, in others, enhancement is elicited (Cooper et al., 2013; Gros et al., 2015). For example, Gros et al. (2015) demonstrated that faces associated with high reward conditions elicited suppression, whereas faces associated with low reward elicited enhancement. Additionally, Cooper et al. (2013) found that observing happy expressions elicited suppression over left hemisphere central electrodes, but enhancement over the right hemisphere. Therefore, it does seem that in some instances, enhancement rather than suppression is demonstrated to facial displays. Thus, further research is needed, using both dynamic and static displays, to determine under what conditions facial expressions elicit mu suppression.

An important consideration in mu suppression research is the ability to disentangle mu from other perceptual processes such as occipital alpha (Hobson & Bishop, 2017). In our study we observed significant task-related effects at the central electrode sites, but not at occipital electrode sites. Put differently, regardless of the task condition, alpha was consistently suppressed relative to baseline for emotional face stimuli. This finding indicates that the mu suppression observed at central electrode sites is distinct from occipital alpha, otherwise these effects would also be present at the occipital electrode sites. Additionally, a hemisphere effect was evidenced at right hemisphere O2, relative to left hemisphere O1, in line with a right hemisphere advantage in processing emotion (Dimberg & Petterson, 2000; Gainotti, 2012). Therefore, despite the conflicting results observed in our discrimination and execution tasks, the activity indexed at the central sites was distinct from that of occipital alpha.

In considering the relationship between mu suppression and empathy, we predicted that greater mu suppression scores would be correlated with scores on the PT, PD and EC subscales of the IRI. This hypothesis was not supported as the correlations were not significant. However, our null results are in line with other research exploring the relationship between mu suppression and self-reported empathy. Several studies have demonstrated that there is inconsistent evidence for the relationship between mu suppression and self-report empathy. Woodruff et al. (2011) demonstrated a weak to moderate negative relationship between self-reported empathy and mu suppression, whereas others have demonstrated a positive relationship (Cheng et al., 2008; Yang et al., 2009). Additionally, other high powered studies have failed to observed a significant relationship between self-report empathy and mu suppression (DiGirolamo et al., 2019; Perry et al., 2010). These inconsistent findings indicate that the relationship between the IRI and the mirror-neuron system as indexed by sensorimotor mu suppression requires further research to determine whether the constructs are mapping the same types of empathic responses.

There are some limitations and recommendations which we believe could be better addressed in follow-up studies. Firstly, when investigating the enhancement effects observed in our study, we explored the mu power of the baseline and stimulus conditions separately (see Appendix A). We observed—not significant after Bonferroni correction—that the mu power during the presentation of the fixation cross differed between the two task conditions. Hobson and Bishop (2017) emphasised the importance of using comparable baseline techniques across task conditions, and we further demonstrated that even when the baselines are identical (i.e. a static fixation cross), there is still the potential for baseline differences to occur.

In addition, we adapted a novel experimental paradigm developed by van der Gaag et al. (2007), and modified this paradigm for EEG, which allowed for the exploration of observation and execution planning in a single paradigm. This adaptation provides an important advancement in the mu response to facial expressions research, given that prior research focuses on observation-based designs. Further research should adopt methodologies that explore both observation and execution in response to faces, as in the study described herein. We believe that our paradigm could be further improved through the use of facial electromyography, which would allow for the exploration of the spontaneous muscle activation during the viewing of emotional expressions (Dimberg et al., 2000).

Additionally, there were some limitations in the stimuli chosen for our experiment. We chose to use a standardised set of static emotional displays, and digitally added tears. This technique ensured that there was as little difference between the tear-free and the tearful displays as possible. However, static expressions are typically only presented in laboratory settings, and thus are not as effective as dynamic displays. As mu is suppressed in response to movement, the use of a dynamic stimulus will aid in strengthening the validity of the present findings. Finally, it must also be cautioned that the perception of emotional tears as genuine or false influences the way that people respond to tearful expressions—wherein displays which are perceived as false do not receive pro-social responses (Krivan & Thomas, 2020; Picó et al., 2020; Roeyen, Riem, Tončić, & Vingerhoets, 2020). Therefore, the use of authentic crying stimuli is a worthy avenue of future investigation, which could be the key to determining the role of empathy in responding to emotional expressions.

Our study aimed to further our understanding of the way that mu is modulated in response to tearful facial expressions of emotion during both discrimination and execution conditions. We provide support for the use of mu suppression to index mirror neuron system involvement in the sharing of facial expressions—though caution that when static posed displays are used as stimuli this effect is weak and largely influenced by task conditions. Moreover, the present findings provide evidence of a complex relationship between sensorimotor representation of expressions and the understanding of faces. Primarily, we have provided further support for the theory that ambiguous emotional expressions require greater sensorimotor engagement to interpret emotional expression. Furthermore, we have demonstrated this support through the novel approach of using tearful facial expressions whilst also demonstrating the tear effect at a psychophysiological level. The representation of tears at the neural level we have observed in our study provides a psychophysiological basis for the prosocial responses tears elicit from observers (Hareli & Hess, 2012; van de Ven et al., 2017). Thus, when it comes to the role of the MNS as indexed by mu, the activation of our own motor cortex aids in our understanding of others.

Chapter 7: Future Directions in Tear Research: Part I

7.1 Chapter Overview

As has been demonstrated in the four previous chapters, tears are a facial feature which signal sadness in the absence of context and modulate neural processes associated with emotion recognition. However, these studies have provided evidence that tears function as a signal using stimuli which are artificial in nature (i.e. static, posed expressions which have been digitally modified to include tears). One tenet which is yet to be addressed in this thesis (and for the most part the field of crying as a whole), is whether the type of stimuli used influence subsequent responses.

Previous studies have demonstrated that tearful displays are more sincere than tear-free counterparts (Zeifman & Brown, 2011). Additionally, only one study has explored perceptions of genuineness wherein tearful expressions were perceived to be more genuine than the same expression without tears (Grainger et al., 2019)[5]. However, this study was using stimuli captured in a moment of genuine experience, wherein the tearful expressions were the genuine stimuli. For this reason, it cannot be assumed that the same perception of genuineness would apply to a posed stimulus. Therefore, the final aim of this thesis was to explore whether perceptions of genuineness were dependent on the type of tearful stimulus used. This chapter details the perspective piece I authored wherein I explore the necessity for empirical investigation of the type of stimuli used in tear research.

7.2 Publication Status

Published in its entirety.

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[5] This study was published after the initial submission of this perspective piece, and as such is not cited.

7.3 Author Contributions

Krivan conceptualised and designed the article and wrote the first draft of the manuscript. **Krivan** and Thomas contributed to manuscript revision, read and approved the submitted version.

7.4 Manuscript

7.4.1 Abstract

Emotional crying is a uniquely human behaviour, which typically elicits helping and empathic responses from observers. However, tears can also be used to deceive. "Crocodile tears" are insincere tears used to manipulate the observer and foster prosocial responses. The ability to discriminate between genuine and fabricated emotional displays is critical to social functioning. When insincere emotional displays are detected, they are most often met with backlash. Conversely, genuine displays foster prosocial responses. However, the majority of crying research conducted to date has used posed stimuli featuring artificial tears. As such it is yet to be determined how the artificial nature of these displays' impacts person perception. Throughout this article, we discuss the necessity for empirical investigation of the differences (or similarities) in responses to posed and genuine tearful expressions. We will explore the recent adoption of genuine stimuli in emotion research and review the existing research using tear stimuli. We conclude by offering suggestions and considerations for future advancement of the emotional crying field through investigation of both posed and genuine tear stimuli.

Keywords: tear effect, face perception, adult crying, emotion, interpersonal communication, crocodile tears

7.4.2 Introduction

Why do we cry? Emotional crying is a uniquely human display that has fascinated both scientists and lay people alike; this interest stems from an attempt to determine the functions of adult emotional tearing. A popular theory is that emotional tears serve a communicative function (Hendriks et al., 2008; Reed et al., 2015; Vingerhoets et al., 2016). Although tears have been readily touted as an honest signal of emotion (Trimble, 2012; Vingerhoets, 2013), there is a lack of empirical evidence to justify this perception. Furthermore, tears reliably elicit empathic responses (Lockwood et al., 2013) and social support from observers (Vingerhoets et al., 2016), whilst also signalling appeasement, which serves to reduce aggression (Hasson, 2009). While the presence of tears on a face can signal the need for social support, tears are also used to manipulate and deceive.

The accurate detection of emotional deception is critical to social functioning. Fake tears, or ‘crocodile tears’ are an insincere tearing display that evokers use to elicit sympathy and support from observers. How evokers produce these insincere tears is not yet known. Crocodile tears are typically associated with the disingenuous tears of celebrities and politicians (Manusov & Harvey, 2011), and conveying fabricated remorse during criminal court proceedings (ten Brinke, MacDonald, Porter, & O'Connor, 2012). Alexander (2003) found that insincere narcissistic crying appears empty and orchestrated, and that witnessing this tearful display results in feeling uneasy and unmoved in a therapeutic environment. As such, insincere emotional displays elicit negative responses (Hideg & van Kleef, 2017) and reduced trust (Krumhuber et al., 2007). However, crocodile tears could also be elicited via deep acting where the evoker draws on previous experience in an effort to feel the emotion they are displaying (Lu et al., 2019). As such, tears elicited in this manner are driven by genuine feeling, however, are acted and physically effortful by nature. Given that tears are known to increase perceptions of remorse during apologies (Hornsey et al., 2019), and remorse is an important factor in sentencing and parole hearings (Bandes, 2016), further research exploring how we distinguish between sincere and crocodile tears is needed.

Despite the negative connotations associated with insincere emotion, most crying research has used standardised or posed faces featuring artificial tears. Although these studies have demonstrated that tears are responded to favourably (Balsters et al., 2013; Lockwood et al., 2013), how the artificial nature of these displays impact person perception is yet to be determined. We call for the empirical investigation of the perception of both posed and genuine emotional tear displays. We first discuss the movement towards the adoption of genuine and ecologically valid stimuli in emotion research. Then, we explore research utilising images of crying faces and highlight the advancements achieved and potential implications for the posed face methodology. Furthermore, we discuss recommendations for future research that highlight the perceptual differences between posed and genuine tearful displays. Finally, we conclude it is necessary to explore perceptions of genuine and disingenuous crying and believe posed and genuine stimuli can aid in this investigation.

7.4.3 Genuine emotional displays

The recent movement towards using genuine expressions has predominantly stemmed from human ability to determine the genuineness of emotional displays (McLellan, Johnston, Dalrymple-Alford, & Porter, 2010). Primarily, genuine expression research has investigated the difference between Duchenne and non-Duchenne smiles (Duchenne, 1862/1990; Ekman, Davidson, & Friesen, 1990) . Smiles are characterised by the activation of the zygomaticus major (i.e., the muscle responsible for drawing the corners of the mouth upwards), while Duchenne smiles feature both zygomaticus and orbicularis oculi activation (i.e., the muscle associated with the crinkling of the eyes). Duchenne smiles are reliably judged as more intensely happy (Leppänen & Hietanen, 2007), and are mimicked more than non-Duchenne smiles (Krumhuber et al., 2014). Additionally, when mimicry is constrained, people are less accurate at recognising emotional expressions (Oberman, Winkielman, & Ramachandran, 2007) and they display a reduced ability to discriminate between posed and genuine smiles (Rychlowska et al., 2014).

Compared to happiness, the literature exploring genuine displays of sadness is limited. Despite this reduced inquiry, findings are similar to smiling research. McLellan et al. (2010) confirmed that participants can discriminate between posed and genuine sadness equally as well as happiness. In a follow-up study, genuine happy and sad displays resulted in greater neural activation in brain regions associated with emotion recognition relative to posed expressions (McLellan, Wilcke, Johnston, Watts, & Miles, 2012). Applied research by Hackett, Day, and Mohr (2008) revealed that participants who expected rape victims to be emotionally expressive, perceived crying victims to be more credible than non-criers. Given that Hornsey et al. (2019) found tearful apologies were more remorseful, it seems that viewer expectations about tears in negative displays are particularly important. Moving forward, research will need to encompass a wider variety of tearing stimuli to afford an understanding of how insincere crocodile tears are distinguished from genuine emotion.

Caveats associated with the use of genuine emotional stimuli stem from the time-consuming, labour intensive demands of creating these displays, as well as less experimental control. For these reasons, some researchers have employed blended emotional displays where smiles are paired with eye-displays that feature expressions other than happiness (Gutiérrez-García & Calvo, 2015). Although this research has offered useful information about facial markers, these expressions are not authentic. As such, future investigations should explore whether people rely on facial markers to determine authenticity, or if they discriminate between shown and felt emotions. An interesting alternative to the caveats associated with the generation of genuine stimuli stems from a normative study by Dawel et al. (2017). While several posed facial databases, most notably the Pictures of Facial Affect database (Ekman & Friesen, 1976), were not perceived as showing genuine emotion, other posed facial expressions were perceived as genuine. Thus, posed perceived-as-genuine expressions offer a compromise to the difficulties associated with generating authentic stimuli, while allowing additional control. This advancement is particularly important for tear research, as it is currently unknown whether posed-tearful displays are perceived as perceptually genuine. As such, it is important that future investigations explore whether there are differences (or similarities) between the posed expressions typically used in crying research and genuine tearful stimuli.

7.4.4 The artificial tear

Most existing research investigating the perception of emotional tearing uses posed facial expressions that feature artificial tears, added using eyedrops or digital enhancement (Ito et al., 2019; Reed et al., 2015). These artificial images have been used to explore how the presence of tears influences the perception of sadness (Hendriks et al., 2007; Ito et al., 2019), and the degree of helping behaviours elicited (Balsters et al., 2013; Hendriks & Vingerhoets, 2006; Lockwood et al., 2013). When images with visible tears are perceived as significantly sadder than the same image without tears it is referred to as the *tear effect* (Provine et al., 2009).

In exploring perceptions of sadness, tears are typically added to sad and neutral faces, and various measures (e.g., reaction time, rating scales, and electroencephalography) are employed to examine how tears are perceived (Balsters et al., 2013; Hendriks et al., 2007). Balsters et al. (2013) demonstrated that even when brief presentations of tearful sad and neutral faces are shown, participants correctly categorise perceived sadness faster for sad expressions with tears, relative to sad and neutral tear-free expressions. However, contradictory evidence has been demonstrated when exploring the affective ratings of Duchenne smiles featuring tears. Reed et al. (2015) demonstrated that a tearful Duchenne smile was perceived as more intense than the tear-free counterpart. Furthermore, a trend towards increased happiness ratings was observed for the tearful Duchenne face. Thus, it is possible that Duchenne smiles signify genuine joy when they are accompanied by tears, akin to a dimorphous expression. Research exploring dimorphous event-elicited expressions of tearful-joy has identified that context is essential to the perception of tearful-joy as positive; as in the absence of context the emotions were perceived as negative (Aragón, 2017). Thus, further work investigating whether posed happy-tear displays and genuine happy-tear displays are perceptually distinct is a worthy avenue of future research.

Recently, researchers have investigated whether the *tear effect* extends beyond sad, happy, and neutral expressions, as tears are elicited in response to a variety of emotions (Vingerhoets, 2013). Ito et al. (2019) concluded that the presence of tears on all negative emotions rendered them more perceptually similar to sadness, when examined in multidimensional space. Reed et al. (2015) further explored the *tear effect* using dynamic prototypical displays of anger, fear, disgust, sadness and neutral expressions. An actress posed these expressions twice, once as traditional expressions, and once after using eyedrops to simulate tears. Importantly, no differences in the perceived authenticity of the displays were observed between tearful and non-tearful expressions. When examining intensity, valence, and emotion-specific ratings, further generalised support was demonstrated for the *tear effect* and the role of tears as a marker of sadness. Although Reed et al. (2015) found no perceptual differences in authenticity between tearful and non-tearful expressions, no other study has considered the influence of perceived genuineness. However, people are able to distinguish between posed and genuine sadness (McLellan et al., 2010). Thus, further research is needed to determine whether people are able to distinguish between posed and genuine tearful displays.

In the context of our everyday lives, it is of interest to understand the relationship between tears, emotional support, and empathy. There is consensus that tears elicit greater emotional support and empathy compared to tear-free expressions (Balsters et al., 2013; Hendriks & Vingerhoets, 2006; Lockwood et al., 2013). Hendriks and Vingerhoets (2006) concluded that tearful expressions elicit greater support and reduced avoidance behaviours relative to other emotional displays. Furthermore, tears elicited greater perceived personal distress. Thus, despite participants' belief that encountering a tearful person would increase their own distress, they still reported greater helping responses to tears. Lockwood et al. (2013) further explored the role of empathy in response to emotional crying using reaction time. Participants responded to neutral and caregiving words after witnessing subliminally presented emotional face primes of happy, sad, and crying faces. Individuals high in cognitive empathy showed no differences in response time. However, individuals low in cognitive empathy were slower to respond to caregiving words after being primed with a crying face, but not after sad or happy expressions. Thus, the level of empathy experienced by the observer also influences how individuals respond to crying persons. Collectively, these studies demonstrate that posed facial expressions elicit empathic responses; however, they neglect to explore the role of empathy in responding to genuine versus posed displays.

To adopt more ecologically valid crying stimuli, researchers have used crying photographs from the image sharing site Flickr. Selecting crying photographs allows for the investigation of the *tear effect* using the inverse of the artificial tear addition technique. Provine et al. (2009) were the first to demonstrate the *tear effect* using Flickr images that included tears, which were digitally removed to create tear-free duplicates. Takahashi et al. (2015) also used the tear removal paradigm in an fMRI study investigating the perception of tears on sad and neutral expressions. The *tear effect* for sad expressions featuring tears was replicated, and they further concluded that the *tear effect* was larger for neutral faces than sad faces. As tears serve as a salient marker of sadness, their presence resolved the ambiguity of the neutral faces.

Although these studies used stimuli with greater ecological validity, it is impossible to tell whether their images were perceived as authentic expressions of emotion by the participants. As Flickr is a website where people primarily upload their own images to share with friends and followers, images shared to the platform are likely posed and self-selected by the individual to present themselves in a positive manner (Angus & Thelwall, 2010; Malinen, 2010). Thus, posed datasets allowed for the investigation of the perception of tears with rigorous control (Balsters et al., 2013; Lockwood et al., 2013); and stimuli with greater ecological validity have replicated these effects (Provine et al., 2009; Takahashi et al., 2015); however, the need for research using genuine tearful expressions remains.

7.4.5 The genuine tear

Recently, researchers have begun to use photographic stimuli featuring emotional tearing, which were captured in a moment of genuine emotional experience. These images were captured during the Museum of Modern Art, Artist is Present exhibit, where nearly 1000 people sat with Marina Abramović and cried during the experience. As these tears were elicited in a moment of genuine emotion, these studies have investigated the perceived warmth and competence of the crying persons (van de Ven et al., 2017; Zickfeld & Schubert, 2018; Zickfeld et al., 2018), as well as the perceived social-connectedness and willingness to provide help to crying persons (Stadel et al., 2019; Vingerhoets et al., 2016). The original study by van de Ven et al. (2017) concluded that tearful individuals were perceived as warmer, though less competent, than tear-free individuals. Two replications of this study also determined that tearful individuals were perceived as warmer; however, neither study replicated the reduced competence effect when using a larger sample of target crying faces (Zickfeld & Schubert, 2018; Zickfeld et al., 2018). Zickfeld et al. (2018) concluded that the competence effect from the original study was likely target specific, and thus the presence of tears is unlikely to alter perceptions of competence.

Importantly, the work conducted using genuine tear stimuli has also replicated the findings that emotional tears elicit support and willingness to help. Vingerhoets et al. (2016)

concluded that participants attribute greater helping behaviours to individuals with tears, than without tears. Furthermore, through mediation analysis it was determined that helping behaviours stemmed from a perception of closeness to the individuals in the crying images. Similarly, tearful stimuli facilitate approach behaviours relative to avoidance (Gračanin et al., 2018; Riem et al., 2017). Furthermore, Stadel et al. (2019) identified that participants show increased willingness to help individuals with tears, and concluded that this willingness was the strongest between female and mixed dyads, compared to male dyads. Therefore, it seems that tears are a signal that elicits helping responses from observers; however, both the gender of the participant and the expressor might mediate the degree of assistance offered. Future research should expand upon these findings, which stem from self-report willingness to help measures, to better encompass whether perception is aligned with actual helping behaviour. Additionally, while these stimuli were captured during a moment of genuine experience, it is unknown what the individuals were feeling. Aragón and Clark (2018) explored responses to genuine dimorphous happy tears. Participants reported a greater likelihood of down-regulation responses to tearful-joy, than joy expressed with smiles. Thus, future research needs to consider the role that emotional state plays in establishing the way that we respond to tears.

7.4.6 Discussion

To date research using images of teary expressions has focused on expressions of sadness and the anticipated perception and response of individuals. Although crying research has recently adopted the use of genuine expressions, there is no empirical evidence exploring differences in perceived authenticity between posed and genuine displays of emotion featuring tears. Table 1 provides a collation of the studies examining the tear effect, and the influence that tears have on empathic responses. This table highlights the type of stimuli used in each experiment, the method of tear addition or removal, and the effect sizes reported in the published literature. It must be noted, that the type of task, the number of identities used, and the gender of the stimuli varied widely across these studies. This variability further highlights the need for empirical studies using both posed and genuine tearful expressions. This empirical investigation will assist with better understanding the perceptual differences between tear stimuli and aid in our understanding of how we discriminate genuine and posed emotion.

Table 7.1

A Comparison of the Effect Sizes Reported in Published Studies Examining Tears

Authors	Stimulus type	Tear method	Effect size
Faster reaction time to tearful images			
Balsters et al. (2013)	KDEF	Digitally added	η^2 = .284†
Gračanin et al. (2018)	MoMA	Digitally removed	η_p^2 = .26†
Riem et al. (2017)	MoMA	Digitally removed	η_p^2 = .69 †
Greater perceived sadness for tearful images			
Provine et al. (2009)	Flickr tear images	Digitally removed	η^2= .26†
Takahashi et al. (2015)	Flickr tear images	Digitally removed	η_p^2 = .793*
Reed et al. (2015)	Female actress using FACS	Eye-drops	*d* = .22
Ito et al. (2019)	TFEID	Digitally added	η_p^2 = .073
van de Ven et al. (2017)	MoMA	Digitally removed	η_p^2 = .15†
Zickfeld et al. (2018)	MoMA	Digitally removed	*d* = .86
Greater willingness to help / greater perceived support for tearful images			
Balsters et al. (2013)	KDEF	Digitally added	η^2 = .375†
Vingerhoets et al. (2016)	MoMA	Digitally removed	*d* = .85 – 1.32
Zickfeld and Schubert (2018)	MoMA	Digitally removed	*ds* = .70 – .82

Note. KDEF – Karolinska Directed Emotional Faces; MoMA – Genuine tear expressions captured during Museum of Modern Art Performance; TFEID – Taiwanese Facial Expression Image Database; Flickr tear images – images of tearful individuals found on Flickr (unknown if genuine or posed). Effect sizes are reported as in the published papers. *denotes that original paper did not report effect size, and thus it was estimated from main effect of tears. †denotes effect size from main effect.

Furthermore, as the majority of the work conducted to date has used posed expressions, there has been limited focus on the other facial responses that accompany emotional tears, including blotchy faces and bloodshot eyes (Provine, Cabrera, Brocato, & Krosnowski, 2011; Provine, Nave-Blodgett, & Cabrera, 2013). Küster (2018) explored the influence of tears and pupil size on the perception of sadness using digital avatars. While both the presence of tears and smaller pupil sizes increased perceived sadness, there was no interaction effect between tears and pupil size. The inverse consideration of the extreme features accompanying emotional crying is the perceptual and affective differences between tearing up and crying uncontrollably (i.e., ugly crying). Research using vignettes has demonstrated that the intensity of tears moderates observer reactions, where in some scenarios just tearing up may elicit more positive responses than weeping (Wong, Steinfeldt, LaFollette, & Tsao, 2011). Thus, further work in this field should explore the relationship between the intensity of the tears and observer responses. It may be that assistance for emotional crying is curvilinear, where there is an optimum level of tearing that elicits helping responses from observers.

Finally, the adoption of investigative techniques like psychophysiology may offer insight into the perceptions of tears to further corroborate the results from self-report studies. Recently, mirror neurons have been proposed as a mechanism for sharing others emotional states, with 'feeling' and 'perceiving' emotion sharing neural substrates (Singer et al., 2004; Wicker et al., 2003). Similarly, facial mimicry studies have identified that when participants' ability to mimic is impaired, they show reduced emotion recognition abilities (Oberman et al., 2007; Rychlowska et al., 2014). In addition, examination of other physiological techniques, such as eye-tracking and galvanic skin response, may yield fruitful information about the features that individuals attend to in decoding an emotional face, and the degree of arousal that tearful expressions elicit. Analysis of the arousal response may assist in determining the motivation for the helping behaviours as a metric of personal distress. Furthermore, the inclusion of psychophysiological metrics allows for greater certainty in the true nature of the self-report responses.

In this paper, we have reviewed recent work using facial expressions as a means of investigating inter-individual functions of crying. Reviewing these studies has revealed that the use of posed expressions has afforded an understanding of the communicative functions of emotional tears by employing rigorously controlled stimuli between conditions. In addition, the use of genuine expressions of emotion in more recent crying research has replicated findings that both posed and genuine expressions of emotion are effective at eliciting support and attention. However, whether posed tearful expressions are being treated as perceptually authentic, or if their staged nature is impacting upon person perception is yet to be determined. Thus, to continue advancing the understanding about the interpersonal functions of human emotional tearing, we need to adopt an approach that better explores how we perceive both genuine and non-genuine crying expressions. This advancement needs to encompass a greater range of tearing stimuli to allow for the exploration of the physiological effects that accompany emotional tearing. This research will provide a basis for understanding the type of emotional tears we respond to. People can distinguish between posed and genuine emotions, yet tears have not received this same inquiry. Determining how we distinguish between posed and genuine tearful expressions, will aid in further understanding the functions of this uniquely human phenomenon.

Chapter 8: Future Directions in Tear Research: Part II

8.1 Chapter Overview

Following the perspective piece outlined in the previous chapter, I conducted three experiments exploring the perceptions of genuineness for three types of tearful stimuli. The first stimuli are tears that were elicited during a moment of genuine experience. These genuine tearful displays are the most authentic tear stimuli presently used in crying research. Secondly, I used the Karolinska Directed Emotional Faces (KDEF) displays, which I have used throughout my thesis, and digitally modified these images to include tears. This procedure allowed for the exploration of how my KDEF tear stimuli are perceived relative to a genuine tearful stimulus. Finally, I also included a sample of posed faces, wherein the individuals were instructed to pose as though they were crying. I included this third sample of images, to explore whether posed crying (with artificial tears added digitally) was perceived as more genuine than posed sadness (with artificial tears digitally added). The following chapter details the results of three experiments exploring the perceptions of genuineness relating to tearful individuals.

8.2 Publication Status

Manuscript in preparation for publication.

8.3 Author Contributions

Krivan – designed the experiments, created the experiments, collected the data, conducted the data analyses, wrote the first and revised drafts of the manuscript.

Thomas – aided in experimental design, provided funding for the experiments, supervised the research, and aided in editing the manuscript.

8.4 Manuscript

8.4.1 Abstract

Numerous studies have demonstrated that tearful expressions elicit increased support, aid and succour from observers relative to tear-free expressions. Although there is consensus that tears are responded to favourably, there is a limited understanding of why tears are such an effective communicative display. One proposed facilitator of these favourable responses is that tears are perceived as an honest expression of emotion, yet there have been limited empirical tests of this assumption. This study sought to address this gap by examining whether participants are sensitive to the genuineness of tearful stimuli. We conducted a series of experiments examining whether participants could distinguish between shown and felt emotion, and whether responses to genuine word primes were facilitated by genuine tearful displays. The results demonstrate that participants are sensitive to the genuineness of emotional tears. Furthermore, tears increased the perceived genuineness of posed displays. Finally, we did not observe any influence of facial prime on responses to positive and negative words associated with genuineness. Collectively, these results demonstrate that observers are sensitive to the genuineness of emotional tears and highlights the importance of experimental stimuli in tear research.

8.4.2 Introduction

Emotional tears are a universally recognised expression of emotion that command attention from observers (Vingerhoets, 2013). This attention is typically manifested as pro-social responses from observers. Tearful displays are known to elicit greater empathy, emotional support, and helping responses, relative to tear-free expressions (Hendriks et al., 2008; Vingerhoets et al., 2016). Furthermore, tears foster approach, rather than avoidance, behaviours and signal appeasement to reduce aggression (Gračanin et al., 2018; Hasson, 2009). As such, tearful displays have been touted as an honest distress signal (Trimble, 2012; Vingerhoets, 2013), despite the lack of empirical evidence for this conclusion (see Krivan and Thomas (2020) for a review of this perspective). However, tears can also be used to manipulate and deceive. Crocodile tears are an insincere crying display that are designed to elicit pro-social responses from observers. For example, a person may feign sadness through a tearful display either to elicit sympathy from observers or to convey remorse (ten Brinke et al., 2012). As such, crocodile tears are typically associated with the disingenuous tears of politicians and celebrities (Manusov & Harvey, 2011). Thus, the ability to distinguish between posed and genuine tears is integral to avoiding manipulation from insincere criers.

Evidently, the accurate decoding of facial expressions is critical to social functioning. Typically, facial expressions are investigated as a tool of social communication wherein facial emotion is a means of signalling affective state. However, not all communicated facial expressions are actually felt by the expressor. In these instances, expressions are posed or feigned by an expressor, and as such convey little information about affective state (Douglas, Porter, & Johnston, 2012). Posed displays can be used to conceal true emotions (Gutiérrez-García & Calvo, 2015), fake genuine experience (Hess & Kleck, 1990), and even to deceive and manipulate observers (Krumhuber & Manstead, 2009; McLellan et al., 2010). As such, posed expressions are deliberate, purposeful displays that intentionally convey emotion (Ekman & Friesen, 1982; Hess & Kleck, 1990; Motley & Camden, 1988). By contrast, genuine emotional displays are spontaneous and congruent to one’s affective state (Dawel, Palermo, O’Kearney, & McKone, 2015; McLellan et al., 2010). As such, genuine emotional displays can be considered “event-elicited” (Dawel et al., 2017), “spontaneous”, or “emotion-induced” (Hess & Kleck, 1990). The ability to accurately decode whether a facial expression is genuine or posed has ramifications for effective social communication. For example, aiding an individual crying crocodile tears could result in being manipulated by a deceptive individual. A further example of ineffective social communication would be reciprocating a smile that was used to mask anger (Gosselin, Beaupré, & Boissonneault, 2002). As a result, researchers have increasingly become interested in how we discriminate genuine from posed emotion.

One method that is frequently used to determine the authenticity of facial displays is physical facial markers. Within the Facial Action Coding System, muscular facial movements are separated into distinct action units (AU: Ekman & Friesen, 1978). These action units quantify muscular activation and are typically associated with specific emotional expressions. For example, a distinctive marker of happiness is the smile (Becker & Srinivasan, 2014; Gutiérrez-García & Calvo, 2015), where the lips are pulled upwards towards the ears, known as AU 12. However, genuine enjoyment features an additional physical marker (Frank, Ekman, & Friesen, 1993). Known as the Duchenne smile, genuine enjoyment pairs AU 12 with the crinkling of the crow's feet around the eyes (AU 6: Ekman, Davidson, & Friesen, 1990). Although not as well researched as genuine enjoyment, genuine sadness also has distinctive facial markers, which are signalled through AU's 1 and 4, wherein the eyebrows are drawn upwards and together (Ekman, 2003; Ekman & Rosenberg, 2005). These AU of genuine enjoyment and sadness are argued to be markers of authenticity as they are difficult to pose (Mehu, Mortillaro, Bänziger, & Scherer, 2012), and are often present in genuine but not posed emotion (Ekman, 2003; Ekman, Friesen, & O'Sullivan, 1988).

The ability to distinguish between posed and genuine emotion is typically investigated using tasks where participants determine whether the faces are *showing* (i.e. does the face look sad) or *feeling* (i.e. was the person feeling sad) a particular emotion (McLellan et al., 2010; McLellan et al., 2012; Namba, Kabir, Miyatani, & Nakao, 2018). In studies of genuineness, superior performance is typically observed in response to happy facial displays (Dawel et al., 2015; McLellan et al., 2010). However, the limited research investigating discrimination of sad facial expressions has shown that when participants are expressly told to focus on the affective state of the stimuli, genuine sadness is discriminated equally as well as genuine happiness (McLellan et al., 2010; Namba et al., 2018). Furthermore, McLellan et al. (2012) used neuroimaging to demonstrate that genuine displays of happiness and sadness elicit significantly greater activation of brain regions associated with emotion perception and intentional attribution. As such, the ability to discriminate genuine from posed emotion is greatest for happiness and requires a focus on affective state for sadness.

A shortcoming of the existing literature must be acknowledged. Namely, the majority of work discussed thus far has relied on a stimulus set developed by McLellan et al. (2010). These stimuli feature 17 females who were informed that the purpose of the experiment was to develop a stimulus set of both genuine and posed displays. Although genuine expressions were elicited via emotion-inducing films, potentially the stimuli were biased by demand characteristics. Participants' knowledge of the task, combined with the explicit instruction to "look into the camera as much as possible", potentially inhibited truly spontaneous facial reactions. Furthermore, a normative study by Dawel et al. (2017) concluded that, with the exception of happiness and disgust, the genuine stimuli from the McLellan stimulus set were not perceived as genuine. Rather, angry, fearful, and sad expressions were found to be ambiguous in perceived genuineness. As such, further research should strive to adopt a stimulus set comprised of males and females, where emotion is captured in a moment of genuine experience.

Although early research into the communicative functions of emotional tears relied on posed stimuli and the use of artificial tears (Balsters et al., 2013; Fischer et al., 2013; Hendriks & Vingerhoets, 2006), recent research has adopted the use of a genuine stimulus set (Stadel et al., 2019; van de Ven et al., 2017; Vingerhoets et al., 2016). These tearful displays were captured in a moment of genuine experience, and feature males and females of different ages and cultures. As such, these genuine tearful displays make for a rich dataset for use in crying research. However, it is yet to be established whether these crying displays are perceived as genuine by observers. As demonstrated by Dawel et al. (2017), not all genuine displays are perceived as genuine by observers. Thus, establishing that genuine tears are perceived as genuine by observers is critical to understanding the communicative functions of tears. Moreover, it may be that the favourable responses typically elicited in response to tears only occur if a perceiver believes that the tears are an honest and sincere expression of emotion. Recent research by Roeyen et al. (2020) provided empirical evidence for this conclusion wherein perceiving tears as crocodile tears reduced the typical positive characteristics associated with crying persons (i.e. warmth and sincerity). Furthermore, this damaging effect occurred regardless of whether the tearful stimuli were genuine or fake. Therefore, establishing whether this genuine stimulus set is perceived as genuine by observers is a critical first step in determining whether individuals are sensitive to the differences between posed and genuine tears.

The aim of the present research was to evaluate whether genuine tears can be discriminated from posed tearful expressions. Specifically, we sought to validate that tearful displays captured in a moment of genuine experience are perceived as genuine by observers. Furthermore, we predicted that if people can distinguish between posed and genuine tearful displays, that genuine faces would be perceived to be ‘feeling’ emotion more than posed displays.

8.4.3 Pilot experiment

8.4.3.1 Method

8.4.3.1.1 Participants

A total of 110 participants were recruited via Amazon Mechanical Turk. Exclusions were based on participants failing the understanding check detailed in the procedure (*N* = 13), and participants who repeatedly selected the same ratings on each scale regardless of the images presented (*N* = 5). These exclusions resulted in a final sample of 92 participants, ranging from 19 to 73 years of age (M_{age} = 33.99, *SD* = 11.31). Fifty-six of the participants were male, and participants were primarily located in America (77.17%). Participants were awarded a small monetary payment as compensation for their time (US$.80). All participants gave informed consent prior to commencing the study. All experiments were approved by the Monash University human research ethics committee and all procedures were carried out in accord with the declaration of Helsinki.

8.4.3.1.2 Stimuli

Stimuli were images of male and female faces, with varying degrees of "genuineness". All stimuli were cropped to ensure faces filled most of the frame and were 464×619 pixels. Posed sad facial expressions consisted of six male and six female faces taken from the KDEF database expressing the emotion sadness. Posed crying expressions were captured as still frames from a YouTube clip, where the persons in the video were asked to show what it looks like when they cry. As these stimuli had never been used in research before, we used a slightly larger sample of male faces, six females and eight males, to account for the fact that females are typically more expressive than males (Briton & Hall, 1995; Brody & Hall, 2008) to ensure we could choose the best faces for the experiment proper. For both sets of posed facial displays, tears were digitally added using online photo editor software (http://funny.pho.to/tears-effect/), to create the sad-tear stimuli. Genuine tearful facial expressions were selected from a series of crying images, where tears were shed in a moment of genuine emotion. These tearful stimuli have been used in previous crying research as effective stimuli (Vingerhoets et al., 2016). Six male and six female faces were included, and tears were digitally removed from these images using Photoshop.

8.4.3.1.3 Procedure

The survey was created using Qualtrics. Participants were given detailed instructions to ensure they understood the terminology used throughout the survey (see Appendix B).

These instructions were matched as closely as possible to a stimuli norming study conducted by Dawel et al. (2017) investigating perceptions of genuineness. After participants had read the instructions, they were presented with an understanding check to ensure they had read and understood the instructions (see Appendix C). We used the same understanding check as the Dawel et al. (2017) study. Incorrect answers were linked back to the instructions screen. Participants who failed to answer these questions correctly after three repetitions were prohibited from completing the survey.

Participants were presented with an emotional face with the questions and scales below. Each rating scale ranged from -100 to +100. For genuine expressions scale anchors were -100 (completely fake), 0 (can't tell), and +100 (completely genuine). Intensity and valence scale anchors were: -100 (not at all intense) through to +100 (extremely intense); and -100 (negative), 0 (neutral), and +100 (positive). After completing the ratings, participants selected which of the emotion categories the facial expressions represented. The presentation of the images was randomised for each participant.

After rating the emotional faces, participants were asked to classify whether a person would be perceived as genuine or fake based on a series of synonyms and antonyms associated with genuineness (i.e. trustworthy/untrustworthy, truthful/untruthful, honest/dishonest, and sincere/insincere). For example, what kind of person would you associate trustworthy with? Genuine (correct answer) or fake (incorrect answer). Participants were then asked to provide basic demographic details and thanked for their participation in the survey. This pilot, and the two experiments reported in this study were pre-registered prior to data collection (https://aspredicted.org/blind.php?x=mh9wi4).

8.4.3.2 Results and discussion

We conducted a series of 3 (face type: genuine, KDEF, YouTube) by 2 (tears: no tears, tears) repeated-measures ANOVAs for each of the rating variables. Where the assumption of sphericity was violated, we corrected using the Greenhouse-Geisser (GG) correction. All follow-up comparisons were Bonferroni corrected. Table 8.1 shows the average ratings for each stimulus on the genuineness, intensity, and valence scales, as well as the percentage of stimuli that were classified as sad.

Table 8.1

Means (SDs) for Each Rating Scale and the Emotion Classification Task.

		Genuineness	Intensity	Valence	Emotion (%)
Genuine	No Tear	34.02 (28.59)	13.75 (29.92)	-.27 (31.37)	41.67 (24.71)
	Tear	32.16 (32.45)	22.20 (29.80)	-14.90 (41.41)	81.97 (21.01)
KDEF	No Tear	.12 (43.17)	13.16 (33.45)	-15.38 (38.15)	71.83 (28.22)
	Tear	8.66 (43.62)	23.29 (31.44)	-20.00 (43.01)	87.95 (20.20)
YouTube	No Tear	19.30 (31.00)	15.32 (28.05)	-3.64 (33.63)	48.37 (26.39)
	Tear	16.25 (38.31)	22.48 (30.36)	-16.03 (43.79)	84.01 (23.01)

Note. Genuineness, intensity, and valence ratings ranged from -100 to +100. Emotion reflects the percentage of responses classified as sad.

8.4.3.2.1 Genuineness ratings

The repeated-measures ANOVA for the genuineness rating data revealed a significant main effect of face type, $F(1.303,118.583) = 51.004$, $p < .001$, $\eta_p^2 = .359$. Post hoc comparisons revealed that the posed KDEF faces were perceived as significantly less genuine than the genuine faces, $t(91) = 9.925$, $p < .001$, $d = 1.035$, and the YouTube faces, $t(91) = 7.100$, $p < .001$, $d = .740$. Furthermore, the YouTube faces were perceived as significantly less genuine than the genuine faces, $t(91) = 8.423$, $p < .001$, $d = .878$. In addition, there was a significant face type by tear interaction, $F(1.751,159.302) = 10.740$, $p < .001$, $\eta_p^2 = .106$ (see Figure 8.1). Follow-up paired-samples *t*-tests revealed that tearful KDEF faces were perceived as significantly more genuine than the tear-free faces, $t(91) = 2.810$, $p = .006$, $d = .293$. There were no significant differences between the tear and the no-tear conditions for the genuine, *t*(91) = .726, *p* = .470, *d* = .076; or the YouTube faces, *t*(91) = .992, *p* = .324, *d* = .103.

We also conducted a series of one sample t-tests against the mid-point (i.e. "can't tell") of our visual analogue scale. Neither the KDEF faces with tears, *t*(91) = 2.904, *p* = .060, *d* = .199, nor without tears, *t*(91) = .027, *p* = .978, *d* = .003 were able to be readily classified as genuine or not-genuine. The genuine faces both with tears, *t*(91) = 9.505, *p* < .001, *d* = .991, and without tears, *t*(91) = 11.412, *p* < .001, *d* = 1.190, and the YouTube faces with tears, *t*(91) = 4.068, *p* < .001, *d* = .424, and without tears, *t*(91) = 5.973, *p* < .001, *d* = .623 were all perceived as genuine.

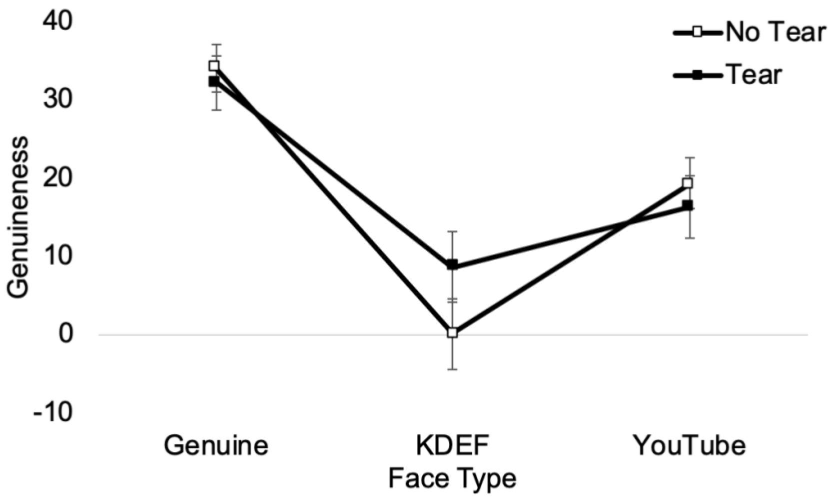

Figure 8.1. Tears by Face Type interaction effects for the genuineness ratings. Error bars are SEM. Higher scores indicate greater perceived genuineness.

8.4.3.2.2 Intensity ratings

The repeated-measures ANOVA for the intensity rating data revealed a significant main effect of tears, *F*(1,91) = 37.328, *p* < .001, η_p^2 = .291, where tear expressions were perceived as significantly more intense than tear-free expressions. No other main effects or interactions were significant *F's* < .930 , *p's* > .397.

8.4.3.2.3 Valence ratings

The repeated-measures ANOVA for the valence rating data revealed a significant main effect of face type, $F(1.578,143.623) = 35.36$, $p < .001$, $\eta_p^2 = .280$, where KDEF faces were attributed greater negative emotional valence than genuine faces, $t(91) = 7.748$, $p < .001$, $d = .808$, and YouTube faces, $t(92) = 7.700$, $p < .001$, $d = .803$. The YouTube faces were also perceived as more negatively valenced than the genuine faces, $t(91) = 2.242$, $p = .036$, $d = .265$. There was also a significant main effect of tears, $F(1,91) = 49.81$, $p < .001$, $\eta_p^2 = .354$, where tearful faces were attributed significantly greater negative valence ratings relative to tear-free expressions. In addition, there was a significant face type by tears interaction, $F(1.844,167.791) = 22.34$, $p < .001$, $\eta_p^2 = .197$ (see Figure 8.2). Follow-up comparisons revealed that the tearful expressions were perceived as more negative for the genuine faces, $t(91) = 7.812$, $p < .001$, $d = .814$, the YouTube faces, $t(91) = 7.053$, $p < .001$, $d = .735$, and the KDEF faces, $t(91) = 2.878$, $p = .005$, $d = .300$, relative to the tear-free images.

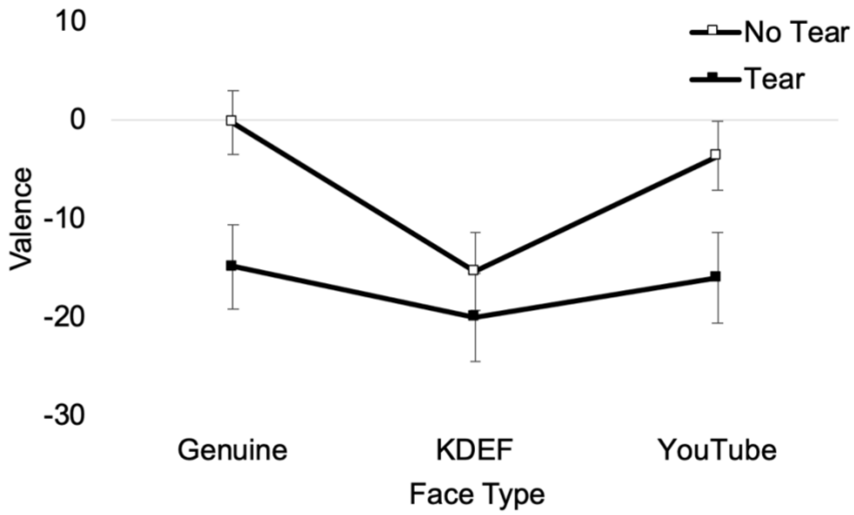

Figure 8.2. Tears by Face Type interaction effects for the valence ratings. Error bars are SEM. More negative scores indicate greater perceived negative valence.

8.4.3.2.4 Emotion classification task

We converted the forced choice classification task into percentages of responses classified as sad. The repeated-measures ANOVA revealed that there was a significant main effect of face type, $F(1.549, 140.970) = 96.07$, $p < .001$, $\eta_p^2 = .514$, where KDEF faces were significantly more likely to be classified as sad relative to genuine faces, $t(91) = 10.415$, $p < .001$, $d = 1.086$, and YouTube faces, $t(91) = 9.212$, $p < .001$, $d = .960$. The YouTube faces were more likely to be classified as sad than the genuine faces, $t(91) = 4.367$, $p < .001$, $d = .467$. There was also a significant main effect of tears, $F(1,91) = 249.69$, $p < .001$, $\eta_p^2 = .733$, where the presence of tears on a face significantly increased classification as sad responses. In addition, there was a significant face type by tear interaction, $F(1.758, 160.012) = 59.52$, $p < .001$, $\eta_p^2 = .395$. Tearful expressions were more likely to be classified as sad for the KDEF, $t(91) = 7.707$, $p < .001$, $d = .804$; genuine, $t(91) = 16.048$, $p < .001$, $d = 1.673$; and YouTube faces, $t(91) = 14.357$, $p < .001$, $d = 1.497$, compared to the same expressions without tears.

8.4.4 Experiment 1

8.4.4.1 Method

8.4.4.1.1 Participants

Thirty-seven participants (26 females) elected to participate in this study. Participants ranged in age from 19 to 46 (M_{age} = 23.46, SD_{age} = 5.12 years). All participants had normal or corrected-to-normal vision, and 34 were right-handed. Two participants reported during debriefing that they knew the experiment was investigating perceptions of genuineness, and as such they were excluded from analyses. Participants were awarded a monetary payment of $15.00 AUD as compensation for their time. Participants gave written informed consent prior to participation in the experiment in accord with the declaration of Helsinki.

We determined sample size following the McLellan et al. (2010) study, which included a sample of 24 participants. We used G*Power (Faul et al., 2007) to estimate the sample size for a repeated-measures, within-participants design. The smallest reported effect size in McLellan et al. was η_p^2 = .128; however, this effect size was across multiple emotions and we focused solely on sadness. For this reason, we set a conservative effect size (η_p^2 = .06); the power analysis called for a total of 27 participants. As such, we recruited 37 participants to allow for participant exclusions.

8.4.4.1.2 Stimuli

Facial stimuli were the images described in the pilot experiment. For these three stimulus categories (i.e. Genuine; Posed KDEF; Posed YouTube), we selected four male and four female facial identities. We selected the images that provided the best representation of the overall ratings for genuineness, valence, and intensity from the pilot study.

8.4.4.1.3 Procedure

The emotional state recognition task was conducted using e-Prime Professional e-Studio 2.0.10.356 software. Participants were informed that they would be presented with separate blocks to judge whether the emotion was *shown* or was *felt* by the target individual. Participant instructions were as follows:

> "Your job is to decide whether or not the faces are SHOWING emotion and whether or not they are FEELING emotion. For instance, sometimes when people smile, it does not mean they are actually happy, and sometimes when people are sad, they may not have the most intense expression of sadness, but they are feeling the emotion."

These instructions were slightly adapted from the original study by McLellan et al. (2010) to include an additional statement used by Dawel et al. (2017). We chose to add the additional statement regarding intensity to ensure participants were not solely relying on the intensity of the stimulus to make their judgements. Participants received two practice blocks (one *show* and one *felt*), which included 12 trials each. None of the identities used in the practice trials were repeated in the experimental trials. The practice trials had the same trial procedure as the experimental trials. Each block began with the word "SHOW" or "FELT". Trials began with the presentation of a fixation cross, varied in length between 500 and 1000 ms (in blocks of 100ms), to prevent anticipatory responses. Participants were then presented with an emotional face, which was visible until they made a response. Half the participants were instructed to use the far-left button to denote "yes" responses and the far-right button to denote "no" responses, while this response mapping was reversed for remaining participants. The order of the *show* and *felt* tasks was counterbalanced between participants and faces in each block were displayed in a unique random order for each participant. There were 48 trials per experimental block, for a total of 96 trials, which took approximately 20 minutes to complete.

8.4.4.2 Results and discussion

As in McLellan et al. (2010) we calculated the percentage of "yes" responses per condition separately for tear and tear-free images (see Table 8.2). If participants were able to discriminate between genuine and posed displays, it was expected that posed displays would be perceived to be showing but not feeling emotion, whereas genuine displays should be perceived as both showing and feeling emotion. As demonstrated in Table 8.2, genuine faces were more likely to be judged as *feeling* compared to *showing* emotion. When a genuine tearful face was shown, participants believed the tearful expressions were both showing and feeling the depicted emotion. However, participants were less likely to report that the face was showing and feeling emotion when tears were removed from the genuinely sad faces. Conversely, for the KDEF posed expressions, participants were significantly more likely to state that the faces were showing emotion, relative to feeling emotion. Furthermore, tear images were significantly more likely to be judged as both showing and feeling emotion, relative to tear-free images. Similarly, the YouTube faces with tears were significantly more likely to be judged as both showing and feeling emotion, relative to tear-free expressions. Although tearful YouTube faces were significantly more likely to be perceived as showing emotion relative to feeling emotion, tear-free images showed no significant difference between the judgement conditions.

Table 8.2

Percentage of YES Responses by Judgement Condition and Face Type.

	Judgement condition	
Face type	Show (% yes)	Feel (% yes)
KDEF		
Tear-free	76_a	48_b
Tears	93_b	75_a
YouTube		
Tear-free	55_a	50_a
Tears	95_b	77_c
Genuine		
Tear-free	40_a	56_c
Tears	85_b	88_b

Note. Different subscripts within a row indicate significant difference in the percentage of yes responses between the show and the feel conditions for each face type. Different subscripts within a column indicate significant differences in the percentage of yes responses between the tear and the tear-free judgements for each face type. No comparisons were made across face types in this table. Level of significance was corrected for multiple comparisons, paired t-tests, p = .004).

To further explore this data, we used a non-parametric signal detection analysis. The data for each participant was converted into hits (H) and false alarms (FA). Hits were defined as correctly responding yes to a genuine expression, while false alarms were defined as responding yes to posed expressions. As outlined in Snodgrass and Corwin (1988), hits and false alarms were corrected according to the following formulas:

$$H = (\textit{number of hits} + .05) / (\textit{trials} + 1)$$

$$\text{FA} = (\textit{number of false alarms} + .05) / (\textit{trials} + 1)$$

The sensitivity (A') equation for when hits ≥ false alarms:

$$A' = 0.5 + [(H - FA)(1 + H - FA)]/[(4H(1 - FA)]$$

When false alarms ≥ hits the equation is modified to:

$$A' = 0.5 - [(FA - H)(1 + FA - H)]/[(4FA(1 - H)]$$

Finally, when hits were equal to false alarms ($H = FA$), it was equivalent to chance ($A' = 0.5$). Values above 0.5 indicate preference towards a genuine expression relative to a posed expression, with scores closer to 1.0 indicative of greater sensitivity towards genuine expressions. By contrast, scores closer to 0 were indicative of decreased sensitivity towards genuine expressions. We conducted two sensitivity analyses. The first analysis compared the sensitivity to genuine displays versus the KDEF displays and the second analysis compared genuine displays with the YouTube displays, Table 8.3 provides the mean corrected hits, false alarms and estimates of sensitivity for each analysis.

Table 8.3

Mean Corrected Hit (H) and False Alarm (FA) Rates and Mean Estimates of Sensitivity (A') and Bias (B'') by Judgement Condition for Tear and Tear-free Expressions.

	Genuine vs. KDEF				Genuine vs. YouTube			
Judgement	H	FA	A'	B''	H	FA	A'	B''
Show								
No tear	.42	.73	.28*	-.18†	.37	.54	.36*	.12
Tears	.81	.89	.43*	-.19†	.76	.90	.34*	-.30†
Feel								
No tear	.56	.48	.55	-.04	.56	.49	.55	-.04
Tears	.84	.72	.58*	-.22†	.84	.73	.57*	-.18†

Note. As we included two types of posed expressions, we calculated a separate sensitivity scores for KDEF and YouTube faces. Sensitivity (A') values with * are significantly different from 0.5 ($p < .05$). Bias (B'') values with † indicate significantly different from 0 ($p < .05$).

One sample *t*-tests revealed that during the show judgements, sensitivity was significantly below chance level, indicating that participants were more likely to make a false alarm than a correct response. Conversely, sensitivity was above chance for the feel condition; however, only significantly so for faces featuring tears. Thus, participants were more likely to say a posed expression was showing emotion, and a genuine expression was feeling emotion.

We also calculated a measure of bias (B''), to examine whether participants were biased towards yes responses. As with the sensitivity measure, the equation for when H > FA was:

$$B'' = [H(1-H) - FA(1-FA)]/[H(1-H) + FA(1-FA)]$$

When FA > H, the H and FA values were replaced as follows:

$$B'' = [FA(1-FA) - H(1-H)]/[FA(1-FA) + H(1-H)]$$

Possible values ranged from -1 to +1, with positive values indicating a bias towards "NO", and negative values indicating a bias towards "YES"; 0 values indicate a neutral criterion (see Table 8.3). During the show condition, B'' scores showed that participants were significantly biased towards responding with "yes" (i.e., "YES" for showing) for both tear-free and tearful expressions in the first sensitivity analysis (genuine faces versus KDEF), but only tearful expressions in the second sensitivity analysis (genuine versus YouTube). During the feel condition, participants demonstrated no bias (i.e. a neutral criterion was used) when judging tear-free expressions. By contrast, the presence of tears on a facial display significantly biased the participants towards responding "yes" during the feel task. Thus, the presence of tears significantly biased participants towards a "yes" response, demonstrating that tears make an expression look sadder and increased the perception that the face felt sad.

We conducted two separate ANOVAs for each of the separate sensitivity indices to examine the influence the type of posed expression has on sensitivity to genuineness. The ANOVAs were comprised of a 2 (judgement: show, felt) by 2 (tears: tear-free, tears) repeated-measures ANOVAs to further explore the differences between the tear and tear-free conditions. The first analysis compared sensitivity between genuine and KDEF faces, which revealed a significant main effect of judgment, $F(1, 34) = 26.021$, $p < .001$, η_p^2=.434. False alarms were more likely during the show condition relative to the feel condition; participants performed worse during the show condition, as evidenced by the increased number of false alarms. There was also a significant main effect of tears, $F(1, 34) = 14.653$, $p < .001$, η_p^2=.301, where participants were significantly more likely to generate a false alarm when the face featured tears.

This main effect was qualified by a significant tears by judgment interaction, $F(1, 34) = 17.990$, $p < .001$, η_p^2=.346 (see Figure 8.3). Follow-up paired-samples *t*-tests revealed that during the show condition participants performed significantly worse than chance and were more likely to say that a tear-free expression was showing emotion relative to a tear expression, $t(34) = -5.270$, $p < .001$, $d = -.891$. This result stems from the fact that tear-free genuine expressions were not perceived to be showing emotion (see Table 8.2). Thus, when tears were removed from a genuine expression, participants were more likely to say a posed expression is sad. By contrast, there was no significant difference during the feel task between the tear and tear-free faces, $t(34) = -1.158$, $p = .255$, $d = -.196$.

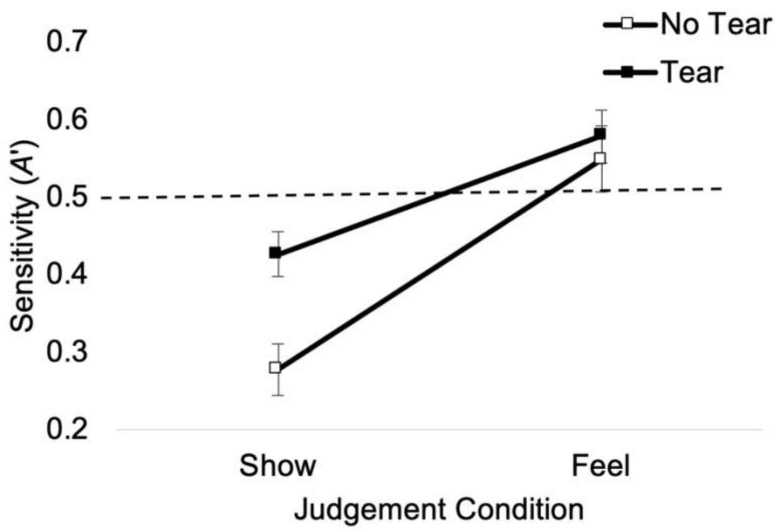

Figure 8.3. The interaction between judgement condition and tears for the first sensitivity analysis (genuine vs. KDEF faces). Error bars are SEM. Scores closer to 0.5 (dashed line) indicate scores significantly closer to chance, with higher scores indicative of better performance.

The second analysis, which examined sensitivity between genuine and YouTube faces, revealed a significant main effect of judgment, $F(1, 34) = 36.896$, $p < .001$, η_p^2=.520, where, as in the first sensitivity analysis, sensitivity was worse for the show task relative to the feel task. As indicated in Figure 8.4, sensitivity was below chance for the show judgements, and above chance for the feel judgements. Neither the main effect of tears, $F(1, 34) = .060$, $p = .808$, η_p^2=.002, nor the judgment by tears interaction, $F(1, 34) = 2.332$, $p = .136$, η_p^2=.064, were significant.

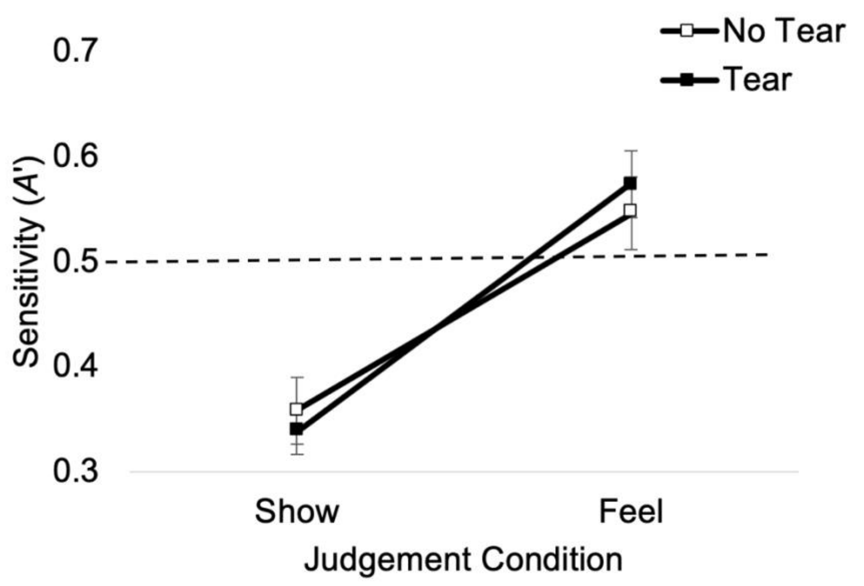

Figure 8.4. A graphical depiction of the second sensitivity analysis (genuine faces versus YouTube faces). Error bars are SEM. Scores closer to 0.5 (dashed line) indicate scores significantly closer to chance, with higher scores indicative of better performance.

8.4.5 Experiment 2

Experiment 1 allowed us to investigate whether people can discriminate between posed and genuine emotional displays of sadness. We confirmed that participants can discriminate between posed and genuine sadness when told to explicitly attend to emotional state. The purpose of Experiment 2 was to examine whether genuineness is responded to when attention is not directly focused on emotional state. Existing research has demonstrated that subliminally presented facial primes can influence responses to subsequent facial expressions (Prochnow et al., 2013; Sweeny, Grabowecky, Suzuki, & Paller, 2009). Although some studies have demonstrated that affective primes influence behavioural performance (i.e. memory tasks), others have demonstrated that affective primes can additionally change psychophysiological responses to stimuli (Dimberg et al., 2000; Prochnow et al., 2013; Sweeny et al., 2009). Moreover, Dimberg et al. (2000) demonstrated that masked images are mimicked with a congruent facial display, even when the participant is unaware of the presentation of the stimulus. In this way, facial primes can change behavioural and physiological responses to subsequent stimuli.

In addition to influencing psychophysiological responses, facial primes also influence responses to subsequent words. Stenberg et al. (1998) concluded that responses to positive words were faster following presentation of a happy face prime relative to a neutral expression. Similarly, Miles and Johnston (2007) further identified that responses to positive words were faster when primed with genuine relative to posed smiles. McLellan et al. (2010) provided further evidence that responses to positive emotions were facilitated by happy displays, where negative words were facilitated by negatively valenced fearful displays. Thus it seems that primes which are of congruent valence to the word facilitate reaction times (Fazio, Sanbonmatsu, Powell, & Kardes, 1986). Conversely, reaction times to negative words were not facilitated by sad facial primes (McLellan et al., 2010). Importantly, responses to positive words were inhibited when preceded by genuine sadness. Thus, genuinely sad facial displays slowed responses to positive words. This slowed response to positive words following sad displays indicates that priming with sad expressions inhibits the classification of positive words.

With this in mind, we sought to further explore the way that a sad facial prime influences subsequent response to words. Given that tears are perceived to be an honest signal of emotion (Trimble, 2012; Vingerhoets, 2013), we predicted responses to words associated with genuineness would be facilitated when priming with a genuine tearful expression. By contrast, tears can also be used to manipulate and deceive. Namely, crocodile tears are renowned as the disingenuous crying of politicians and celebrities (Manusov & Harvey, 2011), or the false tearing displays that are used to garner sympathy during court proceedings (ten Brinke et al., 2012). As such, we predicted that posed artificial tear displays would facilitate responses to negative words that are associated with being disingenuous.

8.4.5.1 Method

8.4.5.1.1 Participants

Experiment 1 participants also completed Experiment 2 within the same testing session.

8.4.5.1.2 Stimuli

We used the same stimuli in Experiments 1 and 2. For the word categorisation task, we used words typically associated with genuineness (i.e. trustworthy, sincere, honest, truthful) and their antonyms (i.e. untrustworthy, insincere, dishonest, untruthful). These words were found to be clearly identifiable as positive or negative using a likableness scale (>5 for positive and <1 for negative, on a 7-point scale, with higher scores indicating greater perceived likeableness) (Anderson, 1968; Chandler, 2018). Furthermore, we piloted the words to ensure that genuine and disingenuous words would be associated with a genuine or a fake person, respectively (see Dawel et al. (2017) for an overview of these terms in prior genuineness research). Pilot participants reliably classified the words correctly ($M_{accuracy}$ = 78% for positive words; 70% for negative words).

8.4.5.1.2 Procedure

Participants were instructed that they would see words presented on the screen, one at a time, and asked to classify whether the word was a positive word or a negative word as quickly and accurately as possible. Participants were informed they would see a face flashed briefly (100 ms) prior to the presentation of the word, but their task was to attend to the meaning of the word.

As in Experiment 1, the experiment began with a series of 12 practice trials. Trials began with the presentation of a fixation cross, varied in length between 500 and 1000 ms, to prevent anticipatory responses. Immediately after, the facial prime was presented for 100 ms. The target word was then presented on the screen until participants made a response. Half of the participants were instructed to press the far-left button for positive words and the far-right button for negative words, while the mapping of responses was reversed for remaining participants. Each of the 48 images was presented with each word, resulting in a total of 384 experimental trials, presented in a unique random order for each participant. Participants were given a short self-paced break every 96 trials. This task took approximately 20 minutes to complete. At the completion of the task participants were fully debriefed, paid, and thanked for their participation.

8.4.5.2 Results and discussion

The dependent variable in this experiment was response time. Responses removed from the dataset consisted of errors (2.53% of responses), and scores ± 3 SD of each individual participants mean (1.81% of responses). Inspection of the pre-processed data indicated that the data were positively skewed, and as such a log10 transformation was applied. A 3 (face type: genuine, KDEF, YouTube) by 2 (word type: genuine, disingenuous) by 2 (tears: no tears, tears) was conducted on the log transformed data, however, means reported in Figure 8.5 reflect response time in milliseconds for ease of interpretation. Bonferroni adjustment was used to correct for follow-up comparisons.

There was a significant main effect of face type, $F(2, 68) = 6.294$, $p = .003$, η_p^2=.156 where YouTube faces were responded to significantly faster than the KDEF faces, $t = 4.060$, $p < .001$, $d = .686$. There was no difference between the genuine faces and the YouTube faces, $t = 1.998$, $p = .161$, $d = .338$, or the genuine faces and the KDEF faces, $t = 1.370$, $p = .539$, $d = .232$. There was also a significant main effect of word type, $F(1, 34) = 12.326$, $p = .001$, η_p^2=.266, where genuine words were responded to significantly faster than disingenuous words. An interaction between face type and tears was marginally significant, $F(1, 34) = 3.031$, $p = .055$, η_p^2=.082 (see Figure 8.5). Follow-up comparisons using paired-samples *t*-tests revealed that there were no significant differences between the tear and the tear-free conditions for the genuine faces, $t(34) = .765$, $p = .449$, $d = .129$; or the YouTube faces, $t(34) = -.488$, $p = .629$, $d = -.083$; however participants were significantly faster at responding to KDEF faces with tears, $t(34) = 2.554$, $p = .015$, $d = .432$. This indicates that participants were faster to respond to both genuine and disingenuous words when preceded by a KDEF face edited to include tears, as opposed to the original tear-free stimuli. There was no evidence supporting the hypotheses that genuine faces would enhance responses to genuine words, or that posed expressions would enhance responses to disingenuous words.

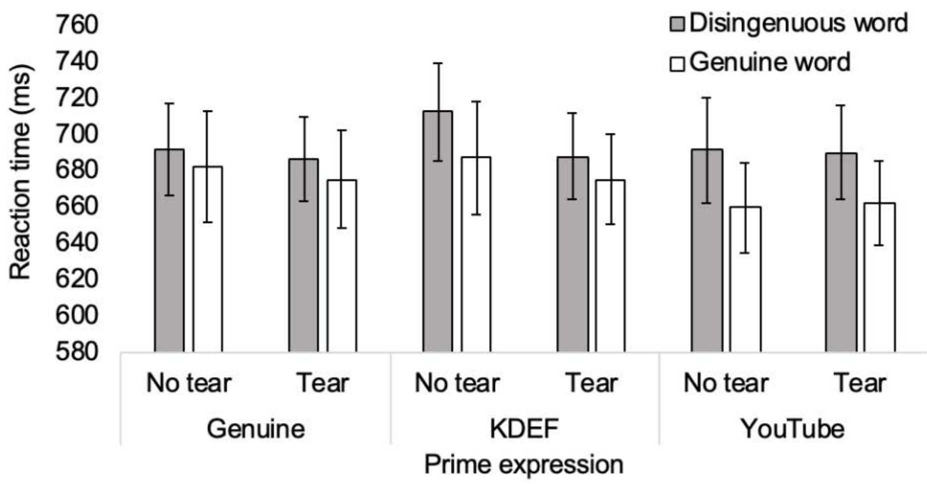

Figure 8.5. Mean reaction time to categorise words as a function of expression type and tear presence. Error bars are SEM.

8.4.6 General Discussion

Our research provides a novel investigation of how genuine tearful expressions of emotion are distinguished from posed, artificial displays. Our results demonstrate that participants are sensitive to the differences between posed and genuine sadness, which further supports existing research (McLellan et al., 2010). We have expanded on this existing literature by showing that participants were sensitive to the differences between posed and genuine tearful images. Firstly, we demonstrated, using rating scales, that genuine tearful displays were perceived as significantly more genuine than posed tearful displays. Additionally, participants were more likely to say posed, relative to genuine, expressions showed emotion, and that genuine expressions were feeling emotion rather than posing. Furthermore, the presence of tears biased judgements; regardless of whether emotions were genuine or posed, as participants were more likely to indicate that tearful expressions were both showing and feeling sadness. Finally, we were unable to demonstrate that tearful prime expressions mediated responses to words.

Overall, participants were more likely to say that tearful expressions both showed and felt emotion. Thus, in the absence of context, tears served as a marker of sadness. This finding provides further support for the *tear effect* in that tears resolve emotional ambiguity and signal sadness (Provine et al., 2009). Furthermore, our sensitivity analyses clearly show that posed displays showed emotion more so than genuine expressions. This finding is consistent with previous work, which has found that posed expressions are easier to identify as a specific emotion relative to spontaneous genuine expressions (Calvo & Nummenmaa, 2016; Namba et al., 2018). This ease of identification stems from the exaggerated nature of posed expressions (Gosselin, Kirouac, & Doré, 1995), and also highlights the ambiguity associated with spontaneous facial displays (Motley & Camden, 1988). As such, when participants are instructed to judge whether a face looks sad, posed facial expressions are more likely to be classified as sad, relative to genuine expressions.

By contrast, when asking participants to judge whether the person in the image felt sad, participants were more likely to classify genuine expressions as feeling sadness, relative to posed expressions. Thus, we provided further support for the idea that participants are sensitive to the genuineness of sad facial displays (Dawel et al., 2015; McLellan et al., 2010; Namba et al., 2018). Furthermore, participants' sensitivity to the affective state of tearful faces was significantly above chance level, which was not the case for tear-free expressions. This sensitivity indicates that the presence of tears on an image significantly aided participants in distinguishing genuine from posed emotion. As identified by Niedenthal and Brauer (2012), humans are sensitive to signals high in emotional salience and credibility. Existing research has identified that tearful displays are a distinctive marker of sadness (Krivan et al., 2020) and are believed to be an honest signal of emotion (Trimble, 2012;

Vingerhoets, 2013), which increase the sincerity of sad facial displays (Picó et al., 2020; Zeifman & Brown, 2011). We found that tears aid in identifying genuine from posed emotion. As such, our data provide empirical evidence that genuine tearful expressions are an honest signal of emotion.

Contrary to our hypothesis, we were unable to demonstrate that genuine and posed expressions facilitated responses to genuine and disingenuous words, respectively. In this way, we have demonstrated further support for McLellan et al. (2010), wherein sad facial primes do not influence classification of positive and negative words. However, this conclusion does not support the conclusion of Stenberg et al. (1998), wherein a sad facial prime facilitated the processing of negative words. Rather, in our study, responses were fastest to genuine (i.e. positive) words overall. Prior research has demonstrated a positivity advantage, where words of a positive valence are responded to more quickly than words of a negative valence (Bayer & Schacht, 2014; Fazio et al., 1986; McLellan et al., 2010; Miles & Johnston, 2007; Stenberg et al., 1998). In some previous studies, faster responses to positive words were facilitated by a prime of congruent valence (Fazio et al., 1986; McLellan et al., 2010), whereas in others there is a general positivity advantage (Stenberg et al., 1998). However, in the present study, all stimuli were negatively valenced. Therefore, we demonstrated faster classification of positive words associated with genuineness, compared to negative words associated disingenuousness—without the inclusion of a congruent facial prime. This superior responding to genuine words that are positively valenced provides support for the positivity advantage. Much like how happy faces are facilitated in facial recognition tasks (Calvo et al., 2016; Leppänen et al., 2003; Palermo & Coltheart, 2004), positive words are also preferentially processed compared to negative words (Bayer & Schacht, 2014; Feyereisen et al., 1986; Stenberg et al., 1998). In this way, the preferential processing and retention of positive, as opposed to negative, information (Matlin & Stang,

1979) was already advantageous, and as such genuine sad expressions were unable to further enhance this classification.

We believe this interpretation is more likely than a recognition issue associated with word choice for three reasons. Firstly, we selected words from previous normative studies (Anderson, 1968; Chandler, 2018), which had clear likeableness ratings, so we were confident that participants would associate these words with positive and negative responses. Secondly, we piloted the words prior to this study with a separate sample, to ensure these words would be associated with our descriptions of being genuine or disingenuous. Finally, we selected antonyms of our positive words to serve as our negative word stimuli (e.g., sincere and insincere). As such, it is unlikely that participants would be familiar with the positive word and not its antonym. However, we acknowledge that positive words are encountered more than their negative counterparts, and as such this exposure could be a facilitator of the positivity advantage demonstrated herein (Matlin & Stang, 1978; Zajonc, 1968). Thus, our study provides evidence in support of the positivity advantage in word classification tasks.

Throughout this study we have provided evidence that participants are able to distinguish between artificial and genuine tears; however, we acknowledge some limitations. Firstly, the images we used were static rather than dynamic. The use of static displays was a necessary step for foundational research; however, we acknowledge that everyday interactions are dynamic in nature. As was identified in Namba et al. (2018), participants are better able to distinguish genuine from posed emotion in dynamic, as opposed to static, displays. As such, further research should endeavour to extend our research to encompass dynamic and genuine tearful displays that offer unique cues to deciphering genuineness, particularly when considering the physiological features that accompany genuine tears (Küster, 2018; Provine et al., 2011), and tears acoustical properties (Lavan, Lima, Harvey, Scott, & McGettigan, 2015). Furthermore, a recent study by Roeyen et al. (2020) demonstrated that if tears are perceived as false or insincere (i.e. crocodile tears) by an observer, this opinion has a damaging effect on crier perception. Interestingly, this effect held regardless of whether the emotional tears were genuine. Therefore, further research exploring not only the type of stimuli used, but also *how* the stimuli are perceived is needed to better understand the communicative functions of tears.

In conclusion, the present studies provide evidence that genuine tearful expressions of emotion are distinct from posed, artificial tear displays. By asking participants to determine whether the facial stimuli were showing and feeling sadness we demonstrated that participants were more likely to attribute showing emotion to a posed expression, in line with posed displays being clearly recognisable (Calvo & Nummenmaa, 2016; Namba et al., 2018). By contrast, when asking participants to determine whether the person in the sad facial displays were feeling emotion, participants were significantly more likely to select a genuine expression felt emotion. Furthermore, the presence of tears facilitated the differentiation between posed and genuine displays. Therefore, the present research supports previous findings that persons are sensitive to genuine displays of sadness and provides important empirical evidence that individuals are sensitive to tearful displays.

Chapter 9: Why Do We Care When Others Cry?

9.1 Summary

As I have demonstrated throughout this thesis, tears demand attention. This thesis provides a valuable addition to the literature exploring the communicative functions of emotional tears. A series of self-report behavioural studies had demonstrated that tears elicit empathy, aid, and succour from observers (Balsters et al., 2013; Hendriks & Vingerhoets, 2006; Hendriks et al., 2008; Vingerhoets et al., 2016; Zickfeld & Schubert, 2018), and the data from this body of work demonstrates that these empathic responses have a physiological basis. The overarching aim of this thesis was to determine why we care when others cry. To achieve this aim, three questions were investigated: 1) do tears serve as a signal of sadness in the absence of context (Chapter 3)?; 2) do tears modulate physiological responses to facial displays (Chapters 4, 5, & 6)?; and 3) do tears increase the authenticity of facial displays (Chapter 8)? These three questions will be addressed sequentially, while outlining the findings. The outstanding research questions pertaining to each of these aims will also be addressed and potential avenues for future research will be highlighted. Finally, the thesis will conclude by outlining why the continued investigation of tears is important to better understand the development of empathy and prosocial behaviour in society as a whole.

9.2 Tears as a Signal

9.2.1 Findings and implications

As explored in Chapter 1, tears serve a unique signalling function (Hasson, 2009). Following the *tear effect*, tears serve as a signal of sadness in the absence of context (Provine et al., 2009). This signal of sadness is effective at communicating distress, which in turn elicits help and succour from observers. However, prior to this thesis, limited work had explored whether the tear effect is evident in expressions other than sadness (Ito et al., 2019;

Reed et al., 2015). In this way, it could be that tears signal sadness for sad expressions but serve to intensify the expression of any emotion they are paired with—functioning as a secretory exclamation point (Provine, 2012). This theory, known as the general enhancement perspective, has received limited empirical inquiry (Ito et al., 2019). Ito et al. (2019) demonstrated that tears on negative facial displays (e.g. angry, sad, disgusted, fearful), made all negative expressions seem sadder. However, tears are also elicited in response to joy (Miceli & Castelfranchi, 2003).

In Chapter 3, these two competing hypotheses were addressed, by using happy and sad facial displays. In support of the tear effect, regardless of whether the tearful faces were happy or sad, they were perceived to be significantly more negative (or less positive in the case of happy-tear expressions), than their tear-free counterparts. This result, however, contradicts recent work that has failed to demonstrate the tear effect for sad displays across two experiments, and concluded that the tear effect was greater for expressions that were not readily perceived as sad, such as neutral expressions (Reed et al., 2019). It must be acknowledged that Reed et al. (2019) used a single female actress as the stimulus for both studies. Therefore, it can only be concluded that this particular display of tearful sadness was not significantly sadder than the display without tears. Further to this conclusion, prior research using happy expressions has also demonstrated support for the tear effect, wherein happy tearful faces are perceived as sadder than the same faces without tears (Reed et al., 2015). As such, the greatest empirical support was demonstrated for the tear effect. However, it must be noted that these prior studies have predominantly used emotion specific rating scales (i.e. how sad is this expression?) (Ito et al., 2019; Reed et al., 2015; Reed et al., 2019). In this sense, an increased perception of sadness is not overly surprising, given the emotional specificity of the response scale. Therefore, a fair test of the general enhancement perspective could only stem from generalised ratings of intensity.

In addition to the increased perception of negative valence demonstrated in Chapter 3, there was also an increase in generalised intensity for tearful expressions. This finding demonstrates that tears make both happy and sad expressions seem more intense—in support of the general enhancement perspective. The finding that tearful displays are more intense than tear-free counterparts is not overly surprising, given that intense emotions are typically associated with profound feelings and are elicited in response to substantial life influences (Sonnemans & Frijda, 1994). One theoretical model—termed here the helplessness[6] model—argues that tears are shed when one feels helpless (Frijda, 1986; Miceli & Castelfranchi, 2003). Under the helplessness model, tears occur once an individual has exhausted all avenues and is unable to alleviate or remedy a situation. In this way, tears are associated with feeling overwhelmed by a situation or emotion. The helplessness model is validated by a series of self-report studies which have demonstrated that tearful individuals are perceived as more helpless than tear-free individuals (Vingerhoets et al., 2016). Additionally, tears are typically associated with substantial and important relational life events (e.g. death, birth, reunion)[7], wherein the expression of overwhelming emotion is appropriate (Fischer et al., 2013; Vingerhoets, 2013). Thus, it may be that tears are inherently perceived as intense as a result of their association with extreme life events. Consequently, tears would be associated with intense feelings and, in the absence of context, these feelings are interpreted as largely negative.

Contrary to expectations, tearful-sad expressions were not responded to significantly faster than sad expressions without tears. Exploring reaction time data with response accuracy measures indicated that responses to sad expressions were at ceiling level, and as such the addition of tears offered no further improvement to the classification of sad faces.

[6] Sometimes termed the powerlessness model

[7] Although these experiences are typically rare and, as such, tears are usually elicited in response to more mundane life experiences (e.g. frustration, disappointment, failure), it is the case that tears are typically associated with substantial events.

Although this finding does contradict earlier research (Balsters et al., 2013), it also supports the conclusion that the tear effect has a greater influence on expressions not readily perceived as sad. Happy faces with tears were responded to significantly slower than happy faces without tears across two experiments. Happy faces are a distinctive marker of happiness and are responded to quickly and accurately in reaction time tasks—known as the happy face advantage (HFA) (Becker et al., 2011; Calvo et al., 2016; Calvo et al., 2018; Kirita & Endo, 1995; Leppänen & Hietanen, 2004; Leppänen et al., 2003; Palermo & Coltheart, 2004). Interestingly, pairing tears, a distinctive marker of sadness, with distinctively positive expressions reduced this HFA. This finding is in line with prior research demonstrating that incongruent facial features increase response time (Calvo et al., 2012). In this way, happy-tear expressions were less positive than happy faces without tears, which in turn increased the time taken to respond that the stimulus was happy. Therefore, in the absence of context, support for both the tear effect and the general enhancement perspective is demonstrated, wherein tearful displays are both more intense and more negative than the same displays without tears.

9.2.2 Limitations and future directions

It must be acknowledged that the reaction time, intensity, and valence ratings observed in this study are limited to context-free displays—a rare occurrence outside of laboratory settings. This limitation is especially relevant for the interpretation of happy-tear displays. In Chapter 3 it was concluded that happy-tears were perceived as less positive than tear-free happy faces. Conversely, some studies have demonstrated that happy tearful displays are uniquely expressive of overwhelming joy (Aragón & Bargh, 2018; Fernández-Dols & Ruiz-Belda, 1995). In this sense, a person would be so overwhelmed with joy that they could not help but cry (i.e. an intense, but positive expression). However, this interpretation is typically reliant on contextual cues. A series of studies have demonstrated that when participants are told that tears are joyous, they perceive those tears as positive (Aragón, 2017; Aragón & Bargh, 2018; Aragón & Clark, 2018). Moreover, tears are perceived as joyous when they are accompanied by a positive vignette that depicts victory, yet are perceived as negative when accompanied by vignettes expressing loss (Aragón & Clark, 2018). As such, these displays are the same, but contextual information changes the expression. Therefore, the context in which tearful displays are perceived will likely mediate the response one has to the expression of emotion.

However, even when the context is known, there are limitations to drawing conclusions about tearful displays. These limitations stem from the argument that humans are capable of experiencing mixed emotions (Larsen & McGraw, 2014). Mixed emotions are the experience of blended emotions, wherein two or more emotions of the same or the opposite valence are experienced simultaneously (Larsen, McGraw, & Cacioppo, 2001; Larsen, McGraw, Mellers, & Cacioppo, 2004). Mixed emotions have previously been considered with regards to tearful displays, wherein the person crying has felt bittersweet (Katz, 1999), which is the dual experience of joy and sadness, and can be brought on by feelings of nostalgia (Larsen, Stastny, & Bradley, 2011; Werman, 1977). Additionally, several theorists have concluded that "tears of joy" dually reflect joy at overcoming sorrow. For example, Vingerhoets (2013) identified that tearful displays of joy at reunion dually reflect feelings of sorrow at the time spent apart. Therefore, tearful joy has been associated with the alleviation of a prior worry and, as such, is an expression of relief (Frey, 1985; Miceli & Castelfranchi, 2003). Nonetheless, neither prototypical emotional displays nor contextual cues are capable of indexing what a person is *feeling.* (Vingerhoets et al., 1997) identified that sadness is the most common emotional antecedent to crying behaviour, however this sadness is often accompanied by feelings of powerlessness. Accordingly, the combination of the intra- and the inter-personal crying fields may yield insight into how tears serve as a communicative signal.

A final limitation to the theory that tears serve as a signal is that it is difficult to explain why we cry when we are alone. International studies of adult crying behaviours revealed that we predominantly cry when alone (37% of responses) or with one person present (29%)—most often a partner (Vingerhoets, 2013). Therefore, if the purpose of crying is to elicit help and support from those witness to the display, why would we prefer to cry when alone? This criticism is not restricted to tearful displays. The Behavioural Ecology View (BECV) asserts that facial expressions are communicative signals rather than expressions of emotion (Fridlund, 1991, 1994, 2017)—yet we make a myriad of faces when alone (Ekman, 1972; Ekman et al., 1990). Under the BECV, the faces made when alone are known as implicit sociality (Fridlund, 1994). The assumption of implicit sociality states that being physically alone does not mean we are psychologically alone (Fridlund, 1991, 2017). Implicit sociality can stem from anticipating social interaction and rehearsing an encounter, or imaging the continued presence of individuals after the conclusion of an encounter (Fridlund, 2017). Similarly, we may treat inanimate objects, pets, or even treat ourselves as social others. Some have argued that private displays are the purest form of expression, as they are free from social demands and display rules (Ekman et al., 1990).

Implicit sociality can also be used to explain private weeping. Firstly, although weeping is responsible for eliciting comfort from observers, this need for comfort may stem from helplessness (Miceli & Castelfranchi, 2003). For the weeper, weeping typically occurs once one has exhausted all methods available to them and feels as though they are unable to remedy their situation. For the expresser, tears as a signal of helplessness, signal that the crier needs help (Miceli & Castelfranchi, 2003). While death, loss, and birth are all commonly reported antecedents to crying behaviour, these events are rare occurrences throughout one's life (Vingerhoets & Cornelius, 2001). In this way, tears are more often produced in response to mundane life sufferings (e.g. frustration, disappointment, failure) (Miceli & Castelfranchi, 2003). Additionally, many of the antecedents to crying are social; for example, loss, separation, conflict and even reunion (Vingerhoets & Bylsma, 2015). Hence, reimagining or replaying events and interactions when alone can result in feeling implicitly social, while free from potentially negative social responses. Thus, tears shed alone are implicitly social and can function as an expressive signal regardless of whether one is alone, or in the presence of others.

9.2.3 Conclusions

Despite these limitations, this thesis has provided empirical evidence that tears function as a biological signal. However, unlike a strict BECV view, tears are capable of signalling emotion, namely sadness (at least in the absence of context). Therefore, crying signals feelings of distress and sadness to those around us, which in turn solicits comfort, empathy, and succour from observers in behavioural tasks (Hendriks et al., 2008). As identified in this thesis, tears modulate our psychophysiological responses to facial displays. As such, tears are a unique signal, which are preferentially processed at the psychophysiological level.

9.3 Psychophysiological Responses to Tears

9.3.1 Findings and implications

The second component of this thesis was to examine whether tears, as a salient biological signal, are preferentially processed at the psychophysiological level. This question was examined through a series of psychophysiological studies using facial EMG and EEG, as these techniques offer the ability to explore the rapid, automatic responses one has to tearful displays.

Chapter 4 details the results of the first psychophysiological study I conducted, which revealed that tears largely did not influence facial mimicry responses as evidenced by facial EMG. Using a masked priming paradigm, a trend towards a reduction in corrugator activity following the presentation of tearful expressions was demonstrated. The corrugator is largely associated with the production of negative emotion and is the muscle responsible for drawing the eyebrows together into a frown (Dimberg et al., 2000; Ekman & Rosenberg, 2005). Although participants exhibited less mimicry in response to a tearful expression, this finding could indicate that they frowned less in response to tearful stimuli. Thus, this reduced frowning response could be a physiological expression of reduced aggression in response to tearful displays. This conclusion supports earlier literature showing that tears reduce aggression in observers (Hasson, 2009; Hendriks et al., 2008; Kottler, 1996). Unfortunately, this trend towards significance observed during the masked prime stage was not present when participants were shown emotional expressions for an extended period of time (i.e., 5 seconds). Therefore, it is difficult to conclude what role tears play in inducing mimicry in observers given the disparity between the subliminally and supraliminally presented tearful displays.

However, the null results observed in the supraliminal presentation phase are in accord with a recent study demonstrating no difference in mimicry responses to sad-tearful displays (Grainger et al., 2019). Furthermore, the literature has generally demonstrated that mimicry is increased in affiliative scenarios (Likowski et al., 2008; Likowski et al., 2011). In the case of sad facial displays, mimicry is typically limited to in-group members (Bourgeois & Hess, 2008) or close partners (Häfner & IJzerman, 2011). Thus, it is possible that mimicry of tearful displays is also limited to in-group members or close partners, rather than strangers. This conclusion is justified given that if tears are shared with a close other, it is usually a partner (Vingerhoets, 2013). From an evolutionary perspective, mimicry of tears might be selective wherein mimicry only occurs for displays that are personally relevant to the individual.

Conversely, it could simply be that mimicry of distress and sadness is not adaptive. Sadness is considered a high cost emotion, wherein responding to a sad display (i.e.

providing comfort and succour) comes at a cost to the observer (Bavelas et al., 1986; Bourgeois & Hess, 2008). When mimicking a social display comes at a cost to the mimicker, mimicry is reduced (Johnston, 2002). In the case of tears, although mimicry could encourage the continued expression of emotion, it also signals understanding and fosters affiliation between interactional partners (Bourgeois & Hess, 2008). However, research exploring self-report emotion regulation responses to tearful joy and sadness has indicated that tears increase the likelihood of a down-regulation response (Aragón & Clark, 2018). Down-regulation responses are used to calm down and comfort individuals, and to aid the individual in regaining control over their emotions. Therefore, if the goal of an interactional partner is to down-regulate a crying individual, mimicking that display would be counterproductive. Consequently, future research exploring mimicry of tearful displays must better account for the social factors that influence mimicry responses: the personal connection between interaction partners; the context in which crying occurs; and the subsequent interactional goals of the perceiver.

While tears were not found to modulate mimicry responses, they were found to modulate early face-related neural responses. The results presented in Chapter 5 demonstrated that the N170 event-related potential (ERP) was modulated by emotional content, which contradicts earlier research that suggested the N170 was only involved in early structural encoding (Bentin et al., 1996; Bentin & Deouell, 2000; Eimer, 2000, 2000). Furthermore, the N170 was found to be modulated by the type of emotion depicted, providing support for a recent meta-analysis, which concluded that the N170 is preferentially modulated by stimuli that require rapid interpretation (Hinojosa et al., 2015). As such, expressions that facilitate survival are prioritised and these expressions have increased social relevance. In Chapter 5, it was revealed that sad tearful displays and happy displays without tears were preferentially processed. As has been outlined, tearful displays are a distinctive signal of sadness—wherein tears aid individuals in identifying sadness. Additionally, tearful displays foster approach behaviours (Gračanin et al., 2018) and helping responses from observers (Hendriks et al., 2008). In this way, tearful displays are preferentially processed at the early neural level, which provides a biological basis for the pro-social responses observed in both Chapter 3 and earlier work. Furthermore, in accord with existing literature, the N170 was also modulated by happy displays without tears. This preferential processing of happy faces can be attributed to the affiliative nature of smiling facial displays and their role in fostering pro-social behaviour (Nummenmaa & Calvo, 2015). Evidently, displays that are more socially relevant elicit larger N170 ERP responses. Therefore, this study provides psychophysiological evidence for the conclusions drawn in Chapter 3, as tears foster the detection of sadness and increase the social relevance of sad faces.

Finally, in Chapter 6 I explored whether the mirror neuron system is sensitive to tears. Mirror neurons are believed to be a critical component in the sharing of affective states, and the way that we as humans experience empathy (Carr et al., 2003; Gallese, 2001). In this way, exploring whether the mu rhythm is sensitive to tearful expressions of emotion allows for physiological validation of the existing self-report research. I demonstrated that expressions that were more perceptually ambiguous: happy-tears, tear-free sadness, and neutral faces elicited increased mu suppression responses. Emotionally ambiguous expressions elicit increased suppression responses as the sensorimotor system works harder to activate these representations. This increased response to ambiguous displays has been previously reported in both the EEG (Karakale et al., 2019; Karakale et al., 2019) and fMRI (van der Gaag et al., 2007) literature. Additionally, this study is the first to provide evidence that the mu rhythm is influenced by the presence of tears on a face. The increased activation observed in response to more ambiguous expressions is the inverse of the results reported in Chapters 3 and 5. Moreover, the reduced suppression response to clearly distinctive displays of happiness and sadness indicates that less neural effort is needed to process these facial expressions. As such, the MNS is engaged in processing information that is critical to social interaction (i.e. facial expressions).

9.3.2 Limitations and future directions

Despite the insights afforded by these experiments, tear psychophysiology research is still in its infancy. In considering mimicry responses, the muscle used to index mimicry for distinct emotions is increasingly being questioned (see Chapter 4). Specifically, the corrugator is widely used to index mimicry of both sadness and anger (Bourgeois & Hess, 2008; Künecke, Hildebrandt, Recio, Sommer, & Wilhelm, 2014; Moody et al., 2007; Neumann, Schulz, Lozo, & Alpers, 2014); however, research by Duchenne (1862/1990) associated corrugator activation with the expression of pain. Figure 9.1 displays the muscles commonly used to index sadness, weeping, and anger in existing research (left side), as well as the muscles that Duchenne originally attributed to the expression of these emotions (right side). Potentially, the key to understanding mimicry of sadness stems from indexing muscles other than the corrugator, such as the depressor (Philip, Martin, & Clavel, 2017; Soussignan et al., 2013), or the Zygomaticus Minor (ZMin). Evidence for this approach has been demonstrated as increased depressor lip activity is observed in response to sad expressions (Philip et al., 2017; Soussignan et al., 2013). Unfortunately, as demonstrated in Chapter 4, it was not possible to use the ZMin muscle to index mimicry of tearful expressions. This inability to index tearful mimicry stemmed from muscular crosstalk, which originated from the larger muscle, the ZMaj. In this way, although the ZMin is a muscle uniquely associated with weeping, it is difficult to index whether tearful mimicry occurs when using surface facial EMG electrodes. With this limitation in mind, indexing a muscle that is generally associated with sadness (i.e. the depressor) could demonstrate whether people mimic tearful displays.

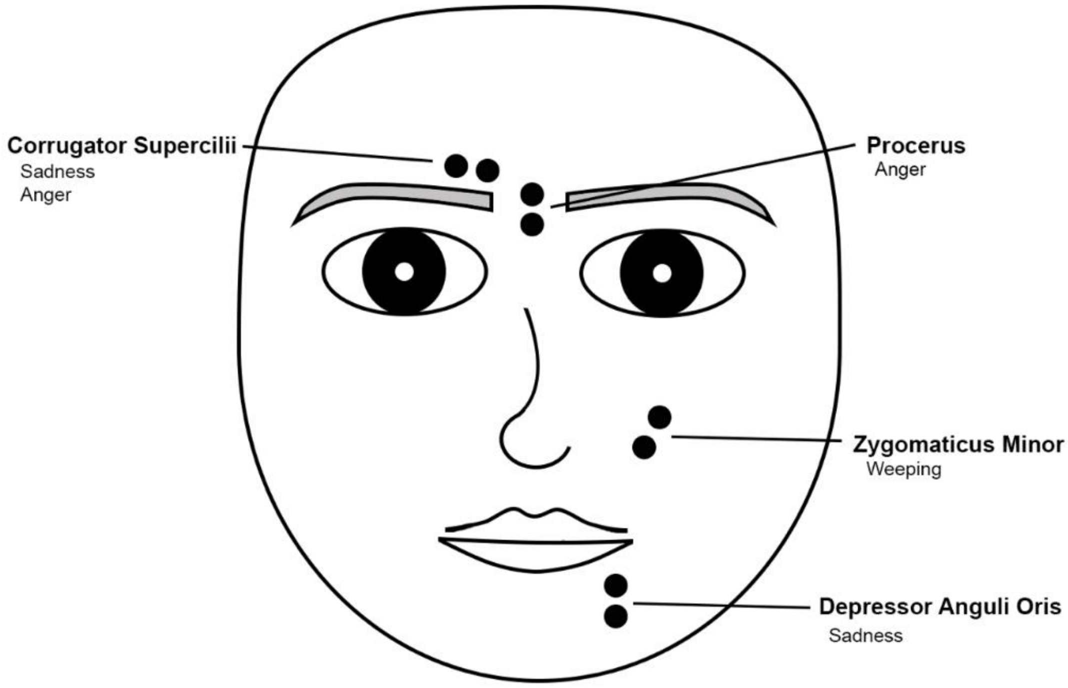

Figure 9.1. Electrode placement for the muscles typically reported to index sadness, and anger (left), and the muscles Duchenne attributed to these expressions (right).

Facial EMG could also be used to further validate the findings of Chapter 6. Combined EEG and EMG would afford an understanding of the time course involved in processing emotional facial displays. In the mu suppression paradigm outlined in Chapter 6, a strength of the design was the isolation of motor preparation and execution. However, a combined EEG/EMG approach would allow for the confirmation that motor planning is not contaminated by actual movement, whilst also allowing for investigation of suppression exhibited during actual movement. This has a particular importance given that the mere observation of facial expressions is enough to automatically invoke mimicry responses, which can occur without awareness (Dimberg et al., 2000; Kret, 2015). This automatic mimicry has implications given that facial feedback via mimicry has been associated with emotion understanding (Mori & Mori, 2009; Soussignan, 2002). Under the facial feedback view, mimicry facilitates motor resonance. Therefore, the concurrent measurement of EEG and EMG would allow for an understanding of how mu suppression is influenced by unconscious motor movement. Evidence for the efficacy of this approach has been demonstrated in existing action-related finger tapping studies (Muthukumaraswamy et al., 2004; Woodruff & Maaske, 2010; Woodruff et al., 2011). Concurrent EEG-EMG was used to confirm that motor activity was not present in the observation-based trials (Muthukumaraswamy et al., 2004). Thus, in the same vein, EEG and facial EMG would allow the disentangling of the time course of the way we process emotional displays—from mimicry to mirroring.

9.3.3 Conclusions

Thus far, it is evident that tears serve as a distinctive signal of sadness, and that this signal is preferentially processed at the physiological level. Therefore, tearful expressions—particularly those of sadness—are interpreted rapidly. Moreover, humans appear to be biologically hard-wired to respond to socially relevant information. This thesis has provided both behavioural and psychophysiological evidence to demonstrate that tears enhance the social relevance of sad faces. However, *what* is it about tears that make them such an effective signal? One explanation is that tears are perceived as an honest expression of emotion and this authenticity affords meaning to the display (Trimble, 2012; Vingerhoets, 2013). Namely, tearful persons are believed to be sincere (Picó et al., 2020; Zeifman & Brown, 2011). Presumably, this sincerity fosters feelings of warmth and social connectedness to the tearful person (Fischer et al., 2013; Ven de Ven et al., 2017; Zickfeld & Schubert, 2018; Zickfeld et al., 2018). Yet, experimental studies have predominantly used posed faces with artificial tears—either elicited via eyedrops or digitally added to a photograph (Balsters et al., 2013; Fischer et al., 2013; Hendriks & Vingerhoets, 2006; Hendriks et al., 2007; Ito et al., 2019; Lockwood et al., 2013; Reed et al., 2015; Švegar, Fiamengo, Grundler, & Kardum, 2016). Recently, tear researchers have preferentially adopted the use of tearful stimuli wherein the tears were shed in a moment of true emotion (Gračanin et al., 2018; Picó et al., 2020; van de Ven et al., 2017; Vingerhoets et al., 2016). However, prior to this thesis, limited empirical work had explored the perceptions genuine and posed stimuli together—a necessary comparison to elucidate why tears are such an effective signal.

9.4 The Type of Stimuli used in Crying Research

9.4.1 Findings and implications

Chapter 7 explored what was proposed as a critical component of future crying research—an empirical investigation of the stimuli used in crying research. As described in Chapter 8, three experiments were conducted to explore the perception of genuineness for three different types of sad stimuli. Unsurprisingly, these experiments demonstrated that genuine-tearful displays were perceived as more genuine than posed faces with artificial tears that were added digitally. Additionally, posed KDEF faces with tears were perceived as significantly more genuine than posed KDEF faces without tears. To further explore whether participants were sensitive to the genuineness of tearful sadness, an experiment was conducted using a paradigm that has previously been used in genuineness research (McLellan et al., 2010; Miles & Johnston, 2007; Namba et al., 2018). When participants were asked if faces were *showing* emotion, participants were significantly more likely to state that a posed KDEF display was showing sadness relative to a genuine display. By contrast, when participants were asked to judge whether the face was *feeling* emotion, participants displayed greater sensitivity to genuine displays. Therefore, my research has provided the first empirical evidence that persons are sensitive to the genuineness of sad tearful displays.

Undoubtedly, the findings from Chapter 8 have implications for the work discussed in Chapters 3, 4, 5, and 6, given that these chapters all relied on the use of posed stimuli. The primary concern for these results is that tearful KDEF faces were perceived as more genuine than posed KDEF faces without tears. This concern stems from an inability to definitively conclude whether this perception of genuineness influenced results. However, several points must be noted. Firstly, the magnitude of the 'increased perception of genuineness' effect was quite small. As such, it is unlikely that the increase in perceived genuineness solely facilitated the behavioural and physiological responses obtained in earlier chapters. Rather, tears as a distinctive signal of sadness remains a more likely explanation. It is reasonable to conclude that genuine signals would be more effective than disingenuous ones. Moreover, it is intuitive that genuine expressions would be responded to more favourably (e.g. enhanced ratings, improved response time, and greater ERP responses).

Evidence for this conclusion can be drawn from research exploring perceptions of Duchenne and non-Duchenne smiles. In the absence of context, both tears and smiles serve as distinctive markers of sadness and joy, respectively. Genuine Duchenne smiles are perceived as more intensely happy, more pleasant, and signal greater affiliation than posed smiles (Leppänen & Hietanen, 2007). In addition, these behavioural responses seem to have a physiological basis wherein Duchenne smiles are mimicked more often and elicit greater neural responses relative to posed smiles (Krumhuber et al., 2014; McLellan et al., 2012). It appears that genuine expressions foster increased pro-social responses from observers, wherein genuineness, at least in the case of smiles, is responded to favourably. Therefore, it is plausible that tearful displays that are perceived as genuine might elicit increased behavioural and physiological responses. However, *how* the perception of tearful genuineness modulates early physiological responses is yet to be determined.

Given that persons are sensitive to the difference between genuine and posed tearful sadness, this sensitivity provides empirical support for the theory that tears are an honest signal of emotion (Trimble, 2012; Vingerhoets, 2013). Tears are associated with sincerity, credibility, and honesty (Picó et al., 2020; Trimble, 2012; Zeifman & Brown, 2011), and it is known that humans are sensitive to signals that are high in salience and credibility (Niedenthal & Brauer, 2012). It makes sense that humans are particularly sensitive to social signals—like tears—which biologically function to elicit support from observers. This sensitivity may stem from the increased cost associated with providing this support, as well as a desire to not be manipulated by an inauthentic expressor (Bavelas et al., 1986). Manipulative tears, known as crocodile tears, are an insincere tearing display designed to elicit support from observers. Although crocodile tears are qualitatively different from the posed tears used in crying research, the understanding that humans are capable of distinguishing posed from genuine emotion has obvious implications for the field of crocodile tear research. Very limited research has been conducted exploring how humans distinguish between genuine and crocodile tears (Roeyen et al., 2020). Roeyen et al. (2020) recently demonstrated that the greatest damage to a crier's image stemmed from the perception that a crying display is fake. Specifically, the perception that tears were false resulted in increased ratings of manipulativeness, and decreased warmth and perceived reliability of tearful individuals. Critically, this damaging perception was present, regardless of whether the tears were genuine or fake. Therefore, further research should explore what specifically makes tears seem genuine, which will aid in determining how persons distinguish between crocodile tears and genuine tears. This distinction will not only aid in understanding tearful displays, but also has the potential to influence fields such as criminal justice and law enforcement, wherein the accurate detection of insincere emotion is paramount.

9.4.2 Limitations and future directions

As the studies presented in Chapter 8 were some of the first to explore perceptions of genuineness in crying research, there is a great deal of future work that needs to be conducted. The next section will outline limitations associated with the use of genuine displays, and what can be done to overcome these caveats in future research.

Firstly, the genuine stimuli used in this research, and that of prior studies, were facilitated by a set of tearful displays that were captured in a moment of genuine experience. One limitation of these naturalistic photographs is that we are unable to know *what* the individual was feeling that lead them to weep. In this way, it is impossible to control for feeling across this stimulus set. However, the creation of a genuine tearful stimulus set, where feeling is known, is also not without limitations. Namely, developing a stimulus set of genuine expressions is a time consuming and labour-intensive project, which subsequently results in lower experimental control over the stimuli than that of posed standardised displays (Dawel et al., 2017; Krivan & Thomas, 2020). An alternative to these caveats was offered by Dawel et al. (2017), as some posed stimuli are perceived as genuine. This 'perceived as genuine' effect was observed across emotions and stimulus sets. In this sense, posed stimuli that are perceived as genuine offer an alternative to genuine tearful expressions. The research conducted in Chapter 8 has demonstrated that this 'posed perceived as genuine' effect is also the case for some posed tearful displays. Therefore, it would be advantageous to conduct a wider-scale investigation of the stimuli used in tear research to examine which posed tearful displays are perceived as genuine. This investigation would offer the opportunity for future research to use tearful displays that are perceived as genuine, while affording additional experimental control over the stimuli.

Alternatively, genuine expressions of sadness that have been modified to include artificial tears could also offer interesting conclusions. Genuine displays of sadness are likely more readily available than genuine tearful displays, and as such would afford additional experimental control over the type of tears that are used. This control would allow for the investigation of how different levels of tearing are perceived (e.g., from tearing up to hysterical crying). Vignette studies have demonstrated that in some scenarios, tearing up is responded to more favourably than weeping (Wong et al., 2011). Therefore, it seems that favourable responses to emotional tears are also dependent on the type of tear shed. The additional control afforded over the tearful displays would allow for the investigation of whether there is an 'optimum' tearing level. It could be that responses to tears are curvilinear, wherein no tears, and hysterical or 'ugly' crying fail to elicit helping responses but tearing up and moderate tearing elicit greater levels of aid (see Figure 9.2). This continued investigation would afford an increased understanding of the way that different types of tears are responded to and these findings may aid in alleviating some of the negative connotations associated with tearful displays.

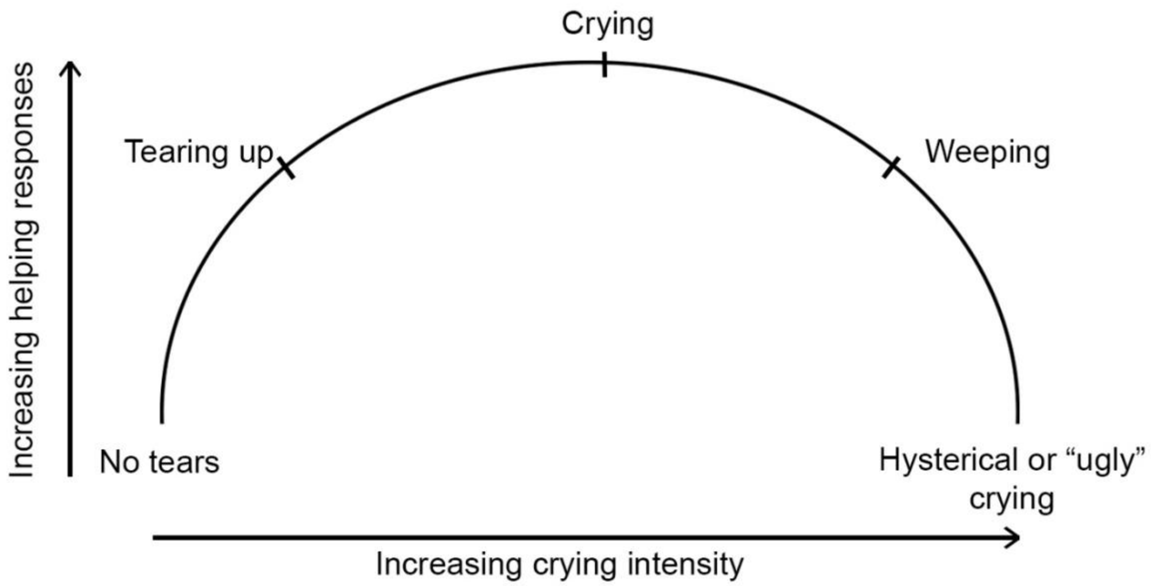

Figure 9.2. A proposed curvilinear model for responses to tearful expressions on an intensity continuum.

However, both the 'posed perceived as genuine' and the 'genuine face artificial tear' paradigms lack ecological validity as neither allow for the investigation of the other physiological responses that accompany crying, such as bloodshot eyes and blotchy, flushed faces (Provine et al., 2011; Provine et al., 2013). These physiological responses are an involuntary response to emotional tears. Although tears can be feigned, it is yet to be determined whether these feigned tears are also accompanied by additional physiological responses. In addition, the conceptualisation that tearing occurs on a continuum (see Figure 9.2), suggests that perhaps increasingly intense tears elicit increased physiological responses. For example, 'tearing up' may elicit slight sclera reddening, while 'hysterical or ugly crying' may elicit extremely puffy, bloodshot eyes and a blotchy, red, flushed face. Therefore, these accompanying physiological features may be that the key to understanding responses to tearful displays, and the ability to distinguish genuine emotion. Arguably, the continued investigation of tearful displays using ecologically valid stimuli are likely to yield interesting insights into how humans perceive and subsequently respond to tearful displays.

9.4.3 Conclusions

Undoubtedly, the work conducted in this thesis is a preliminary investigation into the differences between posed and genuinely tearful stimuli. In saying this, the results of these experiments provide a strong rationale for continued investigation. The promising results obtained herein provide interesting avenues for further research, and the potential use of stimuli that overcome the caveats associated with genuine displays. Additionally, this research has afforded a preliminary insight into how individuals discriminate between posed and genuine emotional displays. Thus, this research provides the opportunity to explore not only displays that are associated with pro-social behaviour, but also how humans are able to distinguish manipulative behaviours from genuine expressions.

9.5 The Big Picture

Tears are undoubtedly mysterious. They signal sadness, distress, and sorrow, as well as feelings of helplessness and powerlessness, which in turn reduces aggression in observers and fosters pro-social responses. Tears are also attended to without conscious awareness, as tears are preferentially processed at the physiological level. All these points, offered jointly throughout this thesis and through existing literature, point to why tearful displays have persisted through evolution. Although Darwin (1872/1979) originally argued that tearful displays were purposeless, it seems that their purpose is, in part, their effectiveness as a social signal.

As identified, tears are a multifaceted signal. It is this diversity in what a tearful display expresses that has likely contributed to the lack of tear research relative to other basic emotional expressions. Tearful displays are universally recognisable; however, it would be counterintuitive to assume that they solely signal sadness. Moving forward, the field of crying research is vast and largely unexplored. Much like the necessity for exploring mixed emotions, it is likely that tearful displays would benefit from less bounded inquiry. Research using ecologically valid and authentic stimuli is at the forefront of emotion research, and pioneering tear research is being conducted exploring tearful genuineness. Tears are an *honest* signal, which means that they reliably elicit succour and comfort from observers. However, tears can also be used to deceive. Therefore, the exploration of how we, as humans, are capable of distinguishing between genuine tearful displays and insincere crocodile tears will give us a greater understanding of the human condition. As has been evidenced throughout this thesis, tears demand attention from observers. I argue that tears should also demand attention from emotion researchers. The continued investigation of how tears are expressed, perceived, and responded to has the unique potential to provide insight into the development of empathy and prosocial behaviour in society as a whole.

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Appendix A

Baseline vs. stimulus analyses for Chapter 6

A 2 (task: observation, execution) by 2 (hemisphere: left right) by 2 (emotion: happy sad) by 2 (tears: no tears, tears) by 2 (segment: baseline, stimulus) repeated measures ANOVA was conducted. We were interested in exploring whether there were any segment related effects. We observed a significant task by segment interaction, $F(1,67) = 17.680$, $p < .001$, $\eta_p^2 = .209$ (See Table 1 for a summary of the marginal means). Analyses of the simple main effects revealed no significant difference between the observation and execution tasks during the baseline, $F(1,67) = 4.297$, $p = .042$, or the stimulus segments, $F(1,67) = 0.653$, $p = .653$. No other segment effects were significant, *F's* < 3.816, *p's* > .055

Table 1.

Summary of the Marginal Means (SE's) for the Baseline and Stimulus Segments across Task Conditions

	Observation	Execution
Baseline	6.538e -7 (1.058 e-7)	7.912e -7 (1.058 e-7)
Stimulus	7.081e -7 (1.058 e-7)	6.652e -7 (1.058 e-7)

Appendix B

The detailed instructions given to the Chapter 8 pilot participants were as follows:

All the expressions you will see were photographed in laboratories[8], but some of them are genuine and some are faked. In genuine expressions, emotions were induced by showing people video clips, pictures or sounds, or by asking them to remember an emotional event. An example of a genuine expression is when somebody smiles and they really feel happy, like when they get a present or see something funny. An example of a faked expression is when somebody smiles for a school photo, without feeling any emotion.

You will see each image at the top of the page. After you have studied the expression you will rate it on three scales:

The **genuineness** scale will ask you to rate how genuine the emotion depicted was ranging from completely fake to completely genuine. Sometimes people show facial expressions of emotion they genuinely feel, and sometimes they display expressions that are faked or posed (e.g. to be polite or because they are acting). An example of a *genuine expression* is when someone smiles and they really feel happy, like when they get a present or see something funny. An example of a *faked expression* is when somebody smiles for a school photo, without feeling any emotion. Your task is to decide whether faces are showing genuinely felt expressions or faked/posed/acted expressions. We want you to ignore the strength of the expressions when you rate how genuine or fake each expression is. For example, an expression of sadness may be very subtle but be completely genuinely felt. Such an expression should be rated as completely genuine. On the other hand, an expression of sadness may be very strong but be completely faked/posed/acted. Such an expression should be rated as completely faked.

[8] This point was not actually true, as the genuine expressions we have used were captured during a moment of genuine experience, rather than in a laboratory. We chose to keep this wording the same as the Dawel et al., (2017) study to minimise the potential for participants to look for subtle differences between the photographs.

The **intensity** scale will ask you to rate the *strength* of the emotional expression, ranging from not at all to extremely intense.

The **valence** scale will ask you what the perceived valence of the emotion was, ranging from negative to positive. By valence we mean whether the emotion is *positive (e.g. happy)* or whether the emotion is *negative (e.g. angry/ sad)*.

Move the slider to the point on the scale which best reflects your perception of the presented expression.

The last question is multiple choice and asks what emotion is being depicted? You need to select which of the seven emotions (Happy/ Sad/ Angry/ Neutral/ Fear/ Surprise/ Disgust) are being expressed.

Appendix C

The two questions which were used as an attention check in Chapter 8 were as follows:

Q1: An example of a genuine expression is: a) when somebody smiles and they really feel happy (e.g. like when they get a present they like) (correct answer), or b) When somebody smiles without feeling any emotion (e.g., for a school photo) (incorrect answer), or c) I don't understand what you mean by genuine (incorrect answer); and

Q2: An example of a fake expression is: (a) When someone shows a fearful expression without feeling any emotion, or when feeling a different emotion to fear (e.g., a parent playing "tigers" with their child might pretend a fearful expression, but feel no emotion or feel happy playing with their child) (correct answer), b) When somebody shows a fearful expression and they really feel afraid (e.g., when watching a scary film or hearing a creepy noise in the dark) (incorrect answer), or c) I don't understand what you mean by fake (incorrect answer).