The Influence of Oxytocin on Older Adults' Emotion Processing

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Abstract

Emotion processing involves attending to and recognising emotional stimuli, as well as experiencing a feeling of emotion and expressing an emotional reaction. Age-related differences in the processing of emotions are apparent when comparing older (over 60 years) and young (18-30 years) participants. Oxytocin has been shown to increase emotion recognition and some measures that are associated with emotional responses in young adults. The findings are not consistent though, and the effects of oxytocin are often moderated by internal and external factors, such as baseline social proficiency. There is reason to think that oxytocin could improve emotion processing in older adults. This was examined in two studies testing emotion recognition and emotion experience. In the first study, 68 older and 68 young adults were randomly allocated to receive oxytocin nasal spray (20IU) or placebo using a double-blind design. Forty-five minutes after receiving the spray, participants completed a range of tasks to assess accuracy in emotion recognition, including a basic emotion recognition task, the Reading the Mind in the Eyes Test, and an emotion-matching task. During the basic emotion recognition task and the RMET, participants wore an eye-tracking device. The results revealed that oxytocin improved emotion recognition for older males, increased older males' scanning of the eyes, nose and mouth regions of the face, and changed the way that both older and young adults integrated gaze direction cues with emotion expression to influence emotion recognition. No differences in recognition were found for older females or young adults. In the second study, 68 older adults were randomly allocated to receive oxytocin nasal spray or placebo and watched film clips to induce the experience of certain emotions: anger, disgust, fear, happiness and sadness. They rated their experience of emotion after watching each film clip. While they viewed the films, physiological measures of their heart rate, skin conductance and movement of facial

muscles were taken to provide a measure of emotional response. The results indicated that oxytocin did not have any effect on emotion experience in older adults. Older adults did show changes in physiological activity, specifically to the sadness and fear film clips, and changes in facial expressiveness during the film clips. The two studies show that oxytocin can influence older adults' emotion processing, but has an influence only on the recognition of emotions and not on the experience of emotions. Males and females appear to respond differently to oxytocin, with the largest effects found in older males, showing that gender is an important moderator of oxytocin effects. The mechanisms for declines in emotion processing with age are not fully understood, although could include the structural or functional brain declines that occur with age. This suggests that changes in oxytocin functioning in older males' brains could be a partial mechanism for emotion recognition difficulties, providing support for the neural model of age-related emotion recognition difficulties.

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Emotion Processing in Older Adults

Emotions are important aspects of life. They play a role in social interaction and social communication, they help us regulate and choose how we respond to events and situations, and they help us to decide our future behaviour. Emotional reactions can be brief or longer-lasting (e.g., seconds to minutes), and mild or intense, often occurring in response to a specific event. In contrast, mood and affect are longer lasting and not necessarily tied to specific events (Lench, Flores, & Bench, 2011). For example, one might experience a sad mood or bereavement when a relative dies that lasts for a few weeks. However, one might also experience sadness as an emotion and experience a response including tears, frowning, and a heavy chest, when a specific memory about their relative is mentioned, which lasts only for a few minutes.

The basic emotions theory holds that there are categories of emotions that are biologically rooted and distinct from each other (Ekman, 1992). The basic emotions are said to have evolved in display and function, and they differ significantly from each other. The basic emotions generally include happiness, sadness, anger, disgust, fear and surprise (Ekman, 1992). Basic emotions might be seen as categories into which a number of more complex emotions could fit (Brosch, Pourtois, & Sander, 2010). The view envisions emotions as single entities that have a distinct response set that is triggered by an event. These responses include physiological changes, bodily and facial movements and/or vocal responses, and are assumed to be coordinated in time and intensity (Barrett, 2006). The expression of basic emotions is common across cultures and species and recognised by people of different cultural groups with above-chance accuracy (Ekman, 1992).

Emotion processing involves attending to and recognising stimuli that are interpreted as emotional, as well as experiencing a feeling of emotion and expressing

this feeling through an emotional reaction (Adolphs & Heberlein, 2002). In order to achieve this, a stimulus must be evaluated as emotional and its significance determined, there must be changes in the brain of the individual and in their behaviour, and these changes must provide the basis for feeling a certain emotion (Adolphs & Heberlein, 2002). Thus, emotions elicit responses through changes in multiple systems, including cognitive, physiological and behavioural, and emotion processing needs to be understood both in terms of emotion recognition and emotion experience (Lench et al., 2011). Emotional reactions differ depending on the type of emotion experienced and the situation it is experienced in, but include changes in facial expression and body posture, vocal responses, action tendencies, and physiological changes such as heart rate. These emotional responses allow communication with others and encourage action or a response to a situation. Due to the important implications of being able to successfully process emotions in terms of social functioning, it is critical to understand changes in the ability to recognise and experience emotions.

Emotion Recognition and Healthy Ageing

Emotions can be recognised in other people, usually through their facial expression and behaviour. Emotion recognition requires linking the perceptual qualities of a stimulus, such as the visual and geometric properties, with other knowledge one has about the facial expression on display (Adolphs, 2002). Difficulty recognising the emotions expressed by others is associated with a range of social impairments, including inappropriate social behaviour and poor social competence, and is associated with psychological disorders such as autism spectrum disorder (ASD), depression and schizophrenia (Demenescu, Kortekaas, den Boer, & Aleman, 2010; Trentacosta & Fine, 2010; Uljarevic & Hamilton, 2013). Changes in the ability to recognise emotions also occur in healthy ageing. Age-related differences in the recognition of basic emotions

from a range of modalities, including faces, voices, and bodies, are apparent when comparing older (over 60 years) and young (18-30 years) participants.

Emotion recognition tasks using the basic emotions of anger, disgust, fear, happiness, sadness, and surprise are often used to compare the recognition accuracy of young and older adults. In the basic paradigm an emotional facial expression, usually posed by a model, will be presented on a computer screen and the basic emotion labels given to allow a forced choice response. Accuracy in recognition of the intended emotion, and/or speed of recognition can be measured for each participant. Different factors might be manipulated depending on the research question, such as the time the image is displayed for, the intensity of the emotional expression, or whether the expression is one emotion or a blend of two.

Older adults are consistently worse at recognising facial expressions of anger, sadness, and fear compared to young adults, and to a lesser extent, happiness and surprise (Ruffman, Henry, Livingstone, & Phillips, 2008). In contrast, older adults demonstrate a marginally significant advantage in recognising facial expressions of disgust relative to young adults (Ruffman et al., 2008). Differences in emotion recognition ability also appear when comparing males and females. In young adults, females are often better than males at recognising emotions from faces (McClure, 2000; Mill, Allik, Realo, & Valk, 2009) and from voices (Lambrecht, Kreifelts, & Wildgruber, 2014). A meta-analysis examining recognition of emotions from faces, body posture, tone of voice, or a combination of these, found that young females perform better than young males and this effect is strongest for the emotion of anger (Thompson & Voyer, 2014). Older females also appear to recognise emotions more accurately than older males (Demenescu, Mathiak, & Mathiak, 2014; Ruffman, Murray, Halberstadt, & Taumoepeau, 2010; Sullivan, Campbell, Hutton, & Ruffman, in press; Williams et al.,

2009). The gender difference appears to be larger when recognising subtle (up to 70% intensity of expression) rather than full intensity emotion expressions (Hoffmann, Kessler, Eppel, Rukavina, & Traue, 2010).

When recognition of emotions is examined from childhood, rather than only in young and older adults, it appears that ability initially improves with age, until about age 20, but that decline is apparent by middle age (Calder et al., 2003; Horning, Cornwell, & Davis, 2012; Mill et al., 2009; Williams et al., 2009). Recognition of the emotions that older adults find most difficult (anger, sadness and fear) declines in a linear fashion from about age 30 to 40 years (Calder et al., 2003; Mill et al., 2009). Recognition ability for other expressions appears to begin to decline around 60 years (Mill et al., 2009). The recognition of disgust appears reasonably stable across the lifespan (Calder et al., 2003).

Usually happiness is recognised at ceiling levels in emotion recognition tasks, meaning that it can be difficult to determine age-related differences in the recognition of happiness. Nevertheless, difficult tasks can be used so that recognition of happiness is not at ceiling level, for instance, showing actors speaking a single word in an emotional tone with a congruent facial expression or having neutral facial stimuli dynamically adjusted to convey other emotional expressions. When these tasks are given, older adults show worse recognition of happiness than young adults (Horning et al., 2012; Lambrecht, Kreifelts, & Wildgruber, 2012). Furthermore, when response biases are accounted for in determining recognition accuracy, older adults also show worse recognition of happiness than young adults (Isaacowitz et al., 2007). These difficulties recognising emotions from facial expressions for older adults are not associated with difficulty assigning a label to an emotion (Sullivan & Ruffman, 2004) or due to cognitive or sensory losses (Calder et al., 2003; Horning et al., 2012;

Lambrecht et al., 2012). Overall, older adults show significant difficulties compared to young adults in the ability to recognise facial expressions of emotion, which are not accounted for by difficulties in other cognitive domains.

Most previous research has investigated emotion recognition from facial expressions; however, some studies have also looked at emotion recognition from other modalities, including vocal (Lambrecht et al., 2012; Mill et al., 2009; Ryan, Murray, & Ruffman, 2010) and bodily expressions (Ruffman, Halberstadt, & Murray, 2009a). Compared to young adults, older adults are worse at recognising anger, sadness and happiness in bodily expressions and vocal expressions of emotion, as well as disgust in bodily expressions (Lambrecht et al., 2012; Mill et al., 2009; Ruffman et al., 2009a; Ryan et al., 2010). Matching studies require participants to listen to a vocal expression of emotion and match it to a displayed bodily or facial expression (Ruffman et al., 2009a). Older adults are worse than young adults in matching faces to voices for anger, fear, sadness, and happiness (Ryan et al., 2010), and in matching bodies to voices for all emotions (Ruffman et al., 2009a). Matching studies do not require an explicit emotion label to be applied to an emotional expression. Therefore, they provide further evidence that older adults have a specific difficulty in recognising emotional content, rather than a difficulty applying labels to pictures.

Complex emotion recognition. Older adults not only have difficulty recognising certain basic emotional expressions, but they also show difficulties in more general social understanding (Henry, Phillips, Ruffman, & Bailey, 2013). The Reading the Mind in the Eyes Task (RMET) measures participants' ability to recognise a combination of basic emotions (e.g., upset or amused), complex emotions (e.g., bored, arrogant, sarcastic, or embarrassed), as well as cognitions (e.g., guilty, fantasising, or worried) from the eye region of the face (Baron-Cohen, Wheelwright, Hill, Raste, &

Plumb, 2001). Complex emotions differ from basic emotions in that it is argued they require the attribution of a belief or intention to the person expressing the emotion in order to be recognised (Baron-Cohen et al., 2001). Older adults have more difficulty recognising complex emotional states, shown using the RMET, showing they are less able to use the eye region of the face to recognise complex emotions (Henry et al., 2013). Furthermore, older adults' performance on the RMET is not related to their performance on tasks assessing recognition of emotions from facial expressions, indicating that different types of emotional understanding might be tapped by these two tasks (Phillips, MacLean, & Allen, 2002).

Older adults also show differences in social judgements when compared to young adults, which are linked to their emotion recognition difficulties. Older adults cannot differentiate lies from truths to the same extent as young adults, due to their difficulty in recognising expressed emotions (Ruffman, Murray, Halberstadt, & Vater, 2011; Tehan Stanley & Blanchard-Fields, 2008). It is hypothesised that when people lie, they leak emotions, including fear, disgust, and anger, which can be used by others to detect the lie (Frank & Ekman, 1997). As discussed above, older adults find many of these emotions more difficult to recognise than young adults do (Ruffman et al., 2008). Furthermore, both older and young adults find it easier to differentiate lies from truths when an older adult is the speaker, indicating that older adults also have difficulty telling convincing lies (Ruffman et al., 2011). Older adults also find it more difficult to distinguish appropriate from inappropriate social behaviour than young adults, and again, this is explained by their difficulty recognising emotions (Halberstadt, Ruffman, Murray, Taumoepeau, & Ryan, 2011). People who behave inappropriately, or those around them, may express emotions that older adults cannot easily recognise, such as anger, fear, or surprise. Overall, older adults' difficulties in emotion recognition lead to

difficulties making social judgements about other people, which could have serious consequences for them in their daily life.

Visual scanning of emotion faces. Negative emotions such as anger, sadness, and fear are recognised best from the top half of faces, whereas happiness and disgust are recognised best from the bottom half of faces (Calder, Young, Keane, & Dean, 2000). Differences in visual scanning of the face between young and older adults were thought to contribute to emotion recognition; however, it appears that differences are related more to gender than age. Whereas young adults show a greater proportion of fixations to the eye region of the face than the mouth region when attempting to label emotions, older adults show about an equal proportion of fixations to the mouth region and eye region of the face (Circelli, Clark, & Cronin-Golomb, 2013; Murphy & Isaacowitz, 2010; Sullivan, Ruffman, & Hutton, 2007; Wong, Cronin-Golomb, & Neargarder, 2005). Studies also found that when only one section of a face is presented - the eye region or the mouth region – older adults were significantly worse at emotion recognition when given the eyes only (Sullivan et al., 2007). Furthermore, older adults' eye looking did not correlate with emotion recognition accuracy, as was the case with young adults (Sullivan et al., 2007). Interestingly, when gender is considered it can be seen that older males might be driving this age difference. Older females scan the eyes significantly more than older males do, and show a similar scanning pattern to young females and males (Sullivan et al., in press). For young and older females, but not for males, scanning the eye region correlates with improved recognition of anger, sadness, and fear. For young and older males, but not females, scanning the mouth region correlates with improved recognition of disgust and happiness (Sullivan et al., in press). Visual scanning differences might contribute to gender differences in emotion recognition but cannot explain age differences in emotion recognition.

The nose is an important area for face identification (Peterson & Eckstein, 2013), and it may also be an important area to scan when recognising emotions from faces. Looking to the nose region gives the viewer a central view of the entire face and may help to integrate information from different regions (Sæther, Van Belle, Laeng, Brennen, & Overvoll, 2009). Furthermore, when faces are moving, the nose is used as a default fixation point to keep attention on the face (Võ, Smith, Mital, & Henderson, 2012). Viewing the nose is important for young, but not older adults, in remembering a face (Firestone, Turk-Browne, & Ryan, 2007). Although it is unclear whether there are gender differences in visual scanning of the nose, scanning the eyes, nose and mouth regions of a face might all be important for the recognition of different emotions.

Eye gaze direction. Social judgements are influenced by both the facial expression of the emotion one is displaying and eye gaze direction. Emotion expression and gaze direction interact to signal whether a person intends to approach or avoid (Adams & Kleck, 2003). The shared signal hypothesis states that when the motivational intent displayed by eye gaze and emotional expression match, the perception of that emotion will be enhanced (Adams & Kleck, 2005). Approach motivation is appetitive in nature and leads to behaviours involving moving toward a goal. In contrast, withdrawal motivation is aversive in nature and leads to behaviours involving moving away from negative stimuli. There is an important distinction between approach and avoidance motivation and positive and negative valence, in that they do not map directly onto each other. Approach-related emotions, including anger and positive emotions, are recognised faster and as more intense when they show direct gaze, whereas avoidance-related emotions include negative emotions with the exception of anger, and are recognised faster and as more intense when they have averted gaze (Adams & Kleck, 2005; Ruijten, Midden, & Ham, 2013; Sander,

Grandjean, Kaiser, Wehrle, & Scherer, 2007; Willis, Palermo, & Burke, 2011). For these reasons, the integration of emotional expression and gaze direction is important.

There are age-related changes in the ability to integrate emotional expressions and gaze direction from a face. The direction of eye gaze can affect the intensity of the emotion perceived in faces (Adams & Kleck, 2005; Ruijten et al., 2013; Sander et al., 2007; Willis et al., 2011). However, this effect is moderated by the age of the perceiver (Slessor, Phillips, & Bull, 2010). Young adults judged happy and angry faces as more intense when the eye gaze was direct. However, older adults did not differentiate between direct and averted gaze when judging the intensity of angry faces (Slessor et al., 2010). Also, older adults judged happy faces with direct gaze as less intense compared to young adults' judgements. Gaze direction had no effect on the perceived intensity of fearful faces for young or older adults (Slessor et al., 2010). Thus, older adults are not as influenced by gaze direction cues as young adults are.

The integration of gaze direction and emotional expression also affects socially relevant decision-making. Young and older adults are both more likely to approach another person for help if s/he displays a happy facial expression with direct, rather than averted gaze (Slessor et al., 2010). Young adults are more likely to approach an angry face if it has averted gaze. However, older adults show a preference for approaching an angry face with direct gaze (Slessor et al., 2010). Thus, it would appear that older adults do not integrate eye gaze and emotion cues in the same way as young adults (Slessor et al., 2010). This could be because older adults are less able to pick up on subtle gaze changes. Older adults are more likely to say someone is gazing directly at them than young adults when a face displays a subtle gaze aversion (1-2 pixels) (Slessor, Phillips, & Bull, 2008). Taken together, these studies show that perception of

emotional faces is influenced by the emotion and gaze direction shown, and that older adults are less able than young adults to integrate these aspects.

Overall, there are consistent differences between young and older adults when recognising facial expressions of emotion, with older adults performing worst when recognising the facial expressions of anger, sadness and fear (Ruffman et al., 2008). Older adults also show differences when recognising emotions from other modalities (Ruffman et al., 2008), recognising complex emotions (Henry et al., 2013), and integrating eye gaze direction with emotional expression (Slessor et al., 2010).

Emotion Experience and Healthy Ageing

Emotion processing also involves the experience of emotion. Many changes occur when an emotion is experienced, including changes in physiological states, body movements, facial expressions, and subjective feeling, and these can all be measured to represent the experience of emotion. When humans experience emotions, physiological reactions occur in the body, controlled by the peripheral nervous system (PNS), which is made up of the somatic and autonomic nervous systems. The PNS controls changes in skeletal muscle through the somatic system, leading to changes in facial expressions and body posture. Physiological arousal is controlled by the autonomic nervous system (ANS), of which there are two pathways: sympathetic and parasympathetic (Appelhans & Luecken, 2006). The sympathetic pathway is involved in excitatory action and is activated during stress or activity. It produces physiological arousal in order to aid the body in responding to and acting on stress. This can involve increased heart and respiratory rate, as well as increased salivation. In contrast, the parasympathetic pathway is involved in rest and stability. It lowers the heart rate and arousal (Appelhans & Luecken, 2006). The ANS innervates each organ independently through the sympathetic and parasympathetic pathways. It also interacts with the

central nervous system (CNS), which consists of the brain and spinal cord (Kreibig, 2010). The ability to switch between excitatory action and rest depends on the ability of the ANS to adjust sympathetic and parasympathetic activity. Coordination of these neural systems is required for the organism to adjust to its environment and respond appropriately. Emotions organise these responses (Kreibig, 2010).

In order for emotion experience to be measured, first of all, emotions must be elicited. There are a number of strategies to do this, including viewing film clips or pictures, daily life monitoring, personalised recall, and real-life manipulation (Kreibig, 2010). Film clips have been shown to be a useful and effective way of eliciting both positive and negative emotions in research (Schaefer, Nils, Sanchez, & Philippot, 2010). There are many aspects of film clips that make them useful. Film clips allow an investigator to elicit intense emotions, even negative ones, within ethical considerations (Rottenberg, Ray, & Gross, 2007). Furthermore, they are not considered deceptive or manipulative. Standardisation of film viewing is high and easily replicable, especially compared to confederate interaction procedures (Rottenberg et al., 2007). With films, participants must ignore their knowledge that it is not real (Rottenberg et al., 2007), yet they have high ecological validity. For these reasons, film clips are often used in emotion research.

During emotion elicitation, different measures of emotion can be taken. Physiological and some behavioural measures can be taken continuously, whereas subjective measures are usually taken after the event (Rottenberg et al., 2007). The advantage of physiological measurements of emotion is that there is no delay between the elicitation event and the recording (Rottenberg et al., 2007). However, self-report of emotional experience naturally introduces a delay and hence, self-report measures might be affected by this delay. Subjective measures of emotion can be taken using

continuous rating dials, although this might interfere with the spontaneous experience of emotion (Rottenberg et al., 2007). Physiological measures are able to provide information about unconscious emotional reactions that are not subjective (Fernandez et al., 2012). It is common to take a number of physiological and behavioural measurements throughout elicitation events, as well as during baseline periods to provide a comparison. Measures of heart rate and skin conductance are some of the most commonly used physiological measures. Behavioural measures of facial expressions can be taken by recording muscle movements.

Older adults often show decreases or no change in physiological responding when experiencing emotions, although increases in physiological responding have been found depending on the measure or the emotion elicited. Heart rate can be measured to show changes in the cardiovascular system during emotion experience. The heartbeat is generated by the sinoatrial node, which produces action potentials to cause the myocardium to contract (Appelhans & Luecken, 2006). There are both sympathetic and parasympathetic connections to the sinoatrial node that have an effect on heart rate. Sympathetic activity excites the sinoatrial node causing an increased rate of firing and increased heart rate. Parasympathetic activity inhibits the sinoatrial node and decreases heart rate (Appelhans & Luecken, 2006). Therefore, changes in heart rate can be caused by both sympathetic and parasympathetic action. Older adults showed decreased arousal, represented by an increase in the interval between heartbeats, to an amusing film clip, compared to young adults (Tsai, Levenson, & Carstensen, 2000). Another study, using films to elicit a range of emotions (amusement, anger, sadness and fear), showed that young and older adults' heart rates were similar during each of the films (Beaudreau, MacKay, & Storandt, 2009).

Older adults who view positive and negative pictures also show reduced physiological responding, measured by heart rate and skin conductance responses, compared to young adults (Burriss, Powell, & White, 2007). Skin conductance level (SCL) is a measure of arousal and so reflects the action of the sympathetic pathway (Dawson, Schell, & Filion, 2007; Potter & Bolls, 2012). An increase in arousal causes the sweat glands in the skin to produce sweat in order to control the body's temperature levels or to allow grasping of an object (Dawson et al., 2007; Potter & Bolls, 2012). Sweat varies the electrical resistance across the surface of the skin and conductance increases as sweat lowers the resistance, allowing conductance to be measured (Potter & Bolls, 2012). Even low levels of sweat, contained within the sweat ducts and not visible on the skin, can change the electrical resistance of the skin (Potter & Bolls, 2012). Therefore, SCL is a good measure of objective arousal and the influence of the sympathetic pathway.

A complex measure of cardiovascular responding during emotion experience is heart rate variability (HRV). Heartbeats are separated by an interval of time, which can vary, and the variation in these intervals over time is reflected in measures of HRV (Bernston, Quigley, & Lozano, 2007). Higher HRV is associated with better emotion regulation and superior performance on emotion regulation tasks (Thayer, Ahs, Fredrikson, Sollers, & Wager, 2012). HRV is a marker for an individual's ability to adjust autonomic activity so as to both show the appropriate response and inhibit inappropriate responses (Thayer et al., 2012). It reflects cognitive inhibitory control over physiological responding (Thayer et al., 2012). HRV can be divided into frequency bands, which allows separation of sympathetic and parasympathetic influences, which simple measures of heart rate do not allow for. High-frequency HRV (0.15-0.4 Hz) involves only parasympathetic activity, whereas mid- (0.05-0.15 Hz) and

low- (0.003-0.05 Hz) frequency HRV involve both parasympathetic and sympathetic activity (Brouwer, van Wouwe, Muhl, van Erp, & Toet, 2013; Lane et al., 2009). In general, studies on emotions focus on the high-frequency band to allow measurement of the influence of parasympathetic activity on heart rate (Brouwer et al., 2013). The two parts of the autonomic branch use different mechanisms to affect heart rate. The sympathetic system uses norepinephrine and has a delayed influence on cardiac activity (about 4 seconds). In contrast, the parasympathetic system uses acetylcholine and has an immediate influence (about 0.5 seconds) (Appelhans & Luecken, 2006). This rapid response of the parasympathetic system allows for fast and flexible responses to environmental demands and situations (Appelhans & Luecken, 2006). High-frequency HRV is therefore helpful in determining the parasympathetic response to emotions.

One recent study (Wrzus, Mueller, Wagner, Lindenberger, & Riediger, 2013) used HRV to examine older adults' responses to unpleasant events occurring in their daily lives, separating circumscribed events that influenced one life domain from complex events that influenced multiple life domains (Wrzus et al., 2013). Heart rate was measured while participants conducted their daily activities, and measures of HRV were found to be larger after complex unpleasant events, but smaller after circumscribed events (Wrzus et al., 2013). These changes in HRV increased with participant age, so the largest changes were seen in older adults (Wrzus et al., 2013). This indicates that the type of situation determines the emotional response and only complex situations lead to increased emotional responding in older adults (Wrzus et al., 2013).

Increased emotional responding might also occur in older adults when the emotional stimuli are relevant to their age group. Sadness is a particularly relevant emotion for older adults, especially as social losses increase, but also because of loss in

health, fitness, professional, and cognitive domains (Seider, Shiota, Whalen, & Levenson, 2011). This may make older adults sensitive to experiences of loss and increase their emotional reactions when experiencing sadness (Seider et al., 2011). In fact, older adults report experiencing greater levels of sadness than young adults in response to film clips (Kunzmann & Gruhn, 2005; Kunzmann & Richter, 2009; Seider et al., 2011). However, in spite of this, older adults show similar heart rate and skin conductance responses to the film clips as young adults (Kunzmann & Gruhn, 2005; Seider et al., 2011) or even reduced responses (Tsai et al., 2000). This shows a gap between older adults' subjective experiences and their physiological emotional responses when experiencing sadness.

When viewing emotional expressions people mimic the expression on their own face, possibly to help them understand the emotion that they are looking at (Hess & Fischer, 2013). There is little evidence of the direct motor matching of emotional expressions, but rather there is evidence for a valence-based account suggesting that mimicking of the valence of the expression occurs (Hess & Fischer, 2013). Therefore, people do not necessarily mimic exact muscle movements, but mimic a general expression of negativity or positivity (Hess & Fischer, 2013). Furthermore, people react with facial muscle movement to positive and negative stimuli other than faces, indicating the movement represents an experience of emotion rather than direct mimicking (Dimberg, Thunberg, & Grunedal, 2002). For these reasons, electromyography (EMG) is a useful behavioural measure of emotional experience. EMG allows the measurement of facial muscle movement to determine which areas of the face are changing (Tassinary, Cacioppo, & Vanman, 2007). Electrodes attached to the face are able to detect the electrical signal of the action potentials causing muscle contraction. EMG is very sensitive and can measure muscle contraction without visible

muscle movement (Tassinary et al., 2007). Facial muscles are usually not contracted alone to produce movement, but rather in specific groups (Cattaneo & Pavesi, 2014). Homologous muscles on either side of the face work together, but on the same side of the face there is less coherence in muscle activity, depending on the task (Cattaneo & Pavesi, 2014). Research often makes use of two muscles: the corrugator supercilli, which knits the brow region and is generally associated with the expression of negative emotions, and the zygomaticus major, which pulls the cheeks up and is generally associated with the expression of happiness (Tassinary et al., 2007). Measurement of activity in these muscles gives an idea of the valence of participants' emotional responses.

Like young adults, older adults show the mimicry response when viewing emotional pictures. EMG responses of the corrugator muscle, which knits the brow, were larger in both young and older adults after the presentation of an angry face than a happy face (Bailey & Henry, 2009). Mimicry was measured at two intervals after stimulus presentation: early (200-500 ms) and late (500-800 ms). Interestingly, the late mimicry response of older adults was associated with *reduced* anger recognition, whereas usually mimicry aids recognition of the expression (Bailey & Henry, 2009). As described previously, older adults are worse at recognising anger expressions, and so their EMG response might reflect the experience of puzzlement or annoyance because of their difficulty recognising the emotion (Bailey & Henry, 2009). Nevertheless, young and older adults both show mimicry of subliminally presented happy and angry faces, suggesting intact implicit mimicry in both young and older adults (Bailey, Henry, & Nangle, 2009).

In summary, older adults experience a range of emotions and show behavioural and physiological responses. Measures of emotional responses, such as HRV, SCL, and

EMG, can be used with older adults to show their reactions to emotional stimuli. There are some differences in emotion experience between older and young adults, with older adults generally showing reduced responding. This might depend on the specific emotion: sadness is particularly relevant to older adults and has been argued to experience less age-related change (Seider et al., 2011).

Although the mechanisms for changes in emotion processing with age are not fully understood, in the next section I consider the structural or functional brain declines that occur with age, and that have been mooted as possible causes for declines in both the recognition and experience of emotion.

Neural Decline Theory

Age-related differences in emotion processing may be caused by changes in neural functioning and brain volumes that occur naturally with age (Mill et al., 2009; Phillips et al., 2002; Ruffman et al., 2008). The neural decline theory focuses on explaining emotion recognition differences in older adults but it may also relate to emotion experience. There is differential decline in separate areas of the brain and this might account for the differing abilities of older adults when recognising certain emotions (Ruffman et al., 2008). Areas that process emotions are also functionally connected (correlated activity in different brain areas) and disruptions will cause difficulties with emotion recognition (Jehna et al., 2011; Kober et al., 2008). To this end, there is evidence for an age-related decline in functional connectivity between brain regions (Grady, 2012). This can be affected by both the integrity of white matter tracts and neurotransmission. Overall, older adults' difficulties in processing emotions might be explained by changes in the structure and function of the brain.

Structure. The brain shows general atrophy with ageing, but frontal and temporal regions in particular show earlier and more rapid decline than other areas

(Ruffman et al., 2008). Within these regions are the main emotion processing structures of the brain. There is a widespread network of brain areas that are involved in the recognition of emotions. Networks involve both cortical and subcortical regions with extensive connections between them (Kober et al., 2008). Cortical regions involved in the perception and processing of emotions include the anterior cingulate cortex (ACC), the orbitofrontal cortex (OFC), the inferior frontal gyrus (IFG), the insula, and the occipital cortex. The prefrontal cortex is also important and plays a role in the cognitive aspects of emotion processing, such as attention, self-referential processing, and affective regulation (Kober et al., 2008). Subcortical areas include the thalamus, the amygdala, the ventral striatum, the periaqueductal gray, and the hypothalamus (Kober et al., 2008). Some brain regions have been shown to have a general role in perception and processing of emotions, such as the prefrontal cortex, ACC, visual cortex, and fusiform gyrus (Kober et al., 2008; Murphy, Nimmo-Smith, & Lawrence, 2003).

The neural circuits for processing different facial expressions of emotion are at least partially distinct and more is known about the brain areas that mediate facial expressions of emotion than other forms of emotional expression (e.g., vocal). The amygdala is involved in the recognition of angry, sad and fearful faces, although it may have a more general role in recognising potentially threatening or highly emotional stimuli (Adolphs, 2010). The amygdala shows linear volume reductions with age (Suzuki, Hoshino, Shigemasu, & Kawamura, 2007). Angry faces activate cortical structures in the frontal lobes such as the OFC and ACC as well as the amygdala (Jehna et al., 2011; Murphy et al., 2003; Suzuki et al., 2007; Vytal & Hamann, 2010). These areas of the frontal lobes show age-related volume decline, with the OFC showing more rapid decline than other frontal areas (Raz et al., 2005), and the ACC also showing

pronounced decline (Suzuki et al., 2007). Sad faces also require activation of the amygdala and ACC for recognition (Vytal & Hamann, 2010) and such decline could explain difficulties recognising anger and sadness.

The amygdala is also involved in fear recognition (Murphy et al., 2003; Vytal & Hamann, 2010). The recognition of fear in facial expressions is shown to decline in a linear fashion from about 30-40 years of age (Calder et al., 2003; Mill et al., 2009; Williams et al., 2009). This is consistent with reports of linear declines in amygdala volume, suggesting amygdala decline could be directly related to age-related fear recognition deficits (Suzuki et al., 2007).

The basal ganglia and insula have been linked to disgust recognition from faces (Jehna et al., 2011; Murphy et al., 2003; Suzuki et al., 2007; Vytal & Hamann, 2010). The globus pallidus, a part of the basal ganglia that is relatively insensitive to the degenerative effects of ageing, is hypothesised to be related to the preservation of disgust recognition in older adults (Calder et al., 2003). Thus, the age-related decline in specific areas of the brain involved in recognition of anger, sadness and fear could explain older adults' difficulties recognising these emotions, while sparing of the globus pallidus could explain older adults' comparability to young adults in the recognition of disgust. Therefore, differential decline in brain areas related to emotion recognition helps to explain older adults' difficulties recognising particular emotions.

The brain areas involved in recognising emotions from pictures of bodily expressions appear to be similar to those involved in recognising facial expressions (de Gelder, Snyder, Greve, Gerard, & Hadjikhani, 2004), although less is known about the brain areas that mediate specific emotions. These areas include the OFC, amygdala, cingulate cortex and the fusiform cortex (van de Riet, Grezes, & de Gelder, 2009). When recognising emotions from vocal expressions many frontal areas are involved

(Buchanan et al., 2000; Imaizumi et al., 1997; Mitchell, Elliott, Barry, Cruttenden, & Woodruff, 2003). Furthermore, activation appears to be localised in the right hemisphere (Buchanan et al., 2000; Mitchell et al., 2003). The amygdala, insula, ventral prefrontal cortices, temporal cortices, the pontine and the caudate are generally involved in recognising emotions from vocal expressions (Morris, Scott, & Dolan, 1999; Ruffman et al., 2008). In general, the neural circuits for recognising emotions in different modalities, including facial, bodily, and vocal, are similar, reflecting older adults' difficulties across all of these modalities (Ruffman et al., 2008). These are areas that decline with aging, providing a mechanism for reduced recognition ability.

Interestingly, the brain areas involved in the experience of emotions are almost identical to those involved in the recognition of emotions, showing that these two processes are highly related. As with the recognition of emotions, different brain areas are involved in the experience of different emotions (Sharpley & Bitsika, 2010). A recent review of a wide range of studies examining the experience of emotions shows that the experience of sadness is associated with the prefrontal cortex and ACC, the experience of anger is associated with the amygdala, OFC and ACC, the experience of fear is associated with the amygdala, and the experience of disgust is associated with the insula and globus pallidus (Sharpley & Bitsika, 2010). These are all the regions previously discussed in terms of emotion recognition. Therefore, it could be predicted that changes in the structure of these brain areas with advancing age will affect not only emotion recognition but emotion experience as well.

Function. Along with structural changes in the brain that could affect emotion recognition in older adults, there are functional changes that affect the transmission of information. There are a number of ways that neurotransmission occurs in the brain and these are affected by ageing. White matter comprises myelin around neuron axons,

which speeds the transmission of electrical signals throughout the brain (Ruffman et al., 2008). White matter volume shrinkage increases with age and is related to the loss of myelin from the axons of neurons (Ge et al., 2002; Gunning-Dixon & Raz, 2003). Areas such as the frontal lobes that have thinner myelinated fibres, due to later development, are especially vulnerable to declines with age (Raz et al., 2005). White matter declines also disrupt connections between neural circuits, because the integrity of axons that transmit information is decreased due to losses in myelination (Fatima et al., 2013; Gunning-Dixon & Raz, 2003). This could potentially affect the transmission of information to the areas of the brain involved in recognising emotions in older adults, compromising emotion recognition.

Transmission of information in the brain is also affected by neurotransmitters, chemicals that transmit electrical signals between different cells within the brain. Neurotransmitters allow a signal to travel across the synaptic cleft between neurons, transmitting information about perceptions and cognitions. To function optimally, neurotransmitters must be at neither too low, nor too high a level, following the Yerkes-Dodson curve (Honey & Bullmore, 2004). Changing neurotransmission in the brain changes the way in which emotions are recognised. When drugs that alter neurotransmitter levels are given to young adults, they disrupt the optimal neurotransmitter levels and this can detract from young adults' ability to recognise facial emotion expressions (Harmer et al., 2003). For example, administration of a benzodiazepine, such as diazepam, which enhances the effect of the neurotransmitter GABA, impaired young adults' ability to recognise the emotional expressions of both anger and fear (Blair & Curran, 1999; Zangara, Blair, & Curran, 2002). It has been shown that levels of neurotransmitters in the brain, such as dopamine, noradrenaline and serotonin, decline with age (Kaasinen et al., 2000; Mukherjee et al., 2002; Rehman

& Masson, 2001). Some neuropeptide hormones, such as oxytocin, also work in the CNS as neurotransmitters. The fact that neurotransmission decreases with age, as does emotion recognition and experience, suggests that improving transmission may help older adults' emotion processing ability.

In summary, the neural decline theory focuses on changes in the ageing brain that affect emotion recognition; however it is likely that these changes in structure and function will also affect older adults' emotion experience. The recognition and experience of an emotion appears to involve a complex neural circuit involving different brain areas and the functional connections between them. Communication between different areas of the brain by neurotransmission is essential for the accurate recognition of certain emotions. Altering the ability of these areas to connect and communicate, by altering neurotransmitter levels, affects emotion recognition ability in young adults. Decreased volume in specific brain areas that mediate emotion recognition, along with a decrease in functional connectivity between these areas, gives a plausible mechanism for age-related emotion recognition deficits.

Oxytocin and Emotion Processing

Oxytocin is a neuropeptide that can facilitate neurotransmission and have an influence on the processing of emotions. Oxytocin is heralded in the popular press as the 'love hormone' and is said to increase positive interactions, trust and attachment. Oxytocin does affect social behaviour in young adults, including trust, and emotion recognition, but, not surprisingly, oxytocin's effects are more complex than the story conveyed in the popular press (Bartz, Zaki, Bolger, & Ochsner, 2011; Shahrestani, Kemp, & Guastella, 2013; Zak, Kurzban, & Matzner, 2005). It is possible that age-related functional changes in oxytocin synthesis, release, transport or degradation could change the way older adults process emotional information (Ebner, Maura, MacDonald, Westberg, & Fischer, 2013; Huffmeijer, van Ijzendoorn, & Bakermans-Kranenburg, 2013).

Production and Function of Oxytocin

Oxytocin is an amino acid neuropeptide synthesised in the paraventricular nuclei (PVN) and supraoptic nuclei (SON) of the hypothalamus (Bos, Panksepp, Bluthé, & van Honk, 2012). Neuropeptides can act in the brain as neuromodulators and/or neurotransmitters, as well as acting as hormones in the peripheral system (Landgraf & Neumann, 2004). Peripheral functions of oxytocin include the regulation of bone density, water and appetite, and in females, parturition and lactation (Carson, Guastella, Taylor, & McGregor, 2013). In the brain, the PVN projects neurons to specific targets for oxytocin, including the ventromedial hypothalamus, ventral tegmental area, nucleus accumbens, amygdala, hippocampus and brainstem (Debiec, 2007; Onaka, Takayanagi, & Yoshida, 2012). In these regions of the brain, oxytocin is released from the axon terminals, cell bodies and dendrites, allowing action in areas where oxytocin receptors are present (Onaka et al., 2012). However, there is also diffusion of oxytocin

extracellularly into cerebrospinal fluid (CSF), allowing further diverse action (Macdonald & Macdonald, 2010). Oxytocin may use CSF as a mechanism to communicate throughout the brain via volume transmission, which allows for simultaneous changes in multiple brain areas (Veening, de Jong, & Barendregt, 2010). This allows oxytocin to influence a range of complex behaviours.

Oxytocin can be administered intranasally to have effects on the brain, without peripheral effects. It is unlikely to pass the blood-brain-barrier between the blood stream (periphery) and the brain, and therefore it needs to enter the CNS directly to have an effect (Churchland & Winkielman, 2012). Intranasal administration is believed to provide a direct route to the CNS (Guastella et al., 2013). It is unclear exactly how intranasal oxytocin enters the brain but two possible routes have been identified (Evans, Monte, Noble, & Averbeck, 2013; Guastella et al., 2013). The first is a route connecting the nasal passages with the olfactory bulbs and rostral brain regions. The second is a trigeminal system connecting the nasal passages with the brainstem and spinal cord regions (Evans et al., 2013; Guastella et al., 2013). It may be that intranasal oxytocin increases central levels by promoting release of endogenous oxytocin through a feed-forward mechanism (Churchland & Winkielman, 2012; Evans et al., 2013).

Emotion Recognition and Oxytocin

The effect of oxytocin on emotion recognition in young adults has received considerable attention. More specifically, in a number of studies (but not all), oxytocin has been shown to improve males' recognition of emotions from faces. Some studies have shown an effect on happy expressions (Marsh, Yu, Pine, & Blair, 2010), some on fearful expressions (Fischer-Shofty, Shamay-Tsoory, Harari, & Levkovitz, 2010), and some show no effect (Di Simplicio, Massey-Chase, Cowen, & Harmer, 2009). These differences in findings are likely due to the range of paradigms that have been used to

measure emotion recognition. Some studies have used dynamic facial expressions, which move from neutral to emotional (Fischer-Shofty et al., 2010; Lischke et al., 2012a), and other studies have used static images of emotional faces presented at different intensities (Di Simplicio et al., 2009; Marsh et al., 2010). In spite of the differences, meta-analyses show that oxytocin enhances the ability to recognise emotions from faces (Shahrestani et al., 2013; Van Ijzendoorn & Bakermans-Kranenburg, 2012). In one meta-analysis, oxytocin was shown to improve the recognition of happiness and fear specifically, although the recognition of happiness might only improve when stimuli are presented for a brief time and recognition is more difficult (Shahrestani et al., 2013). In sum, oxytocin appears to influence the recognition of emotions.

Oxytocin might affect the processing of facial emotion expressions by modulating attention. Oxytocin promoted attention toward happy faces presented briefly in a dot-probe task, where the presentation of a happy face in the same location as a subsequent target significantly increased reaction times to identify that target (Domes et al., 2013). Similarly, a spatial cueing task was used to determine how oxytocin affects automatic attentional shifting to emotional expressions (Ellenbogen, Linnen, Grumet, Cardoso, & Joober, 2011). Participants focused on a central fixation cross and were required to respond as quickly as possible to indicate whether a target appeared to the left or the right. Prior to the target appearing, a cue (a sad, angry, or neutral face) indicated the likely location of the target and was then masked (Ellenbogen et al., 2011). Oxytocin affected attentional engagement with the masked cue; however, this effect was modulated by individual differences. Depression scores moderated the effect of oxytocin on the processing of angry faces. For those with high depression scores, oxytocin decreased an attentional bias to angry faces, whereas for

those with low depression scores, oxytocin increased this bias to angry faces (Ellenbogen et al., 2011). Other research indicates that the detection of both angry and happy faces that are quickly masked by neutral faces is enhanced with oxytocin administration (Schulze et al., 2011). Thus, attention to both positive and negative faces appears to be enhanced with oxytocin.

When contextual information, such as bodily expression, does not match the emotional expression displayed on the face, it usually interferes with emotion recognition. However, oxytocin, compared to placebo, improves the recognition of disgusted facial expressions when combined with angry bodily expressions (Perry et al., 2013). Oxytocin appears to help focus attention on the facial expression rather than on incongruent contextual information, especially in the difficult cases of disgust and anger, emotions that are not easily distinguished (Perry et al., 2013). This is consistent with the idea that an increase in attention toward emotional facial expressions after oxytocin administration might contribute to oxytocin improving recognition of emotions from faces.

However, it is likely that oxytocin also plays a role in later cognitive processing of facial cues. Oxytocin might change the processing of emotional expressions such that the perceived intensity of the emotion is greater, making the emotion easier to recognise (Cardoso, Ellenbogen, & Linnen, 2014). When neutral face stimuli that morph into an emotional expression are shown, oxytocin rather than placebo decreases the intensity at which participants are able to correctly identify the emotion (Cardoso et al., 2014; Lischke et al., 2012a; Prehn et al., 2013). Overall, oxytocin appears to change the way in which emotional facial expressions are attended to and processed.

It has been suggested that oxytocin might improve emotion recognition from faces by increasing looking to the eye region of the face, where important emotional

information is found (Kemp & Guastella, 2011). Visually attending to certain facial features is necessary for both face and emotion recognition (Domes, Steiner, Porges, & Heinrichs, 2012). For this reason, a number of studies have used eye tracking to determine how participants are visually scanning face stimuli during tasks. Oxytocin increases the amount of time young males spend scanning the eye region of neutral (Guastella, Mitchell, & Dadds, 2008) and emotional (Gamer, Zurowski, & Büchel, 2010) faces. However, as with emotion recognition studies, there are discrepancies in research showing the effect of oxytocin on scanning of the eye region of the face. Domes et al. (2012) found that oxytocin can either increase or decrease scanning of the eye region of the face. In that study, neutral face stimuli changed into either happy or angry expressions. When the neutral faces were presented, oxytocin increased scanning of the eye region of the face. As the expression changed to anger or happiness, oxytocin then modulated visual scanning, increasing scanning of the eye region of happy faces but decreasing scanning of the eye region of angry faces (Domes et al., 2012). Furthermore, Lischke et al. (2012a) found no effect of oxytocin on scanning of the eye region of the face in a task using dynamic facial expressions and requiring participants to choose whether the emotion expressed was sadness, anger, fear or happiness. Domes et al. (2010) also did not find an effect of oxytocin on scanning of the eye region when female participants judged the emotional arousal of angry, fearful, happy and neutral faces.

It is not clear if increased scanning of the eye region is directly related to improved recognition of emotions from facial expressions. In fact, only one study has correlated emotion recognition with scanning time to the eyes, finding that increased scanning was associated with recognition of sadness at lower intensities (Lischke et al., 2012a). Additionally, young and older males did not benefit from scanning the eye

region when recognising emotions, although females did (Sullivan et al., in press). Males actually benefited from scanning the mouth, at least when recognising the emotions of happiness and disgust (Sullivan et al., in press). Such results suggest that although oxytocin might increase scanning of the eyes in some tasks, this might not benefit males' emotion recognition.

Like basic emotion recognition, improvement in performance on the RMET is also found after oxytocin administration. Improvements are not consistent, however, and are modulated by participants' baseline ability in judging social cues. For healthy male participants, oxytocin improves performance on the harder items of the test (Domes, Heinrichs, Michel, Berger, & Herpertz, 2007), and for participants with ASD who have more difficulty recognising emotions, oxytocin improves performance on the easier items of the test (Guastella et al., 2010). A possible explanation is that the effects of oxytocin appear to be most pronounced when the task is challenging but not too difficult (Leknes et al., 2012). It is expected that the participants with ASD found the 'easy' items particularly difficult, whereas for typical males, only the 'difficult' items were difficult. In another study, scores on a test of alexithymia, which represents a lack of competence on socio-emotional tasks such as identifying emotions and describing feelings, moderated the effect of oxytocin on RMET performance (Luminet, Grynberg, Ruzette, & Mikolajczak, 2011). Participants scoring highly on the test of alexithymia showed greater improvements on the RMET after oxytocin administration than participants with lower scores (Luminet et al., 2011). This indicates that those participants with more alexithymia traits, who would be expected to be less able to recognise emotions, benefit most from oxytocin administration.

Taken together, the findings on the RMET and other emotion recognition tasks show that oxytocin does not have a universal beneficial effect on emotion recognition

ability. Individual differences in social proficiency appear to affect how oxytocin influences performance on tasks, with individuals who are worse recognising emotions particularly likely to benefit.

Emotion Experience and Oxytocin

The influence of oxytocin on the experience of basic emotions has not been studied, but its influence on the experience of complex social emotions, such as trust and the experience of stress, has been studied extensively.

Effect of oxytocin on social emotions. Intranasal oxytocin has a range of effects on social emotions and behaviour, demonstrated in studies of mostly male participants. Studies have shown trust to increase after oxytocin administration. Trust is usually measured with a monetary trust game that includes sharing of money between an investor and a trustee (Baumgartner, Heinrichs, Vonlanthen, Fischbacher, & Fehr, 2008; Kosfeld, Heinrichs, Zak, Fischbacher, & Fehr, 2005). The investor gives money to the trustee, who receives this money in addition to a proportion of the invested income. The trustee can then either return some money to the investor to benefit both, or take advantage of the investor and keep all the money for him or herself (Baumgartner et al., 2008; Kosfeld et al., 2005). Investors given oxytocin rather than placebo show increased trusting behaviour. They transfer larger amounts of money to the trustee, increasing the risk involved in the transaction (Kosfeld et al., 2005). Furthermore, investors on placebo reduce their trusting behaviour after negative feedback about the trustee, but investors on oxytocin do not change their behaviour, showing reduced betrayal aversion (Baumgartner et al., 2008). Thus, oxytocin increases motivation to engage with others, even after negative feedback.

Stress reactions are buffered by the administration of oxytocin (Meyer-Lindenberg, Domes, Kirsch, & Heinrichs, 2011). Cortisol levels (a hormone produced

under stress) following a socially stressful task are lowered by oxytocin administration and a combination of social support, and oxytocin gives additive effects in reducing stress responses (Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003). A reduction in stress during and after social interaction would encourage engagement and further interaction with others. In fact, oxytocin may also encourage people to seek out social contact after experiencing stress (Cardoso, Ellenbogen, Serravalle, & Linnen, 2013). Following a stressful social interaction, participants given oxytocin who report higher distress also report higher levels of trust relative to those taking placebo (Cardoso et al., 2013). This indicates that in times of stress, oxytocin motivates individuals to trust others and seek out social contact (Cardoso et al., 2013). Overall, oxytocin affects the behavioural and endocrine responses to stress to influence engagement with others.

Effects of oxytocin on emotional responses. The effect of oxytocin on the experience of emotions other than complex social emotions is unknown, although oxytocin has been shown to affect some measures that are associated with emotional responses. For example, oxytocin has been shown to have an effect on the cardiovascular system, which as noted previously, has both sympathetic and parasympathetic connections (Appelhans & Luecken, 2006). Two studies have looked at the effect of oxytocin on HRV specifically. Compared to placebo, oxytocin increases resting HRV, taken when participants are sitting comfortably and not engaged in any tasks (Kemp et al., 2012). Using a specific measure of HRV that is associated with action of both the sympathetic and parasympathetic pathways, Kemp et al. (2012) were able to show that participants were not resting in a calm, quiescent state, but rather that they were ready for action. The positive effect of oxytocin on HRV is not consistent, however. Those who score high on measures of loneliness do not show an increase in HRV after oxytocin administration (Norman et al., 2011).

Oxytocin also has an effect on cardiovascular activity when participants are engaged in tasks. During emotion recognition, oxytocin modulates heart rate changes in response to emotional stimuli (Gamer & Buchel, 2012). Happy faces, versus fearful faces, were associated with heart rate decelerations in participants given oxytocin rather than placebo. Heart rate deceleration is usually associated with neutral or appetitive stimuli (Gamer & Buchel, 2012). In this study, oxytocin had no influence on SCL responses (indicative of sympathetic activity) to emotional pictures (Gamer & Buchel, 2012).

A further study looked at the influence of oxytocin on cardiovascular activity and recovery after a stressful situation (Kubzansky, Mendes, Appleton, Block, & Adler, 2012). The author concluded that cardiovascular changes during the stress task after the administration of oxytocin reflected the participants being in a 'challenge state' where they appraised the task as achievable rather than as a threat. This was related to cardiovascular measures indicating sympathetic activity (Kubzansky et al., 2012), showing that oxytocin can have an effect on sympathetic activity as well as parasympathetic activity.

In sum, the effect of oxytocin on emotion processing has been studied mainly in terms of emotion recognition. Although the effects are not always consistent, there appear to be a range of moderating factors that can influence outcomes. Less is known in terms of the influence of oxytocin on emotion experience; the research thus far indicates that there could be an effect, but further clarification and determination of the different factors involved is required.

Models of Oxytocin Effects

There have been two main hypotheses put forward to explain the behavioural effects of oxytocin. The social salience hypothesis states that the social effects of

oxytocin could be caused by an increase in the salience of certain social cues that are important for social interaction and bonding, such as cues in the eye region of the face (Bartz et al., 2011; Olff et al., 2013). However, this increased salience must be moderated by internal and external factors that influence the emotional significance of the situation (Olff et al., 2013). Different behaviours and responses are determined by different attributions given to a social cue, based on individual factors and contextual cues that a person uses to determine if the environment is safe or unsafe (or positive or negative). The improvement in social functioning after administration of oxytocin likely occurs through oxytocin increasing the salience of important aspects of the perceived stimuli. If an individual is not already processing these cues, oxytocin will improve functioning. In contrast, the same benefit is not found in those already functioning at a higher level (Olff et al., 2013). In safe environments, the increased sensitivity to social cues may help to improve socioemotional processing, such as the recognition of emotions (Olff et al., 2013). But in unsafe environments, increased sensitivity to social cues may promote antisocial behaviours and distress (Olff et al., 2013). Furthermore, whether a certain environment is perceived as safe or unsafe will depend on an individual's processing biases, which are determined by their upbringing, mental health and other individual factors (Olff et al., 2013).

The social-approach/withdrawal hypothesis explains that the social effects of oxytocin could be caused by a change in the processing of stimuli to promote social approach motivation and inhibit social withdrawal motivation (Kemp & Guastella, 2011). This promotes engagement with other people and with stimuli and reduces avoidance-related behaviours such as those associated with anxiety and fear (Kemp & Guastella, 2011). As mentioned previously, approach and avoidance motivations do not correspond directly to positive and negative valence, indicating that the effects of

oxytocin will not always be positive (Kemp & Guastella, 2011). Many of the discussed findings relating to oxytocin administration can be interpreted as an increase in approach motivation to enhance social engagement, such as increases in trusting behaviour and emotion recognition, or decreases in withdrawal motivation, such as decreased stress responses and betrayal aversion during financial games (Kemp & Guastella, 2011). This hypothesis suggests that oxytocin has more of an impact at later cognitive stages of processing than at earlier perceptual stages of processing.

There has been little research focusing on determining which of these hypotheses best explains the effects of oxytocin that have been found thus far. Some studies that have directly tested a motivational hypothesis have found either no results (Theodoridou, Penton-Voak, & Rowe, 2013a) or results that can be interpreted with either a motivational or salience hypothesis (Radke, Roelofs, & de Bruijn, 2013). The experience of emotion might be associated with stronger motivational tendencies than the perception of emotion; however, most studies using oxytocin have investigated the perception of emotions (Kemp & Guastella, 2011). Furthermore, the perception and experience of emotion might not elicit the same motivational tendency. For example, the perception of anger in another person might elicit approach or avoidance (fight or flight tendencies), but the experience of anger is more likely to elicit approach (Kemp & Guastella, 2011). Studies investigating the experience as well as the perception of emotions might shed more light on the mechanism by which oxytocin affects behaviour.

Gender Differences in Oxytocin Effects

Many oxytocin studies have focused on the effects of oxytocin on male participants and have not included female participants. Often, this exclusion is to avoid the potential confounding effects of menstrual cycle and hormone changes on oxytocin levels (Domes et al., 2007; Guastella et al., 2008; Kis, Kemerle, Hernadi, & Topal,

2013). However, subsequent studies have repeatedly reported no effect of menstrual cycle on oxytocin administration and effects (Ditzen et al., 2009; Ellenbogen et al., 2011; Theodoridou, Rowe, Penton-Voak, & Rogers, 2009). Studies that have included female participants have shown that there may be differences in the way in which males and females respond behaviourally and neurally to intranasal oxytocin administration.

Gonadal steroid hormones, oestrogen and testosterone, influence oxytocin receptor density and location (Insel, 2010). Oxytocin levels are lower in males than females, possibly due to up-regulation of oxytocin synthesis by the female reproductive hormone oestrogen (Carter, 2007). Furthermore, females have a higher CSF level of oxytocin than males do (Altemus et al., 1999). Therefore, there will be differences between males and females that might influence the effects of intranasal oxytocin. Some studies have shown that oxytocin can have an effect on males' behaviour without having an effect on females' behaviour. This suggests that the effects of oxytocin might be larger in males than in females. In an emotion recognition task incorporating risk, participants had to learn to judge scowling faces as angry, and were punished for not correctly identifying anger (Lynn, Hoge, Fischer, Barrett, & Simon, 2014). Participants earned points for correctly identifying anger and lost points for incorrectly identifying anger. In this task, male, but not female, participants were affected by oxytocin administration (Lynn et al., 2014). Men given oxytocin were less able to adjust their decision about the presence of anger to risk/uncertainty and showed a bias toward anger recognition, whereas females' decisions were not affected (Lynn et al., 2014).

Males, but not females, also change their performance in perspective-taking tasks after oxytocin administration. Participants viewed photos of men and women facing toward or away from them, wearing a black glove on one hand and a brown

glove on the other. They had to indicate whether the specified glove (black or brown) was on the left or right hand, requiring them to take the perspective of the person in the picture (Theodoridou, Rowe, & Mohr, 2013b). In the placebo group, males were faster at the task than females; however, in the oxytocin group, males performed at the same speed as females (Theodoridou et al., 2013b). Males, but not females, also alter their judgments of moral scenarios after administration of oxytocin, leading to greater endorsement of scenarios that benefit the self (Scheele et al., 2014). These findings indicate that oxytocin can change the way that males, but not females, perform on tasks.

The effect of oxytocin on males' behaviour has been shown to depend on group membership (De Dreu, 2012). Oxytocin has been shown to increase trusting behaviour, but this effect is not universal and appears to be limited to trust within an in-group (De Dreu et al., 2010; Van Ijzendoorn & Bakermans-Kranenburg, 2012). When participants are interacting with others that they determine to be part of an out-group, no effects on trust are found, or increases in defensive aggression occur (De Dreu, 2012; De Dreu et al., 2010). In studies that do not explicitly measure or manipulate group membership, it is unclear whether participants perceive interaction partners, or even stimuli, as part of their in- or out-group, which could influence the results. Furthermore, it is unclear whether group membership influences females' behaviour after oxytocin administration.

Oxytocin has been related to increases in males' negative or aggressive judgements of others. This might relate to increased aggressive behaviour directed at out-group members who are perceived to be a threat (Hoge et al., 2014). At the same time, oxytocin increases positive judgements of others in females, indicating the effects are not consistent across genders (Hoge et al., 2014). Participants judged neutral faces paired with unseen smiling, neutral or scowling faces for trust, competence and warmth (Hoge et al., 2014). Independent of the valence of the paired face, males given

oxytocin judged the faces as less trustworthy, competent and warm, and females given oxytocin judged the faces as more trustworthy, competent and warm (Hoge et al., 2014). In the same study, neutral faces paired with positive, neutral, or negative sentences were later rated by males given oxytocin as more negative, and by females given oxytocin as more positive, again independent of the valence of the paired sentence (Hoge et al., 2014). Similarly, when watching videos of interactions between two people, oxytocin enhances males' perception of competitive relationships, whereas it enhances females' perception of familial relationships (Fischer-Shofty, Levkovitz, & Shamay-Tsoory, 2013a). Overall, these studies show that oxytocin might have opposite effects in males and females when judging others.

There are also differences in the way in which oxytocin affects activity in male and female brains. A well-established finding in male participants is that oxytocin decreases amygdala responses to threatening pictures (Baumgartner et al., 2008; Kirsch et al., 2005; Petrovic, Kalisch, Singer, & Dolan, 2008; Singer et al., 2008). In contrast, in females, an increase in amygdala activity after oxytocin administration has been found to threatening scenes (Lischke et al., 2012b) and to emotional faces (Domes et al., 2010). The amygdala is associated with processing threat in the environment. Therefore, oxytocin appears to increase threat processing for females and decrease threat processing for males. Areas of the brain related to social bonding, including the striatum, amygdala and insula, and connections between these areas, show increased activity in males during cooperative interactions after oxytocin administration (Rilling et al., 2014). However, in females oxytocin does not affect, or decreases, activity in these areas (Rilling et al., 2014). This again indicates that oxytocin might have a larger or opposite effect in males. In sum, gender is an important variable to be considered in

any research using oxytocin. Males and females appear to respond differently to oxytocin, with males often showing a larger or opposite effect.

In conclusion, oxytocin can facilitate neurotransmission and therefore could facilitate emotion recognition and alter emotion experience. It has effects on emotion recognition and some measures of emotion experience in young adults (Kemp et al., 2012; Shahrestani et al., 2013). Importantly, the influence of oxytocin appears to depend on individual and contextual factors, such as the socioemotional ability or gender of the participant.

Present Research

Older adults show consistent difficulties compared to young adults in the recognition of emotions (Ruffman et al., 2008) and also show differences in the way they experience emotions (Carstensen et al., 2011) and their emotional reactions (Beaudreau et al., 2009). Many of these age-related changes can be explained by changes in the structure and functioning of areas of the brain that are related to emotion processing, as well as the functional connections between these areas (Ruffman et al., 2008). Because oxytocin acts as a neurotransmitter in the brain, older adults are a particular group who are likely to benefit from oxytocin administration when processing emotions. One study has shown that intranasal oxytocin can be administered to older adults with no adverse side effects (Barraza et al., 2013). Therefore, intranasal oxytocin can be used with older adults to determine if it influences the way in which they process emotional information (Barraza et al., 2013; Huffmeijer et al., 2013).

The current studies examined how oxytocin influences the perception and experience of emotions in older adults. Social understanding and emotion experience were investigated in two separate studies. The first study used a range of tasks to

examine emotion recognition, including a basic emotion recognition task, the RMET, and an emotion-matching task. In the basic emotion recognition task, participants were presented with facial expressions of emotions representing anger, disgust, fear, happiness, and sadness. They were required to judge the emotion depicted in the face. To examine more complex emotions and social phenomena, the RMET was given to participants. This required participants to recognise the emotion or mental state portrayed in a picture of only the eye region of a face, by choosing from four label options. Participants also matched emotion sounds to pictures of facial expressions and bodily expressions of emotion, to provide a measure of emotion recognition that does not rely on understanding emotion labels. Oxytocin was expected to improve older adults' ability on all tasks, because they have more difficulty recognising emotions and oxytocin has larger effects on those with lower baseline ability (Bartz et al., 2010). Older males were expected to show the largest benefit from oxytocin administration, not only because they show worse emotion recognition than females, but also because oxytocin has been shown to have larger effects in males than in females (Lynn et al., 2014; Theodoridou et al., 2013b).

In the emotion recognition task, emotional faces had either direct or averted gaze. Gaze cues and emotional expression combine to display motivational intent, with avoidance-related emotions (sadness, fear, and disgust) recognised as more intense with averted gaze and approach-related emotions (happiness and anger) recognised as more intense with direct gaze (Adams & Kleck, 2005). Older adults have more difficulty than young adults integrating gaze direction and emotion expression (Slessor et al., 2010). The influence of oxytocin on integration of gaze direction and emotion cues has not been studied, although oxytocin is hypothesised to increase approach motivation (Kemp & Guastella, 2011). Therefore, oxytocin might affect the integration of gaze

cues with emotion expression, at least in young adults. Also, females look to the eyes more than males do, and their recognition of angry, fearful, and sad expressions benefits from eyes looking (Sullivan et al., in press). This suggests that oxytocin might help young and older females (but not males) integrate gaze direction and emotion cues to facilitate recognition for certain emotions.

During the basic emotion recognition task and the RMET, participants wore an eye-tracking device to record their visual scanning of the stimuli. Oxytocin has been shown to increase young males' scanning of the eye region of the face in some studies (Guastella et al., 2008). Yet, scanning the eye region has been shown to benefit females' but not males' recognition of emotions (Sullivan et al., in press), so that increased scanning of the eye region of the face after oxytocin administration might improve females' but not males' emotion recognition. However, it is possible oxytocin might influence scanning of other regions of the face than the eyes, which has not been explored in previous research. Scanning of a number of face regions important for emotion recognition, including the eyes, nose, and mouth was measured.

The second study examined the effects of oxytocin on older adults' emotion experience. This task involved participants watching film clips meant to induce the experience of certain emotions: anger/sadness/disgust, disgust, fear, happiness and sadness. Participants then rated their experience of emotion after watching each film clip. While they viewed the films, physiological measures of their heart rate, skin conductance and movement of facial muscles were taken to provide a measure of their emotional response.

Past research has not examined the influence of oxytocin on basic emotional experience, and the question of whether oxytocin influences emotion experience was explored as an empirical issue. Oxytocin might have an effect on basic emotion

experience because it affects other areas of emotion processing, such as recognition of emotions and experience of complex social emotions like trust (Van Ijzendoorn & Bakermans-Kranenburg, 2012), and because many of the brain areas related to the recognition of emotions are also related to the experience of emotions (Sharpley & Bitsika, 2010). Emotional experience is best investigated with a range of measures, including subjective and physiological measures (Rottenberg et al., 2007). The present study included SCL, HRV and EMG measures of emotional experience. SCL is a measure of emotional arousal, whereas HRV reflects cognitive control of emotional responding (Potter & Bolls, 2012; Thayer et al., 2012). SCL and HRV allow measurement of the sympathetic and parasympathetic components of physiological emotional responses respectively. Facial movements can also be measured to reflect the valence of emotional experience (Hess & Fischer, 2013). SCL, HRV and EMG responses have all been used to reflect the experience of emotions and older adults show changes in these responses when experiencing emotions (Bailey & Henry, 2009; Burriss et al., 2007).

Oxytocin influences cardiovascular measures of emotional responding. It increases HRV, a measure of autonomic control, when participants are resting (Kemp et al., 2012; Norman et al., 2011) and affects heart rate during emotional tasks (Gamer & Buchel, 2012). I also obtained a measure of loneliness because loneliness modulates the relationship between oxytocin and HRV (Norman et al., 2011), and it might be particularly prevalent in older adults due to loss of social systems with age. An increase in HRV after oxytocin administration during rest and while watching the emotional film clips was predicted with moderation by loneliness scores. However, specific predictions for SCL and EMG measures were not made because the influence

of oxytocin on these responses is uncertain. The subsequent two chapters will describe these two studies in full detail and outline the results obtained in each.

Study One: The Effect of Oxytocin on Older Adults' Emotion Recognition

An important aspect of the processing of emotions is the ability to recognise them in other people's facial expressions, actions, or vocal tone. Recognition of emotions is important for social communication and interactions; however, age-related differences are found in accuracy at recognising emotions, as illustrated in the first chapter. Oxytocin is a neuropeptide that can work as a neurotransmitter within the brain to improve the way emotional information is processed (Ebner et al., 2013). Studies in young adults using intranasal oxytocin, described in the second chapter, show that compared to placebo, oxytocin increases emotion recognition ability (Shahrestani et al., 2013; Van Ijzendoorn & Bakermans-Kranenburg, 2012). More specifically, the effects of oxytocin are typically moderated by baseline performance, with greater benefits to those who are functioning at a lower level (Bartz et al., 2011; Olff et al., 2013). Older adults perform consistently worse than young adults when recognising the emotions of anger, sadness and fear from faces (Ruffman et al., 2008). Older adults also show a range of other emotion processing difficulties when compared to young adults, including matching emotions from different modalities (Ruffman et al., 2009a), recognising complex emotions (Henry et al., 2013), and integrating gaze direction cues with emotion expression (Slessor et al., 2010). Reduced levels of neurotransmitters altering functional connectivity might cause these age-related differences in emotion recognition, along with structural changes in specific areas of the brain associated with emotion recognition (Mill et al., 2009; Phillips et al., 2002; Ruffman et al., 2008). Therefore, oxytocin administration could improve neurotransmission in older adults and so improve their emotion recognition.

The current study aimed to address whether oxytocin can improve emotion recognition in older adults. Young and older adults were included in this study to test

the hypothesis that larger effects will be found after oxytocin administration in older adults, due to their increased difficulties with emotion recognition. To this end, young and older participants were administered a placebo or oxytocin in a double-blind study and completed three emotion recognition tasks.

The first task assessed basic emotion recognition. Emotion faces were presented with six emotion labels (angry, disgusted, fearful, happy, neutral, and sad) and participants were required to pick the emotion label they believed matched the emotional expression shown. Accuracy in labelling these emotions was measured. It was expected that oxytocin would enhance the emotion recognition ability of older adults in general and would specifically improve the recognition of anger, sadness and fear, the emotions that older adults find particularly difficult (Ruffman et al., 2008). It was also predicted that the effect of oxytocin would be greatest in older males. There are significant gender differences in the effects of oxytocin, explained in detail in the second chapter. Often males, but not females, given oxytocin show a change in task performance (Lynn et al., 2014; Theodoridou et al., 2013b). Additionally, the effect of oxytocin was expected to be larger in older males because they show worse emotion recognition than older females (Ruffman et al., 2010; Sullivan et al., in press).

The emotion face stimuli also included different gaze directions: direct or averted (left or right), to examine both the effects of gaze direction on recognition of emotions and the effect of oxytocin on recognition of emotions with different gaze directions. The influence of eye gaze direction on the recognition of emotions, rather than for instance, the perceived intensity of emotion, does not appear to have been investigated previously. The shared signal hypothesis, outlined in Chapter One, explains that eye gaze direction and emotional expression combine to portray motivational intent. Avoidance-related emotions (fear, sadness, and disgust) are

portrayed as more intense with averted gaze and approach-related emotions (happiness and anger) are portrayed as more intense with direct gaze (Adams & Kleck, 2005). Older adults have more difficulty than young adults at integrating emotion and gaze direction cues to influence the intensity of the perceived emotion (Slessor et al., 2010). It was therefore expected that congruent gaze cues (direct gaze with angry and happy faces, and averted gaze with fearful, sad and disgusted faces) would improve recognition of these specific emotions for young adults. The influence of oxytocin on processing of emotional faces with different gaze cues has not been examined, although oxytocin is hypothesised to increase motivation to approach stimuli (Kemp & Guastella, 2011). Oxytocin might have an influence on integration of gaze cues with emotional expression in order to affect emotion recognition, at least in young adults. Also, females look to the eyes more than males do, and their recognition of anger, fear, and sad expressions actually benefits from eyes looking (Sullivan et al., in press). This suggests that oxytocin might help young and older females (but not males) to integrate gaze direction and emotion cues to facilitate recognition of certain emotions.

The second task was the Reading the Mind in the Eyes Test (RMET), described in the first chapter, and used to assess recognition of more complex emotions and mental states. Again, older adults consistently perform worse on this task than young adults (Henry et al., 2013). It was expected that oxytocin would improve older adults' accuracy on the RMET. No hypotheses were made about gender differences in oxytocin's effect on performance because it is unclear from the current literature if there are gender differences in performance on the RMET, although in line with the findings for emotion recognition, one might expect older men to benefit more than older women.

The third task involved matching a vocal expression of emotion (angry, disgusted, fearful, happy, surprise, and sad) to facial or bodily expressions of emotion. This task does not involve explicit labelling of the basic emotions and tests emotion recognition from vocal and bodily expressions as well as facial expressions. Older adults perform worse than young adults when matching voices to both faces and bodies (Ruffman et al., 2009a; Ryan et al., 2010). Thus, accuracy at matching voices to faces and bodies was measured. Once more, it was expected that oxytocin would improve older adults' accuracy in matching emotional expressions.

Eye tracking was used to measure visual scanning patterns during both the basic emotion recognition task (around the entire face, including the eyes, nose, mouth, cheeks, chin and forehead) and the RMET (around the entire stimulus, including both eyes). Oxytocin is shown to increase young males' scanning of the eye region of neutral faces (Guastella et al., 2008) and emotional faces (Gamer et al., 2010). However, scanning the eye region benefits females' but not males' emotion recognition ability (Sullivan et al., in press), so that an increase in scanning of the eye region after oxytocin might improve females' but not males' emotion recognition. Scanning of a range of other important areas of the face (nose and mouth) was also measured. These are areas that have not been examined in previous research so that it is not certain how oxytocin might affect scanning.

Method

Participants

Sixty-eight older adults (34 females; M = 72.07 years, SD = 6.49 years) and 68 young adults (34 females; M = 19.68 years, SD = 1.79 years) were recruited to participate in this study, older adults through an existing Psychology Department database and young adults from the student population of the University of Otago.

Older participants received $40 to cover their travel expenses and young participants gained partial course credit by completing a worksheet about the experiment. In a double-blind, between-subjects design, 34 participants in each age group (17 male, 17 female) were randomly assigned to receive 20 international units (IU) of oxytocin via nasal spray, and the remaining 34 participants in each age group (17 male, 17 female) received a placebo nasal spray containing a saline solution. Two mL (20 IU) of the oxytocin solution were delivered through a Propharma pump nasal spray bottle, participants spraying once into each nostril then waiting one minute before spraying into each nostril again, continuing until the spray was finished (as recommended by Guastella et al., 2013). A commercial oxytocin nasal spray formulation is not available in New Zealand. Oxytocin ampoules for intravenous use (10 IU/mL) were purchased through the Pharmacy Department of the Southern District Health Board and prepared by a medically qualified professional. Each pump of the nasal spray released 1 IU (0.1 mL). Placebo bottles contained 2 mL of normal saline.

Exclusion criteria (screened with self-report and contact with older adults' general practitioners) included currently receiving treatment for a psychological disorder, severe or progressive medical illness, history of heart disease or heart troubles including a pacemaker, known allergies to the preservatives in the nasal spray, or smoking. Females could not be pregnant or breastfeeding. Young female participants were required to take a pregnancy test (First Response pregnancy test kit) prior to administration of the nasal spray. Use of oral contraception was recorded for young females and no older females were on hormone replacement therapy. Participants were required to abstain from caffeine and alcohol on the day of testing, and from food or drink, except water, for two hours before drug administration. All participants spoke English and had been a New Zealand resident for at least five years.

Written consent was obtained following a description of the study. Older adults were required to agree to their general practitioner being informed of their inclusion in the study. Ethical approval was obtained from the Multi-Region Ethics Committee (MEC-11-11-096).

Stimuli

Emotion recognition. The emotion recognition task used 96 stimuli from the FACES database (Ebner, Riediger, & Lindenberger, 2010), with an example shown in Figure 1. Each stimulus was 14.5cm high and 11cm wide. Half of the faces were older adult models (24 males, 24 females) and half young adult models (24 males, 24 females). The emotion battery included each of six emotions (anger, disgust, fear, happiness, sadness, and neutral) displayed 16 times (four young females, four young males, four older females, four older males). The emotion of surprise was not included in this stimulus set to avoid its common confusion with fear expressions (Ebner et al., 2010). The stimuli were selected from set A of the FACES database based on the percentage of older, middle-aged and young adults who rated the emotion expressed in the face as the intended emotion (Ebner et al., 2010). The stimuli for each emotion were separated into four groups based on all combinations of age and gender, and within each of these groups, stimuli were ordered based on the preliminary testing done by the stimuli creators. The two highest and two lowest rated stimuli were removed in order to prevent ceiling and floor effects. Face stimuli were also not included for selection if they were rated as expressing the particular emotion by 100% of raters or if their eyes could not be seen, and each individual model was included only once in the stimulus set. From the remaining stimuli, four faces in each group were randomly selected to be included in the stimulus set for each emotion. The face stimuli were altered using Adobe Photoshop CS3 to display averted gaze. The direction of aversion

(left or right) was randomly assigned in equal numbers to stimuli within each group, so for example, of the four older male stimuli displaying anger, two had left-averted gaze and two had right-averted gaze. Averted gaze stimuli were combined with the direct gaze stimuli to produce a total of 192 stimuli within the full set.

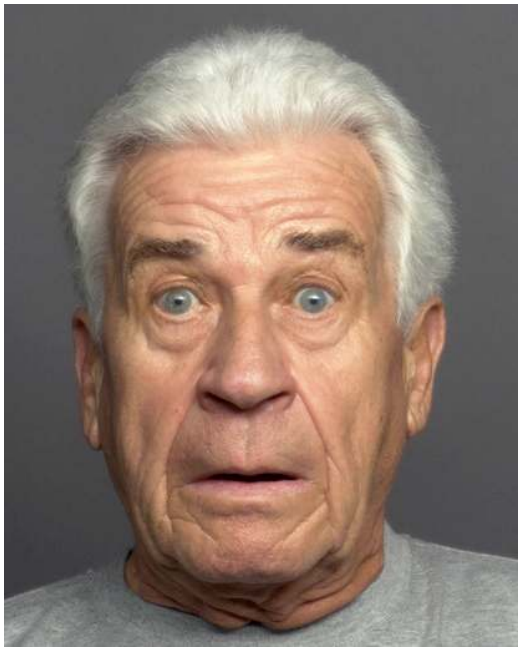

Figure 1. Emotion recognition stimulus, showing an older male expressing fear with direct gaze, presented during one trial of the emotion recognition task.

Reading the Mind in the Eyes Test. Stimuli for the Reading the Mind in the Eyes Test (RMET; Baron-Cohen et al., 2001) included 37 7.4 cm high and 17.3 cm wide black and white images of eyes (18 male), each expressing a complex mental state, with an example shown in Figure 2.

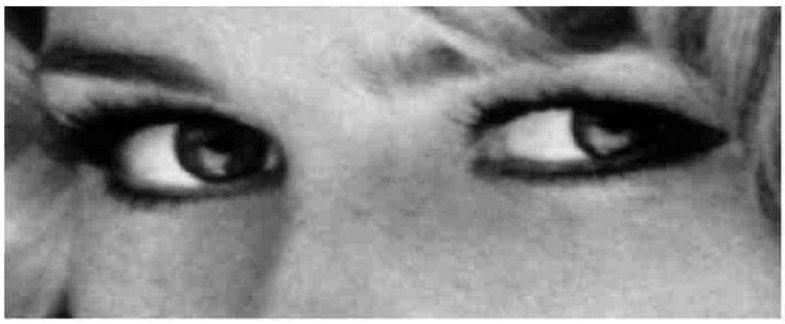

Figure 2. Eyes stimulus, representing eyes showing distrust, presented during one trial of the RMET.

Emotion matching. Two matching tasks were given to participants; a face-voice matching task and a body-voice matching task. Stimuli for these tasks were taken from Ruffman et al. (2009a). The stimulus sets were developed using both older and younger adult participant responses. Participants identified the emotion expressed in face, body and voice emotion stimuli, to give a proportion of participants identifying a stimulus as expressing its intended emotion. The stimuli with the highest and lowest proportion correct scores were excluded to reduce ceiling and floor effects. All selected items had a proportion correct score above chance. The face-voice matching task used 24 faces from the "Facial Expressions of Emotion: Stimuli and Test" stimulus set (FEEST; Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002), and 12 emotion sounds, each presented twice. The emotion faces expressed each of the basic emotions (anger, disgust, fear, happiness, sadness, and surprise). The emotion sounds consisted of two sets; the first non-verbal expressive sounds (angry snorts and "grr" sounds, "ughh" sounds of disgust, gasps and high-pitched tones of fear, a happy humming sound, sad sighs and groans, and light and high-pitched gasps of surprise) and the second a passage read to convey each of the six basic emotions through tone of voice. The passage was, "I was walking down the road yesterday when I saw a large red car in front of me. It stopped, and a small man in a blue coat got out."

The body-voice matching task used 24 images of bodies expressing emotions through various poses (e.g., anger was depicted by a man leaning forward, pointing his finger; disgust by a woman recoiling from a man who is trying to kiss her; fear by a women clutching a mans top; happiness by a women sitting on a beach in the sun; sadness by a woman sitting on the ground and being hugged by another women; and surprise by a girl with both hands on the side of her face), with an example shown in Figure 3. Each of the 24 images was paired with the 12 emotion sounds (twice each) used in the face-voice matching task. The emotion bodies all had faces digitally erased.

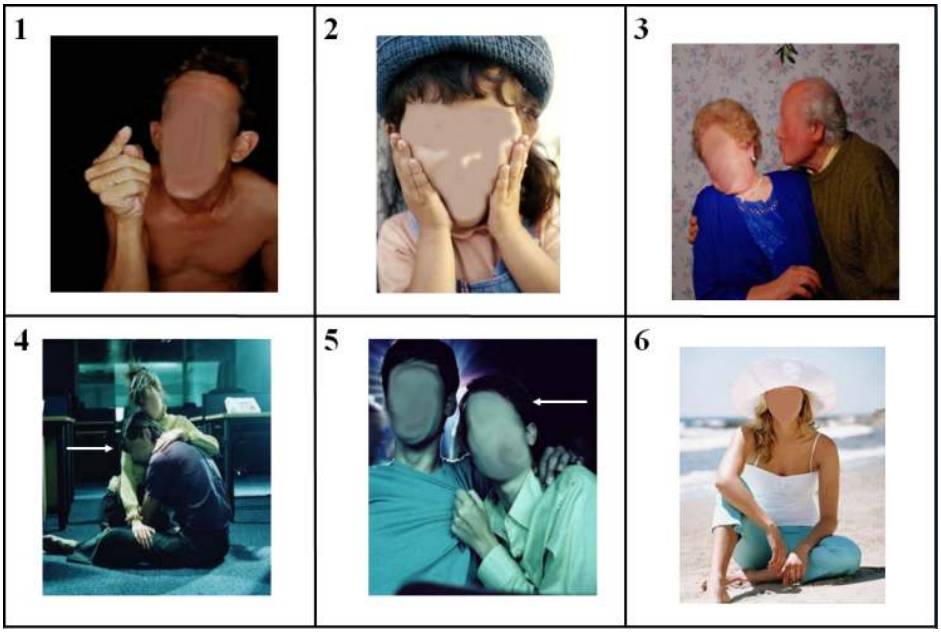

Figure 3. Body stimuli, showing anger, surprise, disgust, sadness, fear and happiness, presented during one trial of the body-voice matching task.

Questionnaires and tests. Participants were given a number of questionnaires and tests to acquire information on demographics, depression, cognitive functioning, visual acuity, and vocabulary (see Table 1). Older and younger adults completed the Beck Depression Inventory-second edition (BDI-II; Beck, Steer, & Brown, 1996). Three participants scored over 13 on the BDI-II and were not included in the data

analysis. (Scores over 13 indicate that participants were scoring in the same range as those diagnosed with mild to moderate depression.) All older adults scored 84 or higher on Addenbrooke's Cognitive Examination-Revised (ACE-R; Mioshi, Dawson, Mitchell, Arnold, & Hodges, 2006). The test authors obtained normative data for this test from a sample of healthy control subjects. The sample's mean score minus two standard deviations was 84, indicating that scores above 84 are within the normal range of people without dementia or mild cognitive impairment (Mioshi et al., 2006). Vision was assessed with Snellen's 3-Meter Visual Acuity Chart, with all older and young adults having normal or corrected-to-normal vision. Fluid IQ was tested with the Matrix Reasoning subtest of the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV; Wechsler, 2008), involving choosing the correct response to complete 26 series puzzles. Crystallised IQ was tested with a subset of 24 items from the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 2007), involving choosing the correct picture to match a given word.

There were no differences between the treatment groups (collapsed across age and gender) on BDI-II, Matrix Reasoning subtest or PPVT scores (all *p*s >.05). No age or gender differences were found in BDI-II scores ($p > .05$). In line with previous research (e.g., Ruffman et al., 2010) older adults scored higher than young adults on the PPVT, $t(134) = -10.84$, $p < .01$, but lower than young adults on the Matrix Reasoning subtest, $t(134) = 6.62$, $p < .01$.

Table 1. Questionnaire Means (*SD*s) for Participants in Experiment 1

	Placebo				Oxytocin			
	Older adults		Young adults		Older adults		Young adults	
	Female	Male	Female	Male	Female	Male	Female	Male
Education	4.13 (1.96)	4.5 (1.87)	-	-	4.88 (1.71)	4.81 (2.01)	-	-
BDI-II	3.76 (4.07)	6.35 (4.99)	5.65 (3.67)	5.35 (4.18)	4.71 (3.26)	4.47 (3.48)	4.47 (3.50)	3.65 (3.55)
PPVT	21.88 (1.58)	21.47 (2.83)	15.94 (3.33)	18.76 (2.02)	22.65 (1.22)	22.06 (1.60)	15.17 (3.09)	17.76 (3.82)
Matrix	18.41 (3.14)	17.0 (4.68)	22.65 (2.23)	21.76 (2.49)	18.29 (3.64)	18.0 (4.49)	20.53 (2.15)	21.88 (2.85)

Notes. Education level was based on a scale of 1 = primary school, 2 = some high school, 3 = high school certificate, 4 = trade certificate, 5 = technical certificate (including nursing, teaching), 6 = BA/BSc and 7 = post-graduate. All young adults were studying at university level and so their education was not recorded.

Procedure

All participants first self-administered the nasal spray. Older adults then completed the ACE-R, and all participants completed the BDI-II, Matrix Reasoning subtest, and then the PPVT. Forty-five minutes after nasal spray administration, consistent with previous research showing oxytocin levels in the brain peak 45 minutes after intranasal administration (Born et al., 2002; Weisman, Zagoory-Sharon, & Feldman, 2012), participants began the computerised emotion tasks.

Emotion recognition. In the emotion recognition task, stimuli were presented on a 17-inch monitor using E-Prime 2.0. When viewed from a distance of 60cm, the stimuli subtended a visual angle of approximately 10.3^{o} horizontally and 13.5^{o} vertically. Each trial consisted of one face stimulus presented in the centre of the monitor, with six emotion labels (anger, disgust, fear, happiness, sadness, and neutral) displayed below the face. Participants were required to indicate aloud which emotion they believed the face was expressing. There was no time limit to choose the emotion label.

RMET. This task was also presented using E-Prime 2.0 from a distance of 60cm. The stimuli subtended a visual angle of approximately 16.1^{o} horizontally and 7.0^{o} vertically. In each item, four mental state words (e.g., decisive, amused, aghast, and bored) were displayed around an eye picture in the centre of the screen. The participant indicated aloud the mental state word they believed best represented the complex mental state expressed by the eyes and their response was recorded by the experimenter. No time limit was given for the responses. A practice item was given, followed by the 36 experimental items.

Emotion matching. The emotion matching tasks were presented on a 17-inch monitor using MediaLab, from a distance of 60 cm. Six face or six body stimuli were presented in an area 26.3cm wide and 17.3cm high, which subtended a visual angle of approximately 23.6^{o} horizontally and 16.1^{o} vertically. During the face-voice matching task, participants were presented with six emotion faces (anger, disgust, fear, happiness, sadness, and surprise) on a computer monitor and listened to an emotion sound through headphones. The emotion sound lasted 10 seconds and then participants were required to choose the emotion face that matched the emotion sound, using the mouse to click on the face. Across the 24 trials each face served as the correct face once and a distracter five times, with the order of both correct and incorrect faces randomised. Similarly, in the body-voice matching task, participants were presented with six emotion bodies faces (anger, disgust, fear, happiness, sadness, and surprise) on the monitor while listening to an emotion sound and chose the body that matched the emotion sound.

Eye-tracking. During the emotion recognition task and the RMET, eye movements were recorded using an ASL EyeTrac-6 Head Mounted Optics device. Eye-tracking data was only obtained from 64 older adults (*M*=71.84 years, *SD*=6.34 years) and 64 young adults (*M*= 19.70 years, *SD*=1.83 years) due to difficulties tracking

some participants. The eye-tracker uses an eye camera to produce a close-up image of the eye and pupil, and an eye illuminator, consisting of a set of near infrared LEDs, to create a stable reflection of the participant's cornea. This allows gaze direction and fixations to be calculated by measuring the relative position of the pupil and the reflection from the surface of the cornea. These features move together, but when the eye rotates the pupil moves further than the corneal reflection, allowing the direction of gaze to be calculated. The head mounted eye-tracker was magnetically attached to an EyeHead integration system, which allowed measurement of gaze direction with compensation for movement of the head. Therefore, participants were able to move their head during the experiment to enhance comfort.

Results

Preliminary Analyses

The variable of stimulus face age was not included in any analyses because this was only used as a control variable so as not to disadvantage older adults by only using young adult stimuli. In addition, initial analyses found no significant differences in emotion recognition ability between young females taking (32.35%) or not taking oral contraception, $t(32) = -.67$, $p = .50$. Therefore, oral contraception use was not considered in further analyses. The data were analysed with analysis of variance (ANOVA). Outliers were adjusted, while maintaining the ordinal position of each value (Tabachnick & Fidell, 2013). In all ANOVAs, where assumptions of sphericity were violated, Huynh-Feldt-corrected F, p, mean square error (MSE), and η_p^2 values are reported. In all t-tests, a correction factor for unequal variances was applied where necessary. Bonferroni correction was applied to multiple comparisons to keep the family-wise error rate at $p < .05$.

Emotion Recognition Accuracy

Emotion recognition task. To examine performance on the emotion recognition task, an accuracy score was calculated for each participant for each emotion and gaze stimulus combination (shown in Table 2). These accuracy scores were examined in a 5 (emotion: anger, disgust, fear, happiness, sadness) X 2 (gaze: averted, direct) X 2 (treatment: oxytocin, placebo) X 2 (age: older, young) X 2 (gender: male, female) mixed ANOVA, summarised in Table 3.

Table 2. Mean (*SD*s) Emotion Recognition Accuracy (Proportion Correct) for Participant Groups for Each Stimulus Expression Type

	Placebo				Oxytocin			
	Older Adults		Young Adults		Older Adults		Young Adults	
	Female	Male	Female	Male	Female	Male	Female	Male
Direct Gaze								
Sadness	0.60	0.45	0.71	0.72	0.68	0.62	0.70	0.65
	(0.19)	(0.15)	(0.18)	(0.14)	(0.20)	(0.14)	(0.18)	(0.13)
Happiness	0.99	0.98	1.00	1.00	0.99	0.99	1.00	0.99
	(0.02)	(0.04)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)	(0.02)
Fear	0.78	0.68	0.89	0.83	0.80	0.82	0.91	0.87
	(0.17)	(0.21)	(0.08)	(0.13)	(0.09)	(0.13)	(0.07)	(0.12)
Anger	0.73	0.59	0.80	0.80	0.69	0.69	0.80	0.78
	(0.21)	(0.25)	(0.12)	(0.13)	(0.16)	(0.19)	(0.10)	(0.12)
Disgust	0.91	0.84	0.84	0.81	0.87	0.86	0.86	0.83
	(0.07)	(0.18)	(0.10)	(0.16)	(0.16)	(0.10)	(0.12)	(0.18)
Averted Gaze								
Sadness	0.58	0.44	0.62	0.60	0.57	0.48	0.69	0.50
	(0.22)	(0.18)	(0.17)	(0.15)	(0.16)	(0.20)	(0.19)	(0.16)
Happiness	0.99	0.98	1.00	1.00	0.99	1.00	1.00	0.99
	(0.03)	(0.06)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.03)
Fear	0.79	0.70	0.92	0.90	0.81	0.83	0.90	0.88
	(0.15)	(0.14)	(0.08)	(0.14)	(0.17)	(0.15)	(0.10)	(0.10)
Anger	0.74	0.52	0.72	0.72	0.70	0.65	0.73	0.76
	(0.16)	(0.21)	(0.17)	(0.17)	(0.16)	(0.16)	(0.15)	(0.13)
Disgust	0.94	0.82	0.90	0.82	0.88	0.91	0.91	0.87
	(0.08)	(0.15)	(0.09)	(0.15)	(0.15)	(0.08)	(0.13)	(0.11)

Table 3. Full ANOVA Table for Emotion Recognition Analysis

Source	*df*	*MS*	*F*	*p*	η_p^2
Gaze	1	0.29	13.43	0.00	0.10
Gaze*Gender	1	0.05	2.20	0.14	0.02
Gaze*Treatment	1	0.01	0.24	0.62	0.00
Gaze*Age	1	0.01	0.31	0.58	0.00
Gaze*Gender*Treatment	1	0.01	0.23	0.63	0.00
Gaze*Gender*Age	1	0.00	0.08	0.78	0.00
Gaze*Treatment*Age	1	0.01	0.42	0.52	0.00
Gaze*Gender*Treatment*Age	1	0.01	0.24	0.63	0.00
Error (Gaze)	128	0.02			
Emotion	4	26.72	240.21	0.00	0.65
Emotion*Gender	4	0.26	2.37	0.06	0.02
Emotion*Treatment	4	0.06	0.52	0.70	0.00
Emotion*Age	4	1.17	10.53	0.00	0.08
Emotion*Gender*Treatment	4	0.14	1.22	0.30	0.01
Emotion*Gender*Age	4	0.16	1.41	0.23	0.01
Emotion*Treatment*Age	4	0.15	1.36	0.25	0.01
Emotion*Gender*Treatment*Age	4	0.07	0.64	0.62	0.01
Error (Emotion)	512	0.11			
Gaze*Emotion	4	0.74	21.57	0.00	0.14
Gaze*Emotion*Gender	4	0.05	1.53	0.20	0.01
Gaze*Emotion*Treatment	4	0.07	2.10	0.10	0.02
Gaze*Emotion*Age	4	0.05	1.53	0.20	0.01
Gaze*Emotion*Gender*Treatment	4	0.06	1.82	0.14	0.01
Gaze*Emotion*Gender*Age	4	0.09	2.56	0.05	0.02
Gaze*Emotion*Treatment*Age	4	0.09	2.72	0.04	0.02
Gaze*Emotion*Gender*Treatment*Age	4	0.01	0.22	0.89	0.00
Error (Gaze*Emotion)	512	0.03			
Gender	1	2.67	13.36	0.00	0.10
Treatment	1	0.56	2.82	0.10	0.02
Age	1	4.62	23.18	0.00	0.15
Gender*Treatment	1	0.51	2.56	0.11	0.02
Gender*Age	1	0.32	1.62	0.21	0.01
Treatment*Age	1	0.45	2.25	0.14	0.02
Gender*Treatment*Age	1	0.98	4.89	0.03	0.04
Error	128	0.20			

This ANOVA revealed four main effects, all qualified by larger interactions. A main effect of emotion, $F(4, 512) = 240.21$, $p < .01$, $MSE = .11$, $\eta_p^2 = .65$, showed that happiness was recognised most accurately ($M = .99$, $SD = .02$), followed by disgust ($M = .87$, $SD = .12$) and fear ($M = .83$, $SD = .14$), followed by anger ($M = .71$, $SD = .16$),

and with sadness least accurately recognised (M = .60, SD = .17). This effect was not analysed further due to its lack of theoretical importance. A main effect of gaze, $F(1, 128) = 13.43$, $p < .01$, $MSE = .02$, $\eta_p^2 = .10$, showed that stimuli with direct gaze (M = .82, SD = .07) were recognised more accurately than stimuli with averted gaze (M = .80, SD = .07). Main effects of age, $F(1, 128) = 23.18$, $p < .01$, $MSE = .20$, $\eta_p^2 = .15$, and gender, $F(1, 128) = 13.36$, $p < .01$, $MSE = .20$, $\eta_p^2 = .10$, showed that emotions were recognised better by young (M = .84, SD = .05) than older adults (M = .79, SD = .08) and by females (M = .83, SD = .06) than males (M = .80, SD = .08).

The main effects of gender and age were qualified by an interaction between gender, treatment and age $F(1, 128) = 4.89$, $p = .03$, $MSE = .20$, $\eta_p^2 = .04$. Further analyses of this three-way interaction, shown in Figure 4, revealed that oxytocin, relative to placebo, increased emotion recognition accuracy for older males specifically, $t(32) = -3.37$, $p < .05$. No treatment differences were found for young males, $t(32) = .07$, $p > .05$, young females, $t(32) = -.31$, $p > .05$, or older females, $t(32) = .71$, $p > .05$. To further examine the effect of oxytocin, I compared older men to older women who had taken the placebo. Older women's emotion recognition was significantly better than older men's, $t(32) = 3.70$, $p < .05$. In contrast, there was no difference between older men and women in the oxytocin group, $t(32) = -.03$, $p > .05$. Despite the substantial boost given by oxytocin to older men's emotion recognition, it was still the case that young adults had better emotion recognition than older adults in both the placebo group, $t(66) = 3.92$, $p < .05$, and the oxytocin group, $t(66) = 3.10$, $p < .05$.

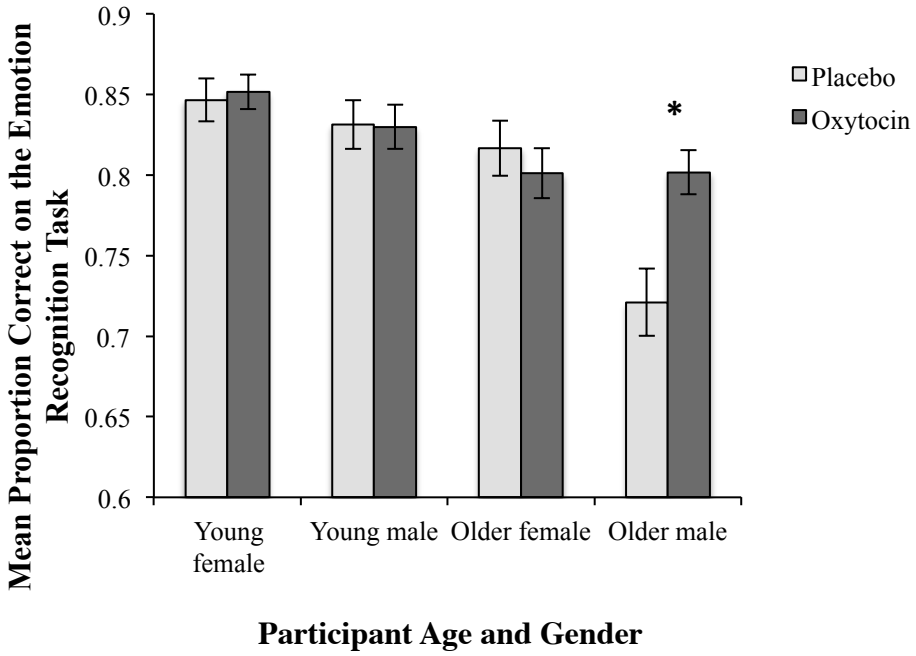

Figure 4. Participant emotion recognition accuracy scores in the placebo and oxytocin conditions, as a function of participant age and gender.
Note. *$p < .05$.

An interaction between emotion and age, $F(4, 512) = 10.53$, $p < .01$, $MSE = .11$, $\eta_p^2 = .08$, revealed that young adults were more accurate than older adults in recognising the emotions of anger ($M = .76$, $SD = .12$ vs. $M = .66$, $SD = .18$), $t(134) = 3.82$, $p < .05$, fear ($M = .89$, $SD = .10$ vs. $M = .77$, $SD = .15$), $t(134) = 5.29$, $p < .05$, and sadness ($M = .65$, $SD = .15$ vs. $M = .55$, $SD = .17$), $t(134) = 3.46$, $p < .05$. An interaction between emotion and gaze, $F(4, 512) = 21.57$, $p < .01$, $MSE = .03$, $\eta_p^2 = .14$, revealed that sadness was recognised better with direct ($M = .64$, $SD = .18$), than averted ($M = .56$, $SD = .19$) gaze, $t(135) = 5.73$, $p < .05$, and anger was recognised better with direct ($M = .74$, $SD = .18$), than averted ($M = .69$, $SD = .18$) gaze, $t(135) = 3.42$, $p < .05$, whereas disgust was recognised better with averted ($M = .88$, $SD = .12$) than direct ($M = .85$, $SD = .14$) gaze, $t(135) = -3.86$, $p < .05$.

These interactions were qualified by an interaction between gaze, emotion, treatment and age, $F(4, 512) = 2.72$, $p = .04$, $MSE = .03$, $\eta_p^2 = .02$. In order to investigate this four-way interaction I examined how gaze, emotion and age interacted in the placebo and oxytocin treatment groups separately, as shown in Figure 5. In the placebo group, the interaction between gaze, emotion and age, $F(4, 264) = 3.46$, $p = .02$, $MSE = .03$, $\eta_p^2 = .05$, revealed that young adults recognised sadness, $t(33) = 3.86$, $p < .05$, and anger, $t(33) = 3.60$, $p < .05$, better with direct than averted gaze, but recognised fear, $t(33) = -3.95$, $p < .05$, and disgust, $t(33) = -2.79$, $p < .05$, better with averted than direct gaze. Older adults did not show any significant difference in recognition between direct and averted gaze faces, all $p > .05$. In the oxytocin group the interaction between gaze, emotion and age was not significant, $F(4, 264) = .89$, $p = .44$, $MSE = .04$, $\eta_p^2 = .01$. In contrast to the placebo group, young adults in the oxytocin group did not show any significant difference in recognition between direct and averted gaze faces, all ps $> .05$, and older adults in the oxytocin group recognised sadness better with direct than averted gaze, $t(33) = 4.17$, $p < .05$.

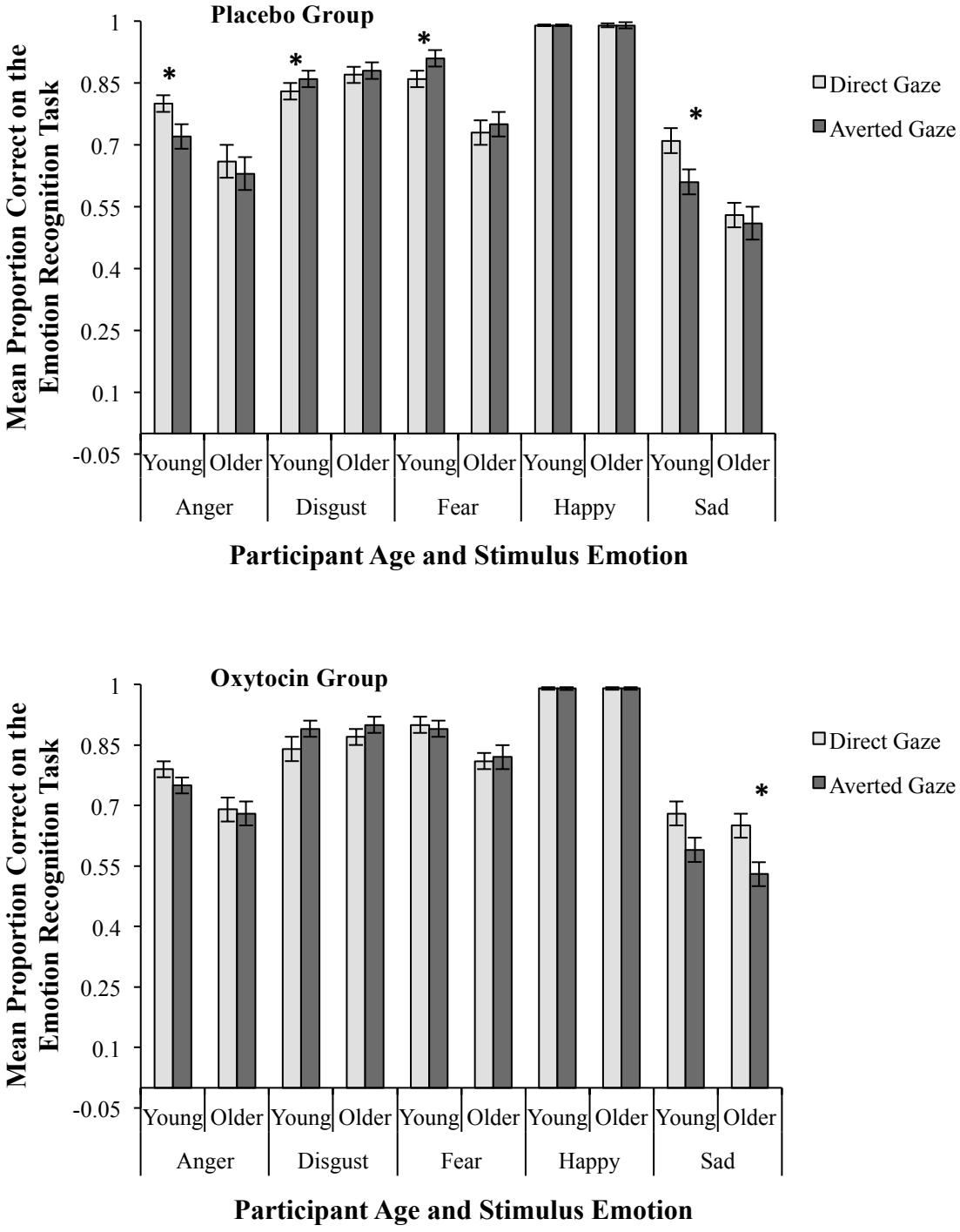

Figure 5. Participant emotion recognition accuracy scores in the placebo group (above) and oxytocin group (below) for direct and averted gaze faces, as a function of participant age and stimulus emotion.
Note. *$p < .05$.

RMET. Mean accuracy scores on the RMET were calculated for each participant (shown in Table 4). RMET accuracy scores were examined in a 2 (treatment: oxytocin, placebo) X 2 (age: older, young) X 2 (gender: female, male) ANOVA, as summarised in Table 5. This revealed a main effect for age, $F(1, 128) = 9.05$, $p < .01$, $MSE = .01$, $\eta_p^2 = .07$. Young adults ($M = .76$, $SD = .10$) performed better on the RMET than older adults ($M = .71$, $SD = .09$).

Table 4. Mean (*SD*s) RMET Accuracy (Proportion Correct) for Each Participant Group

	Placebo	Oxytocin
Older Females	0.74 (0.10)	0.70 (0.05)
Older Males	0.68 (0.10)	0.73 (0.10)
Young Females	0.75 (0.11)	0.77 (0.10)
Young Males	0.75 (0.09)	0.77 (0.11)

Table 5. Full ANOVA Table for RMET Analysis

Source	*df*	MS	*F*	*p*	η_p^2
Gender	1	0.00	0.23	0.64	0.00
Treatment	1	0.00	0.48	0.49	0.00
Age	1	0.08	9.05	0.00	0.07
Gender*Treatment	1	0.01	1.47	0.23	0.01
Gender*Age	1	0.00	0.30	0.59	0.00
Treatment*Age	1	0.00	0.18	0.67	0.00
Gender*Treatment*Age	1	0.02	2.14	0.15	0.02
Error	128	0.01			

Emotion matching. Mean accuracy scores for each emotion were calculated for the face-voice matching task and body-voice matching tasks, for each participant. Emotion matching accuracy scores were examined in a 2 (matching type: face, body) X 6 (emotion: anger, disgust, fear, happiness, sadness, surprise) X 2 (treatment: oxytocin,

placebo) X 2 (age: older, young) X 2 (gender: female, male) mixed ANOVA, as summarised in Table 6.

Table 6. Full ANOVA Table for Emotion Matching Analysis

Source	*df*	MS	*F*	*p*	η_p^2
Type	1	9.54	147.21	0.00	0.54
Type*Gender	1	0.15	2.35	0.13	0.02
Type*Treatment	1	0.10	1.54	0.22	0.01
Type*Age	1	0.05	0.72	0.40	0.01
Type*Gender*Treatment	1	0.06	0.90	0.35	0.01
Type*Gender*Age	1	0.00	0.01	0.94	0.00
Type*Treatment*Age	1	0.01	0.13	0.72	0.00
Type*Gender*Treatment*Age	1	0.12	1.92	0.17	0.02
Error (Type)	128	0.07			
Emotion	5	4.86	77.60	0.00	0.38
Emotion*Gender	5	0.08	1.28	0.27	0.01
Emotion*Treatment	5	0.04	0.59	0.71	0.01
Emotion*Age	5	1.26	20.18	0.00	0.14
Emotion*Gender*Treatment	5	0.06	0.96	0.44	0.01
Emotion*Gender*Age	5	0.08	1.29	0.27	0.01
Emotion*Treatment*Age	5	0.13	2.04	0.07	0.02
Emotion*Gender*Treatment*Age	5	0.03	0.54	0.74	0.00
Error (Emotion)	640	0.06			
Type*Emotion	5	7.09	159.98	0.00	0.56
Type*Emotion*Gender	5	0.03	0.77	0.57	0.01
Type*Emotion*Treatment	5	0.05	1.10	0.36	0.01
Type*Emotion*Age	5	0.27	6.06	0.00	0.05
Type*Emotion*Gender*Treatment	5	0.08	1.69	0.14	0.01
Type*Emotion*Gender*Age	5	0.03	0.75	0.59	0.01
Type*Emotion*Treatment*Age	5	0.01	0.26	0.94	0.00
Type*Emotion*Gender*Treatment*Age	5	0.09	2.00	0.08	0.02
Error (Type*Emotion)	640	0.04			
Gender	1	0.07	0.82	0.37	0.01
Treatment	1	0.05	0.62	0.43	0.01
Age	1	4.18	48.30	0.00	0.27
Gender*Treatment	1	0.27	3.14	0.08	0.02
Gender*Age	1	0.05	0.62	0.43	0.01
Treatment*Age	1	0.02	0.19	0.67	0.00
Gender*Treatment*Age	1	0.02	0.19	0.67	0.00
Error	128	0.09			

This ANOVA revealed a main effect of type, $F(1, 128) = 147.21$, $p < .001$, $MSE = .07$, $\eta_p^2 = .54$, showing that overall vocal expressions of emotions were matched more accurately to facial expressions ($M = .65$, $SD = .16$) than to bodily expressions ($M = .49$, $SD = .16$). A main effect of emotion, $F(5, 640) = 77.60$, $p < .001$, $MSE = .03$, $\eta_p^2 = .38$, showed that sadness was matched most accurately ($M = .74$, $SD = .23$) with surprise ($M = .70$, $SD = .20$), followed by anger ($M = .59$, $SD = .28$), followed by happiness ($M = .53$, $SD = .18$), and followed by fear ($M = .44$, $SD = .21$) and disgust ($M = .41$, $SD = .02$) as the most difficult. A main effect of age, $F(1, 128) = 48.30$, $p < .001$, $MSE = .17$, $\eta_p^2 = .27$, showed that young adults ($M = .64$, $SD = .11$) performed better than older adults ($M = .50$, $SD = .13$).

Interactions between emotion and age, $F(5, 640) = 20.18$, $p < .001$, $MSE = .06$, $\eta_p^2 = .14$, and between type and emotion, $F(5, 640) = 159.98$, $p < .001$, $MSE = .04$, $\eta_p^2 = .56$, were qualified by an interaction between type, emotion and age, $F(5, 640) = 1.69$, $p < .001$, $MSE = .04$, $\eta_p^2 = .05$. Further analysis of this three-way interaction, shown in Figure 6, revealed that young adults matched vocal expressions of emotion to facial expressions more accurately than older adults for anger, $t(134) = 4.81$, $p < .05$, sadness, $t(134) = 8.82$, $p < .05$, and happiness, $t(134) = 4.63$, $p < .05$, and that young adults matched vocal expressions of emotion to bodily expressions more accurately than older adults for anger, $t(134) = 9.69$, $p < .05$, sadness, $t(134) = 4.36$, $p < .05$, happiness, $t(134) = 3.96$, $p < .05$, and disgust, $t(134) = 2.77$, $p < .05$.

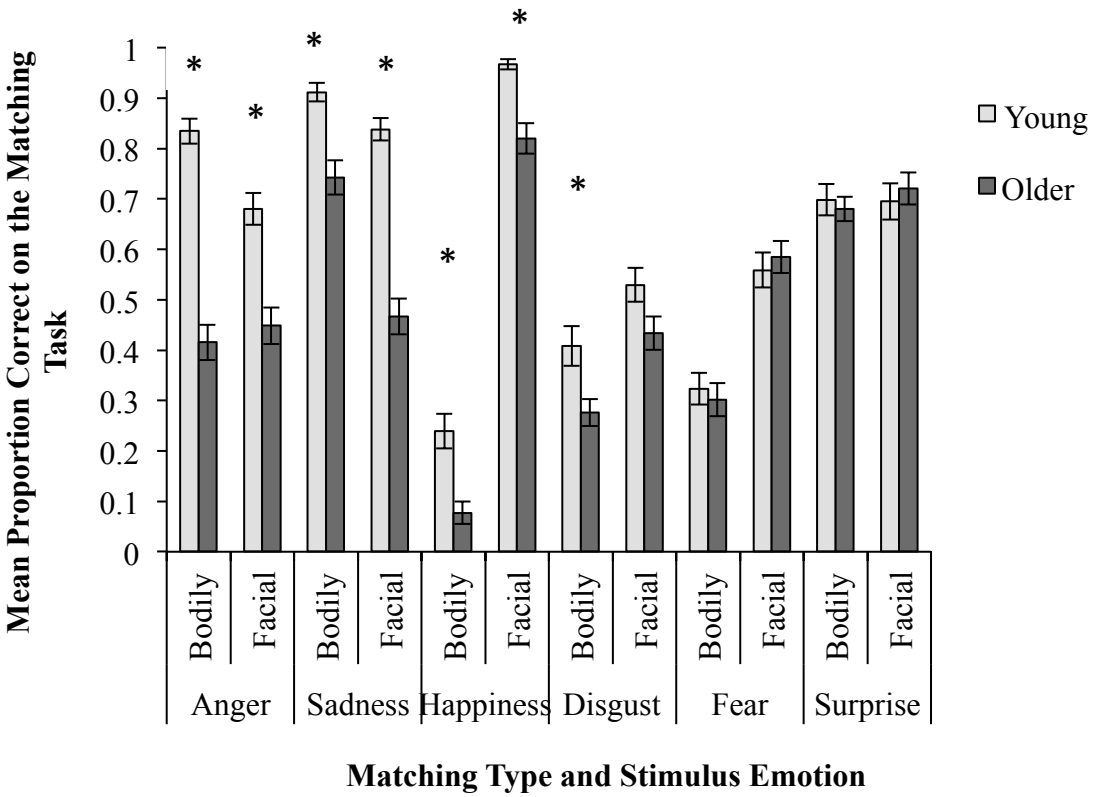

Figure 6. Young and older participant accuracy scores (Proportion Correct) for matching vocal emotion expressions to bodily and facial emotion expressions, as a function of emotion.
Note. *$p < .05$.

Eye Tracking Analyses

EyeNal analysis software, supplied by Applied Science Laboratories, was used to analyse the eye-tracking data for each participant with complete eye tracking data (n = 128). The position of the eyes was sampled repeatedly during tracking to determine when a fixation was occurring. A fixation was defined as gaze on a particular region, with no change in eye position greater than 1-degree visual angle, for 100 ms or longer. These fixations were used to create dwell times. A dwell was defined as gaze remaining within an area of interest, regardless of the number of fixations that occurred within that area. For each participant, the total dwell duration occurring in an area of interest was recorded for each stimulus.

Areas of interest were created on stimuli from the emotion recognition task and RMET in order to measure fixations to specific face regions. A general template was

created for the areas of interest and fitted to all stimuli. On the emotion recognition task stimuli, four areas of interest were defined (see Figure 7). These included rectangles positioned over the left and right eyes of the stimulus (combined to create one eye area), the mouth, the nose, and a larger area encompassing the entire face, which included the eyes, nose and mouth, as well as the cheeks chin and forehead.

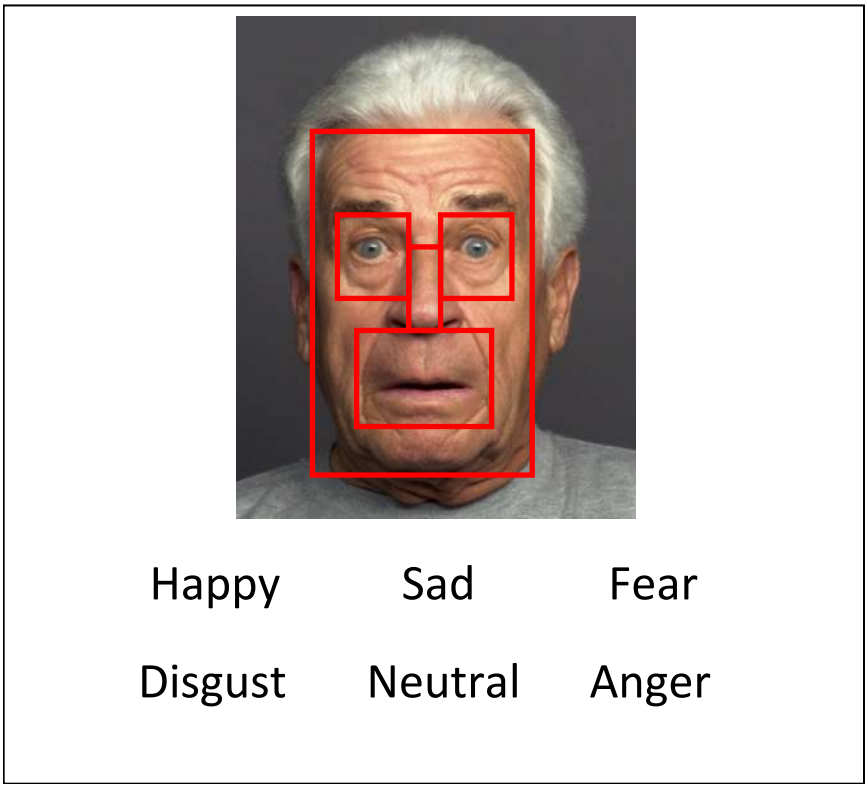

Figure 7. Areas of interest template (red rectangles) used on emotion recognition task stimuli.

On the RMET stimuli, two areas of interest were created (see Figure 8). One rectangle covered the eyes presented in the stimulus and another rectangle encompassed the entire stimulus, including the eyes and the labels. Areas of interest template (red rectangles) used on RMET task stimuli.

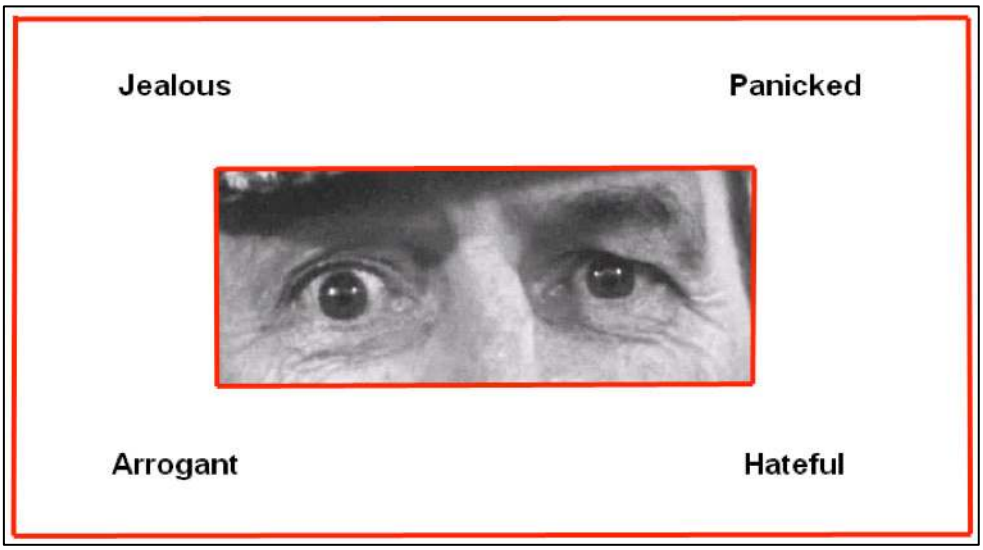

Figure 8. Areas of interest template (red rectangles) used on RMET task stimuli.

Emotion recognition task. Total dwell times in seconds to the eyes, mouth, nose and to the entire face (eyes, mouth, nose, cheeks, forehead, and chin) were calculated for each emotion, for each participant. These dwell times were used to create variables representing mean dwell times to the eyes, mouth, and nose separately as a proportion of dwell time to the entire face by dividing dwell time to each area by dwell time to the face for each participant (shown in Table 7), to indicate the amount of time participants spent dwelling on each of the eyes, nose or mouth regions rather than the cheeks, forehead or chin. These proportion dwell times were examined in a 5 (emotion: anger, disgust, fear, happiness, sadness) X 3 (region: eyes, mouth, nose) X 2 (treatment: oxytocin, placebo) X 2 (age: older, young) X 2 (gender: female, male) mixed ANOVA, as summarised in Table 8.

Table 7. Mean (*SD*s) Dwell Times (seconds) to the Eyes, Mouth, and Nose as a Proportion of Dwell Time to the Entire Face for Participant Groups for Each Stimulus Type

	Placebo				Oxytocin			
	Older Adults		Young Adults		Older Adults		Young Adults	
	Female	Male	Female	Male	Female	Male	Female	Male
Dwelling on Eyes								
Sadness	0.30	0.30	0.31	0.26	0.28	0.32	0.34	0.34
	(0.11)	(0.14)	(0.13)	(0.09)	(0.12)	(0.13)	(0.14)	(0.14)
Happiness	0.28	0.27	0.31	0.27	0.30	0.31	0.31	0.33
	(0.1)	(0.15)	(0.14)	(0.13)	(0.14)	(0.11)	(0.12)	(0.17)
Fear	0.31	0.31	0.34	0.29	0.30	0.35	0.33	0.36
	(0.1)	(0.14)	(0.14)	(0.14)	(0.14)	(0.13)	(0.15)	(0.17)
Anger	0.28	0.28	0.26	0.24	0.27	0.30	0.30	0.32
	(0.12)	(0.16)	(0.17)	(0.11)	(0.14)	(0.13)	(0.13)	(0.15)
Disgust	0.26	0.26	0.31	0.25	0.28	0.30	0.32	0.32
	(0.09)	(0.15)	(0.16)	(0.11)	(0.15)	(0.15)	(0.12)	(0.17)
Dwelling on Mouth								
Sadness	0.36	0.31	0.36	0.43	0.32	0.33	0.31	0.29
	(0.11)	(0.17)	(0.17)	(0.14)	(0.15)	(0.13)	(0.12)	(0.10)
Happiness	0.34	0.33	0.37	0.43	0.31	0.34	0.33	0.30
	(0.14)	(0.21)	(0.18)	(0.16)	(0.17)	(0.15)	(0.16)	(0.13)
Fear	0.33	0.32	0.32	0.39	0.31	0.32	0.31	0.31
	(0.12)	(0.18)	(0.18)	(0.15)	(0.16)	(0.14)	(0.15)	(0.14)
Anger	0.38	0.38	0.39	0.47	0.35	0.40	0.36	0.37
	(0.14)	(0.18)	(0.17)	(0.14)	(0.15)	(0.15)	(0.13)	(0.11)
Disgust	0.38	0.36	0.37	0.45	0.36	0.36	0.34	0.33
	(0.12)	(0.18)	(0.16)	(0.14)	(0.16)	(0.16)	(0.14)	(0.12)
Dwelling on Nose								
Sadness	0.09	0.06	0.07	0.09	0.07	0.09	0.09	0.09
	(0.04)	(0.05)	(0.05)	(0.05)	(0.06)	(0.06)	(0.05)	(0.04)
Happiness	0.11	0.07	0.08	0.11	0.09	0.12	0.10	0.11
	(0.05)	(0.05)	(0.05)	(0.04)	(0.07)	(0.11)	(0.05)	(0.08)
Fear	0.08	0.06	0.07	0.10	0.08	0.08	0.08	0.07
	(0.04)	(0.05)	(0.05)	(0.04)	(0.05)	(0.07)	(0.04)	(0.04)
Anger	0.08	0.07	0.08	0.08	0.08	0.08	0.11	0.08
	(0.05)	(0.05)	(0.07)	(0.04)	(0.05)	(0.04)	(0.05)	(0.04)
Disgust	0.11	0.06	0.09	0.10	0.09	0.11	0.09	0.10
	(0.05)	(0.05)	(0.05)	(0.05)	(0.07)	(0.08)	(0.05)	(0.06)

Table 8. Full ANOVA Table for Emotion Recognition Eye Tracking Analysis

Source	*df*	MS	*F*	*p*	η_p^2
Emotion	4	0.01	7.17	0.00	0.06
Emotion*Gender	4	0.00	1.78	0.15	0.02
Emotion*Treatment	4	0.00	1.21	0.31	0.01
Emotion*Age	4	0.00	0.48	0.71	0.00
Emotion*Gender*Treatment	4	0.00	0.48	0.71	0.00
Emotion*Gender*Age	4	0.00	0.30	0.83	0.00
Emotion*Treatment*Age	4	0.00	4.73	0.00	0.04
Emotion*Gender*Treatment*Age	4	0.00	0.81	0.50	0.01
Error (Emotion)	480	0.00			
Region	2	19.88	138.75	0.00	0.54
Region*Gender	2	0.02	0.16	0.75	0.00
Region*Treatment	2	0.31	2.18	0.14	0.02
Region*Age	2	0.01	0.04	0.89	0.00
Region*Gender*Treatment	2	0.06	0.39	0.58	0.00
Region*Gender*Age	2	0.06	0.45	0.55	0.00
Region*Treatment*Age	2	0.14	0.94	0.36	0.01
Region*Gender*Treatment*Age	2	0.10	0.68	0.45	0.01
Error (Region)	240	0.14			
Emotion*Region	8	0.08	27.54	0.00	0.19
Emotion*Region*Gender	8	0.00	1.33	0.24	0.01
Emotion*Region*Treatment	8	0.00	0.94	0.46	0.01
Emotion*Region*Age	8	0.00	1.21	0.30	0.01
Emotion*Region*Gender*Treatment	8	0.00	0.86	0.53	0.01
Emotion*Region*Gender*Age	8	0.00	1.34	0.24	0.01
Emotion*Region*Treatment*Age	8	0.01	1.75	0.11	0.01
Emotion*Region*Gender*Treatment*Age	8	0.00	0.32	0.93	0.00
Error (Emotion*Region)	960	0.00			
Gender	1	0.02	0.77	0.38	0.01
Treatment	1	0.00	0.06	0.80	0.00
Age	1	0.06	2.94	0.09	0.02
Gender*Treatment	1	0.01	0.66	0.42	0.01
Gender*Age	1	0.00	0.19	0.67	0.00
Treatment*Age	1	0.02	1.16	0.28	0.01
Gender*Treatment*Age	1	0.09	4.42	0.04	0.04
Error	120	0.02			

This ANOVA revealed main effects of emotion, $F(4, 480) = 7.17$, $p < .01$, $MSE = .001$, $\eta_p^2 = .06$, and region, $F(2, 240) = 138.75$, $p < .01$, $MSE = .14$, $\eta_p^2 = .54$, both qualified by an interaction between emotion and region, $F(8, 960) = 27.54$, $p < .01$,

MSE = .002, η_p^2 = .19. This interaction was not analysed further due to my focus on age and treatment effects.

An interaction between emotion, treatment and age, $F(4, 480) = 4.73$, $p < .01$, *MSE* = .001, η_p^2 = .04, shown in Figure 9, revealed that in the placebo group young adults dwelled more than older adults on the eyes, mouth and nose regions as a proportion of entire face dwell time (including chin, cheeks and forehead) for happy expressions, $t(62) = 2.78$, $p < .05$, but not other emotions, all *p*s > .05. In the oxytocin group, there were no age group differences, all *p*s > .05. To further examine the effect of oxytocin, I compared dwelling on the eyes, mouth and nose regions as a proportion of entire face dwell time on happy expressions in young adults who had taken oxytocin and young adults who had taken placebo. This revealed a decrease in dwelling on the eyes, nose and mouth regions compared the chin, cheeks and forehead regions on happy faces with oxytocin over placebo that approached significance, $t(62) = 1.70$, $p = .094$.

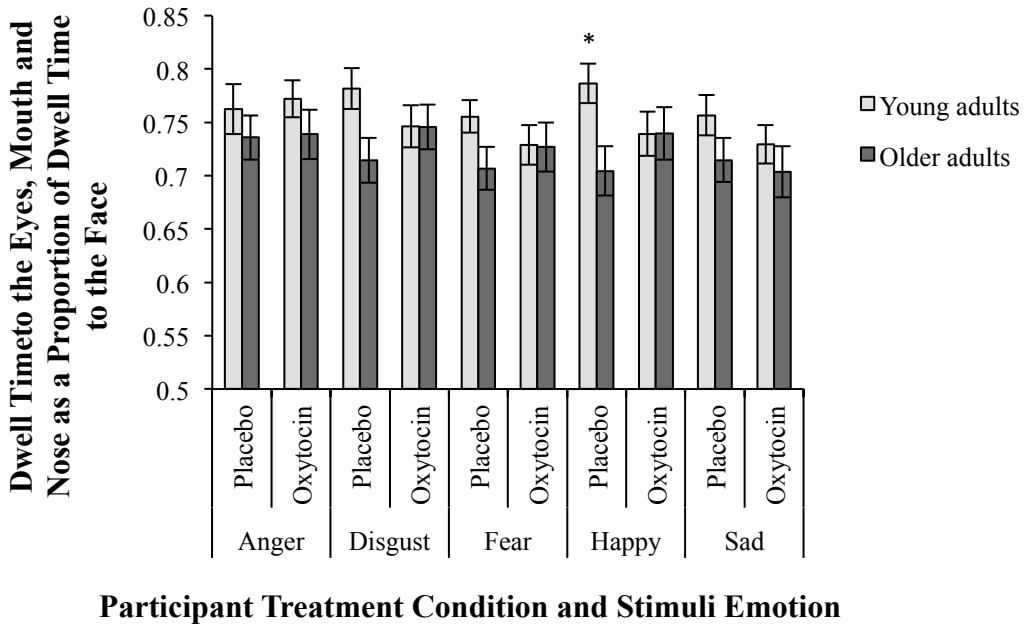

Figure 9. Young and older adult participant dwell times to the eyes, mouth and nose as a proportion of dwell time to the entire face, and as a function of participant treatment condition and stimulus emotion.
Note. *$p < .05$.

An interaction between gender, treatment and age, $F(1, 120) = 4.42$, $p = .04$, $MSE = .02$, $\eta_p^2 = .04$, shown in Figure 10, revealed that for males, there was an effect for age in the placebo group, with young males dwelling more than older males on the eyes, mouth and nose regions as a proportion of entire face dwell time (including chin, cheeks and forehead), $t(30) = 2.95$, $p < .05$, but this difference was not present in the oxytocin group, $t(30) = -.51$, $p > .05$. This indicates that in the placebo group older males spent less time than young males looking at the eyes, nose and mouth regions, and more time than young males looking at the chin, cheeks and forehead regions. No differences were found for females, all ps $> .05$. To further examine the effect of oxytocin I compared dwelling on the eyes, mouth and nose regions as a proportion of entire face dwell time in older males who had taken oxytocin and older males who had taken placebo. This revealed an increase in dwelling on the eyes, nose and mouth regions relative to total dwell time (on the eyes, nose, mouth, chin, cheeks and forehead

regions) when given oxytocin compared to placebo, that approached significance, $t(30) = -1.72$, $p = .095$.

Dwell times to the eyes, mouth, and nose regions, as a proportion of dwell times to the entire face were then correlated with emotion recognition accuracy for each participant group. This revealed a negative correlation between emotion recognition and dwelling on the mouth region for young females administered oxytocin, $r = -.55$, $p = .03$, indicating that their emotion recognition ability decreases with longer dwelling on the mouth region. No other correlations were significant for any participant group, all ps $> .05$. Therefore, older males' improved emotion recognition after oxytocin administration was not correlated with increased scanning of any areas of the face, all ps $> .05$.

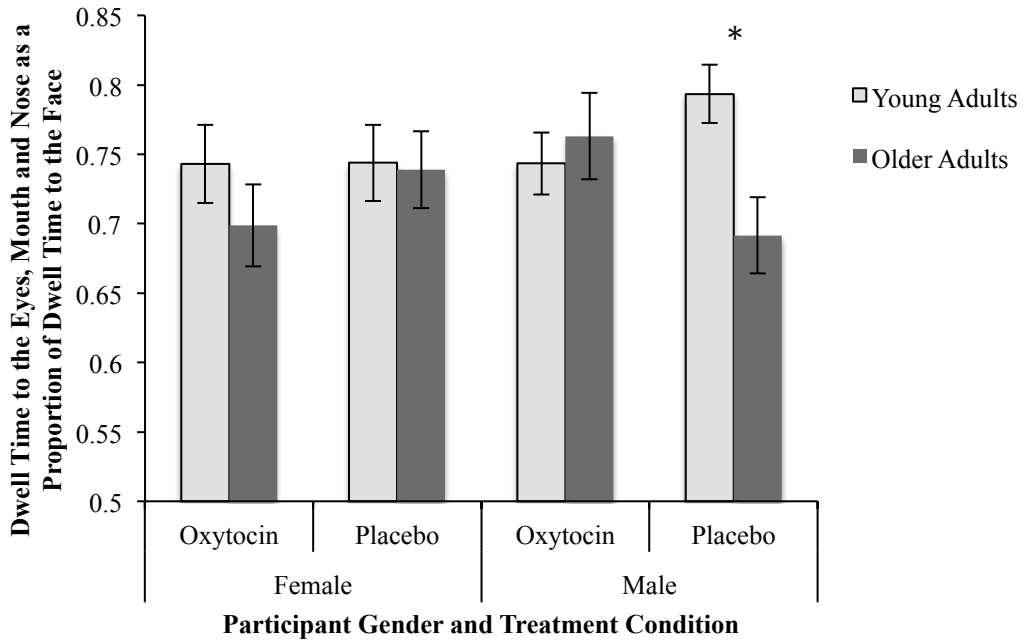

Figure 10. Young and older adult participant dwell times to the eyes, mouth and nose as a proportion of dwell time to the face, and as a function of participant gender and treatment condition.
Note. *$p < .05$.

RMET. Total dwell time in seconds to the eye region of each stimulus and to the entire stimulus, including the eyes and labels, were calculated for each participant with eye tracking data. These dwell times were used to create variables representing dwell times to each eye as a proportion of dwell time to the total stimulus area by dividing dwell time to each area by dwell time to the stimulus for each participant (shown in Table 9) to indicate the amount of time participants spent dwelling on the eyes rather than the labels or white space around the eyes and labels. These proportion dwell times were examined in a 2 (treatment: oxytocin, placebo) X 2 (age: older, young) X 2 (gender: female, male) ANOVA, as summarised in Table 10. This revealed a main effect for age, $F(1, 120) = 5.37$, $p = .02$, $MSE = .008$, $\eta_p^2 = .04$. Overall, older adults ($M = .53$, $SD = .14$) had longer dwell times to the eyes as a proportion of the entire stimulus when compared to young adults ($M = .48$, $SD = .11$).

In order to ensure that effects were not being obscured by a difference between older and young adults' dwell times to, or processing of, the stimulus labels, this analysis was repeated using total dwell times in seconds to the eye region of each stimulus (also shown in Table 9). These total dwell times were examined in a 2 (treatment: oxytocin, placebo) X 2 (age: older, young) X 2 (gender: female, male) ANOVA, as summarised in Table 11. As in the previous analysis, this revealed only a main effect of age, $F(1, 120) = 41.26$, $p < .001$, $MSE = 2.59$, $\eta_p^2 = .26$, whereby older adults ($M = 4.56$, $SD = 2.05$) had longer total dwell times to the eyes than young adults ($M = 2.73$, $SD = .92$).

Dwell time to the eyes as a proportion of dwell time to the total stimulus area was correlated with RMET accuracy for older females given placebo, $r = .58$, $p < .05$, and for young males given oxytocin, $r = .53$, $p < .05$, but not for any other participant group, all ps $> .05$. This shows that for each group, RMET accuracy increased with

longer dwell times to the eyes. Total dwell times to the eyes was not correlated with RMET accuracy for any participant group, all *p*s > .05.

Table 9. Mean (*SD*s) Dwell Times to Each Eye as a Proportion of Dwell Time to the Entire Stimulus and Total Dwell Times to Each Eye for Each Participant Group

	Placebo				Oxytocin			
	Older Adults		Young Adults		Older Adults		Young Adults	
	Female	Male	Female	Male	Female	Male	Female	Male
Proportion Dwell Times	0.54 (0.13)	0.51 (0.13)	0.47 (0.13)	0.5 (0.11)	0.52 (0.14)	0.55 (0.16)	0.46 (0.08)	0.48 (0.14)
Total Dwell Times	4.52 (1.50)	4.15 (1.57)	2.57 (0.86)	2.85 (1.01)	4.74 (2.60)	4.83 (2.43)	2.50 (0.75)	3.01 (1.03)

Table 10. Full ANOVA Table for RMET Eye-Tracking Analysis Using Proportion Dwell Times

Source	*df*	MS	*F*	*p*	η_p^2
Gender	1	0.00	0.35	0.55	0.00
Treatment	1	0.00	0.02	0.90	0.00
Age	1	0.05	5.37	0.02	0.04
Gender*Treatment	1	0.00	0.30	0.59	0.00
Gender*Age	1	0.00	0.30	0.58	0.00
Treatment*Age	1	0.00	0.32	0.57	0.00
Gender*Treatment*Age	1	0.01	0.57	0.45	0.01
Error	120	0.01			

Table 11. Full ANOVA Table for RMET Eye-Tracking Analysis Using Total Dwell Times

Source	*df*	MS	*F*	*p*	η_p^2
Gender	1	0.53	0.21	0.65	0.00
Treatment	1	1.95	0.75	0.39	0.01
Age	1	106.88	41.26	0.00	0.26
Gender*Treatment	1	0.92	0.36	0.55	0.00
Gender*Age	1	2.32	0.90	0.35	0.01
Treatment*Age	1	1.26	0.49	0.49	0.00
Gender*Treatment*Age	1	0.11	0.04	0.84	0.00
Error	120	2.59			

Discussion

The results of the current study indicate that oxytocin has an effect on emotion recognition in older adults. Three main results emerged from the analyses: 1) oxytocin improved emotion recognition for older males; 2) oxytocin increased older males' scanning of the eyes, nose and mouth regions of the face; and 3) oxytocin changed the way that both older and young adults integrated gaze direction cues with emotion expression to influence emotion recognition. A trend emerges from these results; oxytocin appears to have the largest effect in older males. These results are discussed in more detail below.

First, the results indicate that oxytocin improves emotion recognition accuracy in general for older males, the group with the worst emotion recognition ability. Oxytocin did not improve recognition for the specific facial emotions that older adults find most difficult to recognise – anger, sadness and fear – as hypothesised, even though age differences were found on these specific emotions. In the placebo group, older males showed significantly worse emotion recognition scores than other groups, indicating that they had the most difficulty with this task, consistent with previous research (Ruffman et al., 2010; Sullivan et al., in press). Therefore, older males are the group with the most room for improvement. This result is consistent with the idea that the effects of oxytocin are modulated by baseline social competence or performance. In previous research, oxytocin improved performance for those people who were less socially competent at baseline or who found the task particularly difficult (Bartz et al., 2011; Domes et al., 2007; Olff et al., 2013).

Oxytocin improved older males' emotion recognition ability to the level of older females, but not to the level of young adults, with significant age differences still apparent after oxytocin administration. Therefore, oxytocin changes cannot fully

explain age-related emotion recognition difficulties. Other factors, such as brain volume decreases, additional changes in function and amount of neurotransmitters, or white matter changes, likely also contribute to age-related emotion recognition difficulties (Ruffman et al., 2008). Oxytocin appears to have had a larger effect on gender differences in performance within the older adult group, by improving older males' performance. Gender differences are common in the oxytocin literature. Most past research has examined the effect of oxytocin on young males, but oxytocin appears to have a different, and often opposite effect when administered to females (Fischer-Shofty et al., 2013a; Hoge et al., 2014). Thus, there is a precedent for oxytocin affecting males without having an effect on females, in a range of tasks including adjusting decision-making based on risk (Lynn et al., 2014), judging moral scenarios (Scheele et al., 2014), and perspective taking (Theodoridou et al., 2013b). Examining the effect of oxytocin separately in males and females appears to be especially important when there are gender differences in performance on the particular task.

Oxytocin did not affect older or young adults' recognition of complex emotions in the RMET or their matching of vocal to facial or bodily expressions of emotion. It also did not have an effect on visual scanning in the RMET. Oxytocin has also been shown to have no effect on the ability to match faces displaying the same emotional expression when a target face displaying a particular emotional expression is displayed along with two other faces, one of which displayed the target emotional expression (Horta de Macedo, Zuardi, Machado-de-Sousa, Chagas, & Hallak, 2014). An age-difference was found on the RMET, with older adults performing significantly worse than young adults, consistent with previous research (Henry et al., 2013). It is possible that there is some other variable moderating the effects of oxytocin that was not measured in this study. An age-difference was also apparent in the matching tasks, with

young adults matching the emotions of anger, sadness, happiness and disgust more accurately than older adults, consistent with previous research (Ruffman et al., 2008; Ruffman, Ng, & Jenkin, 2009b; Ryan et al., 2010). Unlike previous research, older adults were not worse at matching fear to faces or bodies.

Second, the results show that oxytocin affected older male's visual scanning patterns. An increase in scanning of the eyes/nose/mouth area of the face was observed for older males who had taken oxytocin rather than placebo; however, scanning of each of these areas individually did not change after oxytocin administration. Furthermore, older males' improvement in emotion recognition after oxytocin administration was not correlated with their increased looking to the eyes/nose/mouth. Thus, it appears that an increase in scanning of important areas of the face after oxytocin administration is distinct from improved emotion recognition. Research suggests that older adults do not gain as much information from the eye region of the face as young adults do, even when they are looking at such regions (Slessor, Riby, & Finnerty, 2013; Sullivan et al., 2007).

Previous research has demonstrated that oxytocin can increase scanning of the eye region specifically for young males (Domes et al., 2012; Guastella et al., 2008). However, these studies used neutral faces or tasks in which valence discrimination was required (e.g., differentiating anger from happiness). In contrast, oxytocin does not appear to influence looking to the eye region when more explicit judgements of multiple emotional expressions are required (Domes et al., 2010; Lischke et al., 2012a). Rather, oxytocin increases scanning of a range of facial areas, including the eyes, nose and mouth, as shown in the current study. It has also been suggested that increased scanning of the eye region of the face with oxytocin is a mechanism for oxytocin improving recognition of emotions from faces (Guastella et al., 2008). However, the

results of the current study suggest that these two oxytocin effects are not related, at least for older males. Likewise, Lischke et al. (2012a) found that scanning the eye region was not correlated with emotion recognition accuracy for young males. Thus, a different mechanism must be involved in improved emotion recognition with oxytocin administration.

Third, the results show that oxytocin changed the way that both older and young adults integrated gaze direction cues with emotion expression, to influence emotion recognition. In the placebo group, gaze direction cues were integrated with emotion expression by young adults but not by older adults, consistent with previous studies (Slessor et al., 2008; Slessor et al., 2010). Thus, young adults recognised sadness and anger more accurately with direct than averted gaze and recognised fear and disgust more accurately with averted than direct gaze. Previous research has examined how gaze cues interact with emotion cues to have an effect on the perceived intensity of the emotional expression (Adams & Kleck, 2005; Ruijten et al., 2013; Sander et al., 2007; Slessor et al., 2010; Willis et al., 2011). The current results extend such findings to show that the integration of gaze cues and emotion cues can also improve recognition ability for sadness, anger, fear and disgust in young adults. In contrast to the findings for young adults, older adults in the placebo group did not integrate the gaze cue with the emotional expression to influence their perception of the stimulus.

The findings for young adults given placebo – improved recognition of anger with direct gaze, and improved recognition of fear and disgust with averted gaze – are consistent with the shared signal hypothesis (Adams & Kleck, 2005), which states that gaze direction and emotional expression combine to represent the motivational intent of the expresser. This means that approach-related emotions (anger and happiness) are associated with direct gaze and avoidance-related emotions are associated with averted

gaze. In this study direct gaze rather than averted gaze improved young adults' recognition of sadness. Past research has indicated that sadness is recognised faster and as more intense with averted gaze than direct gaze, indicating that this emotion, along with fear and disgust, is perceived as avoidance-oriented (Adams & Kleck, 2003, 2005). This may reflect differences in the perception of sadness when judging intensity versus judging emotion expression. It could also indicate that sadness was perceived as an approach-oriented emotion in this study. Research has shown greater approach-related responses to sad expressions, indicating that the perception of sadness may be related to approach behaviours in the perceiver (Mizokawa, Mintemoto, Komiya, & Noguchi, 2013). It is unclear exactly why the perception of sad expressions with different gaze cues did not follow the predicted pattern based on the shared signal hypothesis.

In the oxytocin group no age difference was found in the integration of gaze and emotion cues, with one exception. Young adults administered oxytocin no longer showed any difference in recognition of emotion expressions based on the direction of the gaze cue. In contrast, those older adults administered oxytocin showed a difference in their recognition of sad faces based on the direction of the gaze cue. Sad expressions with direct gaze were recognised more accurately than sad expressions with averted gaze by older adults administered oxytocin. Thus, oxytocin changed the way in which both young and older adults integrated gaze direction cues.

Whereas young adults processed and integrated the gaze direction cue with the emotion expression appropriately when given placebo, oxytocin appeared to impair their ability to integrate these cues. One possibility is that oxytocin increased young adults' following of the gaze direction cue; reducing the amount of information they gained from the face. In fact, research shows that in young males oxytocin increases automatic responding to gaze direction cues on the face and their ability to suppress

automatic spatial responding to gaze cues is reduced (Tollenaar, Chatzimanoli, van der Wee, & Putman, 2013). This would take their focus away from the face and reduce their ability to integrate emotion and gaze cues. Another possibility is that oxytocin functioning follows the Yerkes-Dodson law such that neurotransmitter levels that are either too low or too high are detrimental to functioning (Honey & Bullmore, 2004). If this is the case, and young adults have optimal levels of oxytocin, then administering oxytocin would impair their performance as found.

Older adults, on the other hand, did not integrate the gaze direction and emotion expression cues when given placebo. Interestingly, older adults' recognition of sad expressions based on gaze direction did change after oxytocin administration, indicating that oxytocin improved their integration of gaze direction cues with emotion expression specifically for sadness. Sadness might be a particularly relevant emotion for older adults, who have to cope with many losses associated with ageing and there are at least some findings indicating that older adults experience more sadness than young adults in response to sadness-evoking stimuli (Seider et al., 2011). Thus, oxytocin might have had a specific effect on sad expressions because of their relevance to older adults.

In summary, oxytocin does have an influence on one aspect of older adults' emotion processing, their emotion recognition. Oxytocin increased older males' recognition of emotions and their scanning of the eyes, nose and mouth of the face. It also changed the way that young and older adults processed gaze direction cues. The effects of oxytocin on older adults' emotion recognition were modulated by gender and baseline abilities with older males benefitting more.

Study Two: The Effect of Oxytocin on Older Adults' Emotion Experience

Emotion processing involves not only attention to and recognition of emotion cues, but also the experience and expression of emotion. Oxytocin has been shown in Study 1 to have an effect on the initial perceptual stage of emotion processing in older adults by improving emotion recognition in older males, but it is unclear whether it might also influence experience and expression of emotion as well. The experience of emotion involves generation of an emotional feeling and then the expression of an emotional response. Emotional responses involve changes in many systems, including behavioural, physiological, vocal, and motor (Lench et al., 2011). Many of these responses are controlled by the ANS, which controls physiological arousal with two pathways: the sympathetic and parasympathetic (Appelhans & Luecken, 2006). As discussed in the first chapter, physiological responses, such as heart rate and skin conductance, can be measured to indicate the experience of emotions. Older adults show changes in measures of heart rate and skin conductance when experiencing emotions, although sometimes these responses are less than those of young adults (Burriss et al., 2007; Tsai et al., 2000).

Changes in heart rate due to emotional experience can be studied using measures of HRV, which reflects the variability in the interval between successive heartbeats. HRV indicates cognitive control over emotional responding (Thayer et al., 2012). HRV is influenced by both the sympathetic system (which speeds heart rate) and the parasympathetic system (which slows heart rate) (Appelhans & Luecken, 2006). However, HRV can be separated into frequency bands (unlike simple measures of heart rate) to show the influence of sympathetic and parasympathetic systems separately. Accordingly, high-frequency HRV can be used to reflect the functioning of only the parasympathetic system (Brouwer et al., 2013; Lane et al., 2009). In contrast, SCL

reflects arousal level and is affected only by the sympathetic system (Dawson et al., 2007; Potter & Bolls, 2012). Therefore, examining both HF-HRV and SCL provides measures of both branches of the ANS, the parasympathetic and sympathetic systems respectively.

A further measure of emotional experience is facial expressiveness. Young adults mimic others' facial expressions in order to help them understand the emotion that they are looking at, and mimicry has been thought to represent an experience of emotional valence (Hess & Fischer, 2013). Older adults also express emotional experience through facial expressions, and show an initial mimicry response to emotional pictures (Bailey & Henry, 2009). EMG allows the measurement of facial muscle movement to determine the valence of the expression (Tassinary et al., 2007). Measurement of muscle activity in the corrugator supercilli, which knits the brow region, is generally associated with the expression of negative emotions, whereas activity in the zygomaticus major, which pulls the cheeks up, is generally associated with the expression of happiness (Tassinary et al., 2007). Additionally, specific facial movements can be measured by videoing participants' facial expressions during emotion elicitation and using computer software to determine how the face is moving (Littlewort et al., 2011).

Oxytocin has been shown to influence changes in some physiological responses to emotional stimuli, but research investigating the role of oxytocin in the *experience* of basic emotions is lacking. Only a few studies have examined how oxytocin might influence measures of emotion experience and all of these studies have involved young adults. Studies have shown an influence of oxytocin on the cardiovascular system, with increases in HRV during rest (Kemp et al., 2012) and when engaged in tasks (Gamer & Buchel, 2012). However, as with all oxytocin effects, HRV changes are not consistent

and can be moderated by the experience of loneliness, with those who are lonely showing less benefit from oxytocin administration (Norman et al., 2011). This might be a particularly relevant finding in terms of older adults, who could experience greater loneliness due to social losses, death, and lifestyle changes. Although only 5 to 15% of older adults describe themselves as lonely, for those over 80 years of age, this increases to about 50% (Pinquart & Sörensen, 2001). Thus, measuring loneliness in older adults is important.

Oxytocin can improve the recognition of emotions (Shahrestani et al., 2013), and Study 1 of the present thesis indicates that oxytocin improves emotion recognition for older adults, specifically older males. However, it is unknown whether oxytocin influences older adults' experience of emotions. It is possible that oxytocin does influence emotion experience because it affects other aspects of emotion processing, including recognition of emotions and experience of trust (Van Ijzendoorn & Bakermans-Kranenburg, 2012), and many of the brain areas related to the recognition of emotions are also related to the experience of emotions (Sharpley & Bitsika, 2010). Nevertheless, this suggestion remains speculative as there is little research that directly examines this issue, and it is something of an empirical issue, explored herein, to examine whether oxytocin influences emotional experience.

In addition to age differences in oxytocin effects, gender differences were also found in Study 1, with the largest effects found for older males. This is consistent with the oxytocin literature showing larger effects in males than females after oxytocin administration (Lynn et al., 2014; Scheele et al., 2014). Gender differences also occur in emotional responses, with females often appearing to be more emotionally reactive than males, although studies investigating these differences generally include only young adults. One study including older and young adults found no interactions

between age and gender, indicating that it is possible gender differences in emotion experience remain stable over the lifetime (Burriss et al., 2007). Gender differences are found in self-reports of emotion, with females reporting stronger emotions than males (Burriss et al., 2007; Chentsova-Dutton & Tsai, 2007; Vrana & Rollock, 2002). However, this effect might be specific to certain emotions. Chentsova-Dutton and Tsai (2007) found that women reported more anger and love specifically than men.

Females also might show higher levels of arousal when experiencing emotions than males. SCL responses in females are larger when reliving emotional events (Chentsova-Dutton & Tsai, 2007) and when watching film clips designed to elicit sadness (Fernandez et al., 2012; Kring & Gordon, 1998). In contrast, males have been shown to have larger SCL responses when viewing anger and fear film clips (Kring & Gordon, 1998) so that differences might depend on the type of emotion experienced. Females' facial expressiveness is also usually larger than that of males, although again, this might depend on the type of emotion experienced. Females smile (shown with EMG activity in the zygomaticus muscle, which raises the cheek) more than males when reliving positive emotional events (Chentsova-Dutton & Tsai, 2007) or when viewing positive pictures (Bradley, Codispoti, Sabatinelli, & Lang, 2001). However, males and females show similar corrugator activity to negative pictures (Bradley et al., 2001). Accordingly, it is necessary to examine gender differences in any influence of oxytocin on older adults' emotion experience.

The current study aimed to address whether oxytocin influences emotion experience, focussing directly on older adults. The previous study showed that oxytocin has a larger effect on emotion processing in older than young adults, and so only older adults were included in this study. Older adults were administered oxytocin

or placebo in a double-blind study and physiological measures were taken at rest and during an emotion experience task.

The emotion experience task involved participants watching emotion-inducing film clips (anger/sadness/disgust, disgust, fear, happiness, sadness) in order to evoke an emotional reaction. Participants were then required to give subjective ratings of their emotional experience following each film clip, rating their experience of anger, disgust, fear, happiness, and sadness on scales from not at all intense to very intense. During the film clips, a number of measures were taken to examine participants' emotional reactions, including HRV, SCL, and EMG. In addition, a video recording was taken of participants to provide a measure of their facial expressiveness. The physiological measures of HRV and SCL were also taken during resting periods prior to oxytocin administration and post-administration, in order to determine how oxytocin influences these measures while older participants are at rest.

Overall, it was expected that oxytocin would have some influence on emotion experience and that effects might be larger in males than in females. Specific hypotheses were not made about EMG or SCL responses because the influence of oxytocin on these responses is uncertain. Oxytocin has been shown to increase HRV, although this effect is moderated by loneliness (Kemp et al., 2012; Norman et al., 2011). It was predicted that oxytocin would increase HRV at rest and during film clip viewing. Furthermore, it was predicted that this effect would be moderated by loneliness ratings. Two measures of loneliness were given to participants: the De Jong Gierveld Loneliness Scale (De Jong-Gierveld & Kamphuis, 1985) and the UCLA Loneliness Scale - version 3 (Russell, 1996). On the basis of previous research (see above), participants with higher scores on these measures were expected to show less HRV response to oxytocin administration than participants with low scores.

Method

Participants

Sixty-eight older adults (34 females; *M* = 72.38 years, *SD* = 6.25 years) were recruited to participate in this study, through an existing Psychology Department database. Participants received $40 to cover their travel expenses. In a double-blind, between-subjects design, 34 participants (17 male, 17 female) were randomly assigned to receive 20 international units (IU) of oxytocin via nasal spray and the remaining 34 participants received a placebo nasal spray containing a saline solution. The nasal spray was prepared and later self-administered following the same procedure described in Study 1. Exclusion criteria were the same as for Study 1. Written consent was obtained following a description of the study. Participants were required to agree to their general practitioner being informed of their inclusion in the study. Ethical approval was obtained from the Multi-Region Ethics Committee (MEC-11-11-096).

Stimuli

Emotion experience task. Five film clips were chosen in order to elicit specific target emotions of anger, disgust, fear, happiness and sadness. The films were North Country (anger/sadness/disgust), Trainspotting (disgust), The Grudge (fear), Love Actually (happiness) and The Champ (sadness). A separate study in our laboratory has shown that the film clip North Country elicits the negative emotions of anger, sadness and disgust, and all other clips elicit the target emotion (Ruffman, personal communication, 2012). To this end, anger is a difficult emotion to elicit with film and often occurs alongside other negative emotions (Rottenberg et al., 2007). From here, the film clip eliciting anger, sadness and fear will be referred to as the negative film clip, for simplicity and to reduce confusion with the other emotional film clips. The clips were 1.39 min to 4.46 min long. An amusing clip was also used for

practice at the beginning of the task. Details of the specific scenes used are available on request.

Questionnaires. Participants were given a number of questionnaires and tests to tap demographic information, affect, and loneliness (see Table 12). The Positive and Negative Affect Schedule (PANAS: Watson, Clark, & Tellegen, 1988) was used to monitor general changes in mood across the experiment, unrelated to emotion changes after watching film clips. This schedule contains 20 items; 10 positive (e.g., interested) and 10 negative (e.g., distressed) mood descriptors, to which participants indicate to what extent they feel that way on a five-point scale from very slightly or not at all (1) to extremely (5).

Participants also completed two measures of loneliness. The De Jong Gierveld Loneliness Scale (De Jong-Gierveld & Kamphuis, 1985) was used to provide an overall measure of loneliness and consists of 11 statements (e.g., I miss the pleasure of the company of others) tapping emotional and social loneliness, in which participants indicate the amount the statement applies to their situation. The UCLA Loneliness Scale-version 3 (Russell, 1996) was also used to provide a global measure of loneliness. This scale is simplified from earlier versions, with an easier-to-understand response format and wording for older adults (Russell, 1996). The UCLA Loneliness Scale consists of 20 statements (e.g., How often do you feel that you have a lot in common with the people around you?) to which participants indicate how often the statement applies to them.

Table 12. Questionnaire Means (*SD*s) for Participants in Experiment 2

	Placebo		Oxytocin	
	Female	Male	Female	Male
Education	4.60 (1.72)	4.87 (2.10)	5.24 (1.25)	4.94 (1.73)
PANAS Positive – time 1	30.88 (6.54)	30.82 (7.38)	30.71 (5.41)	32.35 (9.80)
PANAS Negative – time 1	11.47 (2.53)	11.18 (1.51)	11.18 (1.78)	10.71 (1.16)
PANAS Positive – time 2	30.00 (8.65)	32.76 (8.74)	30.35 (5.71)	33.59 (10.91)
PANAS Negative – time 2	11.41 (3.45)	10.65 (.93)	10.71 (1.16)	10.18 (.53)
PANAS Positive – time 3	30.59 (8.43)	30.82 (9.20)	29.88 (6.94)	33.12 (11.63)
PANAS Negative – time 3	10.82 (1.51)	11.00 (2.03)	10.94 (1.89)	10.41 (1.18)
De Jong Gierveld Loneliness Scale	2.71 (2.89)	3.71 (3.16)	1.94 (2.16)	3.65 (3.10)
UCLA Loneliness Scale-version 3	39.88 (9.21)	39.35 (9.00)	34.41 (5.55)	35.71 (8.59)

Notes. Education level was based on a scale of 1 = primary school, 2 = some high school, 3 = high school certificate, 4 = trade certificate, 5 = technical certificate (including nursing, teaching), 6 = BA/BSc and 7 = post-graduate. PANAS = Positive and Negative Affect Schedule.

Procedure

Participants first completed the PANAS. Then, pre-treatment baseline measurements of HRV, obtained with electrocardiogram (ECG), and SCL were taken for five minutes while participants rested with their eyes closed. For the HRV recordings, the skin on participants' non-dominant wrist and both ankles was abraded gently and cleaned with an alcohol wipe. Three circular foam ECG conductive adhesive electrodes were attached in a Lead-II formation with active electrodes on the non-dominant wrist and opposite ankle and a reference electrode on the other ankle. For the SCL recordings stainless steel fingerplates were attached to the palmar surface of the middle phalanges of the first and third fingers of the non-dominant hand with a velcro strap.

Participants then self-administered the nasal spray and completed the De Jong Gierveld and UCLA Loneliness Scales. Forty-five minutes following nasal spray

administration, participants again completed the PANAS. Post-treatment baseline measurements of HRV and SCL responses were taken for five minutes while participants rested with their eyes closed.

Following this baseline measurement, the emotion experience task was administered with continuous measurement of HRV, SCL and EMG responses. Furthermore, a video recording of each participant's face was made during this task. EMG recordings of muscle movement were taken from the left zygomaticus region and left corrugator supercilli. The corrugator knits the brow and is associated with anger and the zygomaticus lifts the corner of the mouth into a smile and is associated with happiness. Standard EMG site preparation and electrode placement procedures were followed (Tassinary et al., 2007). The skin over both regions was gently abraded with NuPrep gel and cleaned with an alcohol wipe. Gold-plated, hat-shaped electrodes with 9mm housings were placed in pairs parallel to the length of the muscle, with an inter-electrode distance of 1cm. An additional electrode was placed in approximately the centre of the forehead to act as a ground. Ten20 conductive gel was used to fill the electrodes and firmly attach them to the skin.

Initially, participants watched an amusing film clip as practice and to familiarise them with the components of the task. Participants viewed the five emotion film clips in a random order and after each rated how intensely they felt anger, disgust, fear, happiness and sadness, rating each emotion separately on a 1 (not at all) to 8 (very intensely) scale. Between the film clips, participants completed a two-minute filler task, a word-find game. Finally, all equipment was removed and participants completed the PANAS for a third time.

Data Acquisition

Heart rate variability. Heart rate was continuously measured with a PowerLab Instruments 8-channel bioamplifier that recorded the signal at a sampling rate of 1000Hz. LabChart7 was used to calculate the interbeat interval (IBI) between successive R-waves in order to calculate HRV. The raw heart rate data were pre-processed by using a 45Hz low pass filter to remove high frequency noise, and the derivative to remove low frequency noise. R-waves were automatically detected using LabChart7 and the recording was visually scanned for missing R-waves, which were manually inserted. A spectral analysis was applied to the interbeat intervals to produce high frequency-HRV (HF-HRV: 0.15-0.4Hz), expressed in normalised units (nu).

Skin conductance level. SCL was continuously measured with a PowerLab Instruments galvanic skin response amplifier at a sampling rate of 1000Hz. The raw data were screened for movement artefacts, which were manually removed.

Electromyography. Activity in both muscle regions was recorded continuously with a PowerLab 8/30 Data Acquistion System at a sampling rate of 2000Hz with a 10Hz high pass, 500Hz low pass filter and a 60-Hz notch filter. The raw data were screened for movement artefacts, which were manually removed. The root mean square method was used to calculate EMG responses, which signifies the square root of the average power of the EMG signal over a given period of time.

Computer expression recognition toolbox (CERT). CERT is an automated facial expression recognition program based on the Facial Action Coding System (FACS: Ekman & Friesen, 1978). Within FACS, facial expressions are described as a combination of tension or relaxation in specific muscles, called action units (AUs). CERT detects a face within a still or video image and recognises 19 of the AUs, and six prototype facial expressions, as well as the location of 10 facial features and the

orientation of the head (Littlewort et al., 2011). CERT was used to process facial movement in the videos taken of each participant completing the emotion experience task. For each of the AUs, CERT provides a measure of intensity (muscle contraction) in each video frame. CERT's AU recognition ability has been tested using both a posed expression database (Extended Cohn-Kanade Dataset) and a spontaneous expression database (M3 Dataset). CERT achieved correct values for 90.1% on the posed database and 79.9% on the spontaneous database (Littlewort et al., 2011).

Results

Preliminary Analyses

All assumptions were met in the multivariate analyses of variance (MANOVAs). Outliers were adjusted while keeping the ordinal position of each value (Tabachnick & Fidell, 2013) and a Bonferroni correction was applied to multiple comparisons to keep the family-wise error rate at $p < .05$. To check whether oxytocin influenced general changes in mood across the experiment, PANAS scores (reported in Table 12) were examined using *t*-tests at each time point. No differences were found between treatment groups at any time point, for males or females (all $p > .05$). Thus, male and female participants' general affect did not change because of treatment.

Baseline Physiological Measures

Mean scores for HF-HRV and SCL for each participant were calculated during the pre-treatment baseline and post-treatment baseline (shown in Table 13). In order to determine whether oxytocin affected resting HF-HRV or SCL, baseline pre- and post-treatment means were examined in a 2 (treatment: oxytocin, placebo) x 2 (gender: female, male) x 2 (time: pre-treatment baseline, post-treatment baseline) MANOVA with HF-HRV and SCL as dependent variables, as summarised in Table 14. There were no significant effects.

Table 13. Means (*SD*s) of HF-HRV and SCL for Participant Groups during Baseline Measurements

	Placebo		Oxytocin	
	Female	Male	Female	Male
HRV Pre-treatment	36.28 (17.99)	33.64 (20.23)	33.64 (15.73)	29.01 (14.98)
HRV Post-treatment	35.02 (13.50)	33.55 (18.79)	33.55 (14.16)	32.63 (15.92)
SCL Pre-treatment	4.04 (2.78)	5.20 (3.10)	5.20 (2.83)	4.39 (1.78)
SCL Post-treatment	3.91 (4.90)	5.24 (4.67)	5.24 (3.75)	5.59 (3.51)

Table 14. Full MANOVA Table for Baseline Physiological Measurements Analysis

Source	Hypothesis *df*	Error *df*	*F*	*p*	η_p^2
Time	2	63	0.64	0.53	0.02
Time*Gender	2	63	0.27	0.77	0.01
Time*Treatment	2	63	1.11	0.34	0.03
Time*Gender*Treatment	2	63	0.21	0.81	0.01
Gender	2	63	1.75	0.18	0.05
Treatment	2	63	0.03	0.98	0.00
Gender*Treatment	2	63	0.28	0.75	0.01

To determine whether loneliness scores influenced the relation between oxytocin and resting HF-HRV, as in previous research (Norman et al., 2011), a total loneliness score was calculated for each participant by summing the scores on the De Jong Gierveld and UCLA Loneliness Scales, which were highly correlated, $r(68) = .68$, $p = < .01$. The previous MANOVA was repeated with total loneliness score as a covariate. Again, no significant effects were found (summarised in Table 15).

Table 15. Full MANOVA Table for Baseline Physiological Measurements Analysis with Loneliness Covariate

Source	Hypothesis *df*	Error *df*	*F*	*p*	η_p^2
Time	2	62	0.39	0.68	0.01
Time*Loneliness	2	62	0.20	0.82	0.01
Time*Treatment	2	62	0.84	0.44	0.03
Time*Gender	2	62	0.29	0.75	0.01
Time*Gender*Treatment	2	62	0.21	0.81	0.01
Loneliness	2	62	0.37	0.69	0.01
Treatment	2	62	0.01	1.00	0.00
Gender	2	62	1.61	0.21	0.05
Gender*Treatment	2	62	0.28	0.76	0.01

Emotion Experience Task

Subjective ratings. Participants rated five emotions for each film clip on an ordinal scale from 1 (not at all) to 8 (very intensely). Responses were not normally distributed so that nonparametric measures were used to analyse the subjective ratings. Mean ratings for each of the film clips are shown in Table 16. To determine whether participants experienced the intended emotions during viewing of each film clip, I conducted pairwise comparisons with the Wilcoxon Signed Rank test (shown in Table 17). These indicated that for the sad, disgusted, happy, and fearful film clips, the intended emotion was rated significantly higher than any other emotion, all *p*s < .01, with ratings of the non-target emotions relatively low in comparison. For the negative film clip, participants rated feeling anger, disgust, and sadness at the same level and significantly higher than happiness or fear, as expected based on previous research conducted in this laboratory.

To determine whether oxytocin or gender had any influence on participants' ratings of emotions after the film clips, I conducted Mann-Whitney *U* tests (shown in Table 18 and Table 19). There were no significant effects of oxytocin or gender on

ratings for any of the films (using an adjusted alpha of .01, with the five comparisons in each film clip constituting a family of analyses).

Table 16. Means (*SD*s) of Participants' Emotion Ratings for Each Emotion Film Clip

Emotion Film Clip	Emotion Rating				
	Anger	Disgust	Fear	Happiness	Sadness
Negative	7.28 (2.09)	7.19 (2.23)	3.90 (2.56)	1.19 (0.63)	6.78 (2.09)
Disgust	3.25 (2.55)	**7.79 (1.74)**	2.44 (2.13)	1.32 (0.89)	4.53 (2.67)
Fear	3.01 (2.37)	3.49 (2.11)	**6.32 (2.42)**	1.24 (0.60)	3.75 (2.73)
Happy	1.75 (1.54)	1.65 (1.37)	1.90 (1.75)	**6.94 (1.68)**	3.65 (2.04)
Sad	3.37 (2.57)	3.26 (2.60)	2.69 (2.23)	1.31 (0.97)	**6.93 (2.17)**

Notes. Ratings of target emotions in bold differ from all other emotion ratings within a row at $p < .05$. For the negative film clip, ratings of anger, disgust and sadness were significantly higher than other ratings but not different to each other.

Table 17. Wilcoxon Signed Rank Tests of Subjective Ratings for Each Film Clip

	Negative Ranks	Positive Ranks	Ties	*Z*	*p*
Negative Film Clip					
Sad – Anger	27	14	27	-1.88	0.06
Disgust – Anger	15	15	38	-0.33	0.74
Sad – Disgust	32	15	21	-1.67	0.09
Happy – Anger	65	0	3	-7.07	0.00
Fear – Anger	56	2	10	-6.54	0.00
Happy – Sad	64	1	3	-7.03	0.00
Fear – Sad	53	8	7	-5.88	0.00
Happy – Disgust	65	0	3	-7.06	0.00
Fear – Disgust	57	0	11	-6.59	0.00
Happy Film Clip					
Anger – Happy	65	1	2	-7.06	0.00
Sad – Happy	61	1	6	-6.78	0.00
Fear – Happy	66	1	1	-7.11	0.00
Disgust – Happy	65	2	1	-7.12	0.00
Sad Film Clip					
Happy – Sad	66	0	2	-7.09	0.00
Anger – Sad	61	3	4	-6.69	0.00
Fear – Sad	63	2	3	-6.89	0.00
Disgust – Sad	63	2	3	-6.59	0.00
Disgust Film Clip					
Happy – Disgust	67	0	1	-7.23	0.00
Anger – Disgust	64	1	3	-7.01	0.00
Fear – Disgust	67	0	1	-7.15	0.00
Sad – Disgust	56	4	8	-6.23	0.00
Fear Film Clip					
Anger – Fear	58	1	9	-6.59	0.00
Happy – Fear	65	0	3	-7.03	0.00
Fear – Fear	57	7	4	-5.71	0.00
Disgust – Fear	57	2	9	-6.31	0.00

Table 18. Mann-Whitney *U* Comparisons of Subjective Ratings in Placebo Versus Oxytocin Groups for Each Gender Group and for Each Film Clip

	Male			Female		
Ratings	Mann-Whitney *U*	*Z*	*p*	Mann-Whitney *U*	*Z*	*p*
Negative Film Clip						
Happiness	142.00	-0.12	0.95	144.50	0.00	1.00
Anger	119.00	-0.91	0.39	138.00	-0.23	0.84
Fear	116.00	-1.00	0.34	142.50	-0.07	0.95
Sadness	124.00	-0.72	0.50	142.00	-0.09	0.95
Disgust	102.00	-1.54	0.15	136.00	-0.30	0.79
Happiness Film Clip						
Happiness	139.00	-0.19	0.87	113.50	-1.10	0.29
Anger	108.50	-1.45	0.22	144.00	-0.03	1.00
Fear	137.00	-0.30	0.81	135.50	-0.37	0.76
Sadness	140.50	-0.14	0.89	111.00	-1.18	0.26
Disgust	110.50	-1.32	0.25	135.50	-0.50	0.76
Sadness Film Clip						
Happiness	114.50	-1.34	0.31	127.50	-1.44	0.56
Anger	128.00	-0.59	0.59	91.50	-1.89	0.07
Fear	86.50	-2.12	0.05	128.50	-0.59	0.59
Sadness	126.50	-0.64	0.54	136.50	-0.28	0.79
Disgust	130.00	-0.52	0.63	113.00	-1.14	0.29
Disgust Film Clip						
Happiness	123.50	-1.03	0.47	118.00	-1.48	0.38
Anger	94.00	-1.79	0.09	83.00	-2.27	0.03
Fear	123.00	-0.80	0.47	137.50	-0.29	0.81
Sadness	127.50	-0.59	0.56	137.50	-0.24	0.81
Disgust	122.00	-0.86	0.45	116.00	-1.05	0.34
Fear Film Clip						
Happiness	123.00	-0.96	0.47	127.50	-1.44	0.56
Anger	111.50	-1.17	0.26	88.00	-2.04	0.05
Fear	119.00	-0.89	0.39	100.00	-1.57	0.13
Sadness	128.00	-0.58	0.59	115.00	-1.06	0.32
Disgust	110.00	-1.20	0.25	107.00	-1.32	0.21

Table 19. Mann-Whitney *U* Comparisons of Subjective Ratings in Males Versus Females for Each Treatment Group and for Each Film Clip

	Placebo			Oxytocin		
Ratings	Mann-Whitney *U*	*Z*	*p*	Mann-Whitney *U*	*Z*	*p*
Negative Film Clip						
Happiness	110.50	-2.09	0.25	110.50	-2.10	0.25
Anger	126.50	-0.64	0.54	131.50	-0.47	0.66
Fear	143.50	-0.04	0.97	105.50	-1.36	0.18
Sadness	134.50	-0.35	0.73	131.50	-0.46	0.66
Disgust	132.00	-0.44	0.68	102.00	-1.54	0.15
Happiness Film Clip						
Happiness	133.50	-0.39	0.71	131.50	-0.46	0.66
Anger	94.00	-2.10	0.09	132.00	-0.61	0.68
Fear	137.50	-0.28	0.81	133.50	-0.46	0.71
Sadness	90.50	-1.89	0.06	127.50	-0.59	0.56
Disgust	82.00	-2.60	0.03	127.50	-0.79	0.56
Sadness Film Clip						
Happiness	107.50	-1.72	0.21	119.00	-1.79	0.39
Anger	107.00	-1.37	0.21	111.50	-1.16	0.26
Fear	100.50	-1.58	0.13	112.50	-1.22	0.27
Sadness	130.00	-0.51	0.63	127.00	-0.62	0.56
Disgust	105.00	-1.43	0.18	138.00	-0.23	0.84
Disgust Film Clip						
Happiness	130.00	-0.75	0.63	110.00	-1.79	0.25
Anger	78.00	-2.43	0.02	89.00	-1.98	0.06
Fear	115.00	-1.14	0.32	143.50	-0.04	0.97
Sadness	142.00	-0.09	0.95	123.00	-0.75	0.47
Disgust	109.00	-1.31	0.23	129.00	-0.59	0.61
Fear Film Clip						
Happiness	134.00	-0.59	0.73	93.50	-2.65	0.08
Anger	80.50	-2.28	0.03	118.50	-0.93	0.38
Fear	114.00	-1.07	0.31	93.50	-1.79	0.08
Sadness	100.50	-1.55	0.13	140.00	-0.16	0.89
Disgust	83.50	-2.13	0.03	131.00	-0.47	0.66

Physiological measures. To examine the physiological measures during the emotion experience task, mean scores for each physiological measure (HF-HRV, SCL and EMG) were taken for each participant during the emotional peak of each film clip, determined to be the last minute of each clip. Mean scores were also calculated during

the second minute of the distracter task before each film clip to give baseline measures for that emotion film clip. Mean data are presented in Table 20. The means for HF-HRV and SCL met the assumptions necessary for multivariate analysis; however, the EMG means were not normally distributed and had small variance. Therefore, EMG was not included in the MANOVA and was analysed separately using nonparametric measures.

Table 20. Means (*SD*s) of Film Clip HF-HRV, SCL, and EMG Measurements for Participant Groups

	Placebo				Oxytocin			
	Female		Male		Female		Male	
	Baseline	Film Clip	Baseline	Film Clip	Baseline	Film Clip	Baseline	Film Clip
HRV								
Negative	36.69 (19.22)	39.54 (22.29)	40.35 (19.45)	41.59 (20.90)	41.04 (11.36)	39.93 (18.92)	31.74 (18.61)	43.11 (18.73)
Disgust	35.45 (16.43)	47.93 (22.82)	37.79 (19.10)	39.89 (17.85)	49.64 (19.83)	41.76 (19.81)	31.79 (16.05)	45.58 (24.06)
Fear	34.60 (17.05)	38.86 (22.66)	38.55 (18.32)	46.07 (28.64)	37.48 (17.68)	47.94 (26.05)	30.27 (19.59)	47.32 (20.02)
Happiness	40.48 (15.28)	39.62 (22.27)	36.58 (13.62)	39.45 (23.50)	39.52 (15.06)	39.80 (19.49)	38.52 (19.68)	49.47 (21.84)
Sadness	35.05 (17.27)	46.23 (18.22)	41.59 (20.31)	49.94 (23.45)	39.83 (20.66)	49.80 (22.69)	32.77 (20.52)	47.12 (26.14)
SCL								
Negative	10.88 (7.12)	11.04 (6.66)	10.99 (5.41)	11.86 (5.57)	9.51 (4.68)	8.89 (4.83)	12.53 (5.12)	12.25 (4.96)
Disgust	10.92 (6.77)	10.69 (7.16)	11.68 (5.35)	11.36 (5.30)	8.77 (5.96)	8.95 (5.02)	12.61 (4.92)	12.55 (4.98)
Fear	11.98 (7.41)	10.89 (7.91)	11.99 (6.72)	11.08 (6.04)	9.36 (4.88)	8.53 (5.27)	11.87 (5.47)	11.63 (5.37)
Happiness	9.85 (7.08)	10.59 (7.83)	11.14 (5.29)	12.35 (4.92)	9.68 (5.99)	9.30 (5.40)	12.77 (5.91)	12.28 (5.20)
Sadness	10.58 (7.28)	9.25 (7.60)	12.43 (6.15)	10.94 (6.35)	10.14 (4.80)	7.82 (4.87)	12.39 (4.91)	10.99 (4.45)
EMG - Corrugator								
Negative	0.016 (0.010)	0.017 (0.011)	0.013 (0.007)	0.014 (0.010)	0.011 (0.004)	0.012 (0.006)	0.013 (0.005)	0.012 (0.005)
Disgust	0.014 (0.007)	0.032 (0.027)	0.013 (0.005)	0.016 (0.010)	0.012 (0.006)	0.018 (0.010)	0.012 (0.005)	0.018 (0.009)
Fear	0.017 (0.011)	0.015 (0.006)	0.015 (0.008)	0.013 (0.007)	0.013 (0.006)	0.015 (0.006)	0.013 (0.005)	0.012 (0.004)
Happiness	0.013 (0.006)	0.011 (0.004)	0.013 (0.005)	0.012 (0.005)	0.013 (0.006)	0.010 (0.003)	0.012 (0.005)	0.011 (0.004)
Sadness	0.016 (0.009)	0.016 (0.007)	0.014 (0.005)	0.015 (0.008)	0.013 (0.005)	0.013 (0.006)	0.012 (0.005)	0.013 (0.005)
EMG – Zygomaticus								
Negative	0.014 (0.005)	0.013 (0.006)	0.012 (0.005)	0.011 (0.005)	0.015 (0.012)	0.014 (0.011)	0.021 (0.032)	0.012 (0.002)
Disgust	0.014 (0.005)	0.016 (0.008)	0.014 (0.005)	0.016 (0.007)	0.015 (0.011)	0.019 (0.022)	0.014 (0.003)	0.019 (0.023)
Fear	0.014 (0.004)	0.013 (0.004)	0.012 (0.004)	0.012 (0.005)	0.015 (0.012)	0.014 (0.011)	0.014 (0.003)	0.013 (0.002)
Happiness	0.014 (0.004)	0.016 (0.006)	0.013 (0.003)	0.014 (0.004)	0.013 (0.005)	0.017 (0.008)	0.013 (0.003)	0.014 (0.002)
Sadness	0.014 (0.005)	0.013 (0.005)	0.013 (0.004)	0.012 (0.003)	0.015 (0.011)	0.014 (0.011)	0.014 (0.003)	0.022 (0.040)

HF-HRV and SCL baseline and film clip means were examined in a 2 (treatment: oxytocin, placebo) x 2 (gender: female, male) x 2 (time: baseline, film clip) x 5 (emotion: negative, disgust, fear, happiness, sadness) MANOVA with HF-HRV and SCL as dependent variables, as summarised in Table 21. No significant effects of gender, $F(2, 62) = 1.56$, $p = .32$, $\eta_p^2 = .04$, or treatment, $F(2, 62) = .13$, $p = .88$, $\eta_p^2 = .004$, were found. A main effect of time was significant, $F(2, 62) = 4.31$, $p = .018$, $\eta_p^2 = .12$, qualified by an interaction between emotion and time, $F(8, 56) = 4.64$, $p < .001$, $\eta_p^2 = .40$. This emotion by time interaction was significant for both dependent variables individually: HF-HRV, $F(4, 252) = 6.12$, $p < .001$, $MSE = 321.12$, $\eta_p^2 = .09$, and SCL, $F(4, 252) = 5.11$, $p = .001$, $MSE = 3.35$, $\eta_p^2 = .08$, and so the interaction was examined further for both dependent variables. HF-HRV increased from the baseline to the film clip for the emotions of fear, $t(67) = -2.97$, $p < .05$, (baseline $M = 35.22$, $SD = 18.07$, versus film clip $M = 45.05$, $SD = 24.29$), and sadness, $t(67) = -3.32$, $p < .05$, (baseline $M = 37.31$, $SD = 19.62$, versus film clip $M = 48.25$, $SD = 22.34$). SCL decreased from the baseline to the film clip for the emotions of fear, $t(67) = 3.71$, $p < .05$, (baseline $M = 11.30$, $SD = 6.16$, versus film clip $M = 10.54$, $SD = 6.22$), and sadness, $t(67) = 5.81$, $p < .05$, (baseline $M = 11.39$, $SD = 5.84$, versus film clip $M = 9.75$, $SD = 5.97$).

Table 21. Full MANOVA Table for Film Clip HF-HRV and SCL Measurements Analysis

Source	Hypothesis *df*	Error *df*	*F*	*p*	η_p^2
Time	2	62	4.31	0.02	0.12
Time*Gender	2	62	1.28	0.29	0.04
Time*Treatment	2	62	0.71	0.49	0.02
Time*Gender*Treatment	2	62	2.42	0.10	0.07
Emotion	8	56	1.29	0.27	0.16
Emotion*Gender	8	56	0.60	0.77	0.08
Emotion*Treatment	8	56	1.00	0.44	0.13
Emotion*Gender*Treatment	8	56	0.80	0.61	0.10
Time*Emotion	8	56	4.64	0.00	0.40
Time*Emotion*Gender	8	56	0.77	0.63	0.10
Time*Emotion*Treatment	8	56	1.30	0.26	0.16
Time*Emotion*Gender*Treatment	8	56	1.44	0.20	0.17
Gender	2	62	1.16	0.32	0.04
Treatment	2	62	0.13	0.88	0.00
Gender*Treatment	2	62	0.65	0.52	0.02

To determine whether loneliness scores influenced the relation between oxytocin and HF-HRV during the film clips the previous MANOVA was repeated with total loneliness score as a covariate. In this case, no significant effects were found (summarised in Table 22).

Table 22. Full MANOVA Table for Film Clip HF-HRV and SCL Measurements Analysis with Loneliness Covariate

Source	Hypothesis *df*	Error *df*	*F*	*p*	η_p^2
Time	2	61	0.78	0.47	0.03
Time*Loneliness	2	61	1.35	0.27	0.04
Time*Gender	2	61	1.35	0.27	0.04
Time*Treatment	2	61	0.41	0.67	0.01
Time*Gender*Treatment	2	61	2.24	0.12	0.07
Emotion	8	55	0.38	0.93	0.05
Emotion*Loneliness	8	55	0.64	0.74	0.09
Emotion*Gender	8	55	0.55	0.82	0.07
Emotion*Treatment	8	55	1.06	0.41	0.13
Emotion*Gender*Treatment	8	55	0.82	0.59	0.11
Time*Emotion	8	55	2.44	0.02	0.26
Time*Emotion*Loneliness	8	55	1.59	0.15	0.19
Time*Emotion*Gender	8	55	0.73	0.67	0.10
Time*Emotion*Treatment	8	55	1.85	0.09	0.21
Time*Emotion*Gender*Treatment	8	55	1.44	0.20	0.17
Loneliness	2	61	0.04	0.96	0.00
Gender	2	61	1.13	0.33	0.04
Treatment	2	61	0.11	0.90	0.00
Gender*Treatment	2	61	0.63	0.54	0.02

To determine whether oxytocin or gender had any influence on EMG measures during the film clips, Mann-Whitney *U* tests were conducted on difference scores calculated between the baseline and the film clip (shown in Table 23 and Table 24). No effects of treatment or gender were found.

Table 23. Mann-Whitney *U* Comparisons of EMG Responses in Placebo Versus Oxytocin Groups for Each Gender Group and for Each Film Clip

	Male			Female		
Film Clip	Mann-Whitney *U*	Z	*p*	Mann-Whitney *U*	Z	*p*
Corrugator						
Negative	137.00	-0.26	0.81	136.50	-0.28	0.79
Disgust	96.50	-1.65	0.10	119.00	-0.88	0.39
Fear	141.00	-0.12	0.92	109.00	-1.22	0.23
Happiness	141.50	-0.10	0.92	140.00	-0.16	0.89
Sadness	126.00	-0.64	0.54	137.00	-0.26	0.81
Zygomaticus						
Negative	126.00	-0.64	0.54	136.50	-0.28	0.79
Disgust	116.50	-0.97	0.34	119.50	-0.86	0.39
Fear	110.00	-1.19	0.25	130.50	-0.48	0.63
Happiness	139.00	-0.19	0.87	104.50	-1.38	0.17
Sadness	133.00	-0.11	0.93	86.00	-1.81	0.07

Table 24. Mann-Whitney *U* Comparisons of EMG Responses in Males Versus Females for Each Treatment Group and for Each Film Clip

	Placebo			Oxytocin		
Film Clip	Mann-Whitney *U*	*Z*	*p*	Mann-Whitney *U*	*Z*	*p*
Corrugator						
Negative	135.50	-0.31	0.76	110.50	-1.17	0.25
Disgust	94.00	-1.74	0.09	141.50	-0.10	0.92
Fear	140.00	-0.16	0.89	102.50	-1.45	0.15
Happiness	123.50	-0.72	0.47	127.00	-0.60	0.56
Sadness	144.50	0.00	1.00	128.50	-0.55	0.59
Zygomaticus						
Negative	136.00	-0.29	0.79	104.00	-1.40	0.17
Disgust	127.50	-0.59	0.56	109.50	-1.21	0.23
Fear	119.50	-0.86	0.39	137.50	-0.24	0.81
Happiness	136.00	-0.29	0.79	89.50	-1.90	0.06
Sadness	107.00	-1.05	0.31	124.50	-0.42	0.68

To determine whether EMG measures changed across time from baseline to the film clips, I conducted pairwise comparisons with two-tailed Wilcoxon Signed Rank tests (shown in Table 25). These indicated that corrugator activity significantly

increased from baseline during the disgust film clip, $T = 431.00$, $z = -4.53$ (corrected for ties), N – Ties = 68, $p < 0.01$, and significantly decreased from baseline during the happiness film clip, $T = 556.00$, $z = -3.51$ (corrected for ties), N – Ties = 67, $p < 0.01$. Zygomaticus activity significantly increased from baseline during the happiness, $T = 647.00$, $z = -3.22$ (corrected for ties), N – Ties = 68, $p < 0.01$, disgust, $T = 647.50$, $z = -3.22$ (corrected for ties), N – Ties = 65, $p = 0.01$, and sadness, $T = 494.50$, $z = -3.38$ (corrected for ties), N – Ties = 62, $p < 0.01$, film clips, and significantly decreased from baseline during the negative film clip, $T = 640.50$, $z = -2.19$ (corrected for ties), N – Ties = 62, $p = 0.03$.

Table 25. Wilcoxon Signed Rank Tests of EMG Responses for Each Film Clip

	Negative Ranks	Positive Ranks	Ties	*Z*	*p*
Corrugator					
Negative	31	35	2	-0.09	0.93
Disgust	16	52	0	-4.53	0.00
Fear	34	33	1	-0.13	0.90
Happiness	45	21	2	-3.51	0.00
Sadness	32	36	0	-0.67	0.51
Zygomaticus					
Negative	35	26	7	-2.19	0.03
Disgust	22	43	3	-2.78	0.01
Fear	29	36	3	-0.47	0.64
Happiness	21	47	0	-3.22	0.00
Sadness	44	18	4	-3.38	0.00

CERT. Mean scores for each of the CERT AUs were calculated across each of the film clip video recordings for each participant. These means are reported in the Appendix. I examined CERT means in a 2 (treatment: oxytocin, placebo) x 2 (gender: female, male) x 5 (emotion: negative, disgust, fear, happiness, sadness) MANOVA, with each AU as a dependent variable, as summarised in Table 26. This revealed main

effects of gender, $F(20, 34) = 4.28$, $p < .001$, $\eta_p^2 = .72$, and emotion, $F(80, 784) = 1.80$, $p < .001$, $\eta_p^2 = .16$.

Analysis of the dependent variables individually showed gender differences for a number of AUs, which are presented below. AUs were expressed with greater intensity by males than females for AU10 Lip Raise, $F(1, 53) = 18.20$, $p < .001$, $MSE = .032$, $\eta_p^2 = .26$ (males $M = .05$, $SD = .06$, versus females $M = .04$, $SD = .09$), AU17 Chin Raise, $F(1, 53) = 29.67$, $p < .001$, $MSE = .869$, $\eta_p^2 = .36$ (males $M = 1.72$, $SD = .39$, versus females $M = 1.12$, $SD = .44$), and AU23 Lip Tightener, $F(1, 53) = 21.85$, $p < .001$, $MSE = .139$, $\eta_p^2 = .29$ (males $M = 1.30$, $SD = .16$, versus females $M = 1.11$, $SD = .18$). AUs were expressed with greater intensity by females than males for AU7 Lids Tight, $F(1, 53) = 13.31$, $p = .001$, $MSE = .034$, $\eta_p^2 = .20$ (males $M = .12$, $SD = .07$, versus females $M = .19$, $SD = .09$), and AU25 Lips Part, $F(1, 53) = 13.91$, $p < .001$, $MSE = .284$, $\eta_p^2 = .21$ (males $M = .46$, $SD = .20$, versus females $M = .69$, $SD = .28$).

Analysis of the dependent variables individually also showed emotion differences for a number of AUs, which are presented below. AUs were expressed with greater intensity during different emotion videos for AU12 Lip Corner Pull, $F(4, 212) = 5.69$, $p < .001$, $MSE = .054$, $\eta_p^2 = .10$, AU17 Chin Raise, $F(4, 212) = 4.28$, $p = .002$, $MSE = .051$, $\eta_p^2 = .08$, AU6 Cheek Raise, $F(4, 212) = 4.70$, $p = .001$, $MSE = .005$, $\eta_p^2 = .08$, and AU25 Lips Part, $F(4, 212) = 4.98$, $p = .001$, $MSE = .016$, $\eta_p^2 = .09$.

Paired comparisons were used to determine the degree of AU expression in the different emotion film clips. Means for these comparisons are presented in Table 27. AU12 Lip Corner Pull (likely indicative of smiling) was expressed more intensely during the happiness film clip than during the anger, $t(56) = 4.26$, $p < .05$, disgust, $t(56) = 3.27$, $p < .05$, fear, $t(56) = 3.97$, $p < .05$, and sadness, $t(56) = 3.55$, $p < .05$, film clips (all other comparisons were not significant, $p > .05$). AU17 Chin Raise (perhaps

indicating tension) was expressed more intensely during the fear film clip than during the happiness film clip, $t(56) = 5.73$, $p < .05$, (all other comparisons were not significant, $p > .05$). AU6 Cheek Raise (again, likely indicative of smiling) was expressed more intensely during the happiness film clip than the anger film clip, $t(56) = 3.97$, $p < .05$, (all other comparisons were not significant, $p > .05$). Finally, AU25 Lips Part (indicating mouth opening) was expressed more intensely during the happiness film clip than during the anger, $t(56) = 3.51$, $p < .05$, fear, $t(56) = 3.35$, $p < .05$, and sadness, $t(56) = 3.81$, $p < .05$, film clips (all other comparisons were not significant, $p > .05$).

Table 26. Full MANOVA for Film Clip CERT Measurements Analysis

Source	Hypothesis *df*	Error *df*	*F*	*p*	η_p^2
Emotion	80	784	1.80	0.00	0.16
Emotion*Gender	80	784	1.06	0.35	0.10
Emotion*Treatment	80	784	0.79	0.91	0.07
Emotion*Gender*Treatment	80	784	0.94	0.62	0.09
Gender	20	34	4.28	0.00	0.72
Treatment	20	34	0.80	0.70	0.32
Gender*Treatment	20	34	0.74	0.76	0.30

Table 27. Means (*SD*s) for Comparisons of Significant AUs between Film Clips

Areas	Film Clip Anger	Disgust	Fear	Happiness	Sadness
AU12 Lip Corner Pull	0.858 (0.544)	0.841 (0.537)	0.890 (0.493)	0.699 (0.547)	0.852 (0.492)
AU17 Chin Raise	1.407 (0.582)	1.430 (0.528)	1.515 (0.558)	1.335 (0.535)	1.435 (0.551)
AU25LipsPart	0.547 (0.296)	0.587 (0.294)	0.568 (0.268)	0.633 (0.299)	0.541 (0.277)
AU6CheekRaise	0.111 (0.177)	0.149 (0.163)	0.119 (0.163)	0.157 (0.179)	0.131 (0.165)

Discussion

The results of the second study indicate that oxytocin does not have any effect on emotion experience in older adults. Older adults did show changes in physiological activity during the different film clips, as well as changes in facial expressiveness during the film clips, yet oxytocin did not affect these measures.

Previous research examining the influence of oxytocin on the experience of emotion has examined young adults, as well as complex emotional states such as trust and stress rather than basic emotions (Heinrichs et al., 2003; Van Ijzendoorn & Bakermans-Kranenburg, 2012). One possibility is that oxytocin only influences more complex social emotions such as trust or empathy rather than basic emotions. However, oxytocin did not affect any physiological measures of emotion experience either, which should indicate basic or complex emotional experience. Additionally, many of the studies of complex emotional experience involve financial games or direct interactions with other people (Baumgartner et al., 2008; Kosfeld et al., 2005). It might be that oxytocin only influences experience of emotion when there are other people directly involved in this experience. In the present study, viewing film clips does not entail direct interactions with other people.

More specifically, the predicted increase in HRV at rest or during the emotional film clips was not found, despite previous findings indicating that oxytocin does have an influence on HRV (Kemp et al., 2012; Norman et al., 2011). Furthermore, loneliness ratings did not influence the current findings, as found in the past (Norman et al., 2011). These previous studies only included young participants and it might be that effects do not extend to older adults. It could also be that only specific measures of HRV are able to show changes after oxytocin administration (such as non-linear

measures: Kemp et al., 2012), although oxytocin has been shown to increase HF-HRV (as used in the current study) in at least one study (Norman et al., 2011).

Another finding was that SCL did not change at rest or during the emotional film clips after oxytocin administration. This is consistent with previous results by Gamer and Buchel (2012), who showed participants emotionally valanced pictures and found no effect of oxytocin on SCL, despite finding an effect on a measure of heart rate.

The subjective ratings made by participants indicate that the film clips elicited the expected emotions during viewing. Furthermore, changes in physiological activity were found for the sadness and fear film clips, with increased HF-HRV and decreased SCL responses. This pattern of physiological responses has been associated with emotion regulation (Lemaire, El-Hage, & Frangou, 2014; Thayer et al., 2012), indicating that older adults might have been actively regulating their emotional responses during these film clips. Higher HRV is associated with emotion regulation (Thayer et al., 2012) and SCL decreases when older adults are regulating their emotions during tasks (Lemaire et al., 2014; Lohani & Isaacowitz, 2014). This regulation might have resulted in suppressed sympathetic activity with increased parasympathetic activity. The sadness- and fear-eliciting film clips might have been provocative for the older adults because they represented themes of death and home invasion respectively, themes that are particularly relevant to older adults. Therefore, older adults might have been more inclined to regulate their emotional response during these film clips than others presented. However, it is unclear from the current study whether participants (knowingly or not) engaged in emotion regulation strategies during the film clips.

Yet another finding was that there were changes in facial expressiveness when older adults viewed the emotional film clips. In general, corrugator activity increases to negative film clips and zygomaticus activity increases to positive film clips

(Tassinary et al., 2007), and this pattern of results was found. Corrugator activity increased during the disgust film clip and decreased during the happy film clip, and zygomaticus activity increased during the happiness film clip and decreased during the anger film clip. This is consistent with the idea that EMG responses in these two muscle groups represent the valence of the emotional experience (Hess & Fischer, 2013).

Interestingly, increases in zygomaticus activity also occurred during the disgust and sadness film clips. This could reflect a number of different factors, including random facial movement, use of this particular muscle to express sadness and disgust, or limiting the experience of negative emotion through smiling. Mimicry of emotional expressions is reduced when participants are trying to distance themselves from the experience of a particular emotion (Hess & Fischer, 2013). Older adults might have smiled during the disgust and sadness films as a way of limiting the amount of negative emotion they felt.

A final finding was that there were changes in expressiveness for males and females during film clip viewing. The CERT data indicated that females tended to open their mouths more than males while viewing emotion clips. This might reflect a general gender stereotype in emotional expressiveness, where females are more expressive and open in their emotional reactions, but males are less expressive and try to reduce their emotional expression (Fischer & LaFrance, 2014). In fact, females tend to smile more than males do, and this effect is enhanced when people know that they are being watched (LaFrance, Hecht, & Paluck, 2003). Participants in the current study knew they were being videoed, which might have caused female participants to smile more than male participants, leading to differences in facial expressiveness.

In summary, the results of this study indicate that older adults did experience a change in emotional experience during the task and appeared to actively regulate their emotional response to the sadness and fear film clips. However, oxytocin did not have an effect on any aspect of emotional experience measured during this study. Thus, the influence of oxytocin on emotion processing in older adults appears to be limited to their recognition of emotions and does not extend to their experience of emotions.

General Discussion

There are now well-documented age-related changes in emotion processing. However, the underlying cause of such changes is not clear and although changes in brain structure and functioning have been hypothesised as mechanisms, few studies have directly examined these claims. The current research shows that the neuropeptide oxytocin can influence older adults' emotion processing, but has an influence only on the recognition of emotions and not on the experience of emotions. The first study, examining emotion recognition, showed that oxytocin improves older males' ability to recognise emotions from faces and also increases older males' scanning of important areas of the face: the eyes, nose and mouth. However, these effects were not correlated, and so oxytocin did not improve recognition by increasing scanning of the eye region of the face. Oxytocin also changed the way that older and young adults integrated gaze direction cues with emotional expression, by reducing young adults' ability to integrate these cues to affect their recognition of emotions and increasing older adults' ability to integrate these cues for sad expressions. However, oxytocin did not affect performance on the RMET or on matching of emotional sounds to emotional faces or bodies. One possibility is that these tests were not sufficiently sensitive because they included fewer items than the emotion recognition task (the RMET included 37 items and the matching task included 48 items, compared to 192 items in the emotion recognition task).

The second study, examining emotion experience, showed that oxytocin did not affect subjective emotional experience or measures of emotional responding during viewing of emotional film clips. Despite this, older adults did appear to react to the emotional film clips shown, evidenced by their change in subjective responses, facial expressiveness, and physiological responding, suggesting that the stimuli were sufficiently evocative to have enabled oxytocin to have an effect on emotional

experience. Overall, it appears that oxytocin's influence on emotion processing in older adults is limited to older males' emotion recognition and does not extend to the experience of emotion or emotional responding.

Previous research has shown that oxytocin can improve emotion recognition ability in young males (Shahrestani et al., 2013; Van Ijzendoorn & Bakermans-Kranenburg, 2012). My results extend this finding to older males, and further show that oxytocin does not influence older females' emotion recognition ability. The group differences in basic emotion recognition are consistent with the notion that baseline social competence can modulate the effects of oxytocin. That is, changes in social functioning have been shown to occur after administration of oxytocin, but individual differences in social proficiency affect how oxytocin influences performance on tasks (Bartz et al., 2011; Olff et al., 2013). For instance, people with ASD or schizophrenia, who have more difficulty recognising emotions, show increases in performance after oxytocin administration (Averbeck, Bobin, Evans, & Shergill, 2012; Domes, Kumbier, Heinrichs, & Herpertz, 2014; Fischer-Shofty, Shamay-Tsoory, & Levkovitz, 2013b; Guastella et al., 2010). In contrast, oxytocin can impair recognition of emotions in adults who do not have difficulties with recognition (Cardoso et al., 2014), indicating that baseline level of ability determines whether oxytocin improves or impairs performance. In the first study, older males performed the worst on the emotion recognition task after taking placebo and were the only group to benefit from oxytocin administration.

There are a number of reasons why the effects of oxytocin might be moderated by baseline competence, which will be discussed in detail throughout this chapter. Oxytocin might affect functional connectivity in the brain, which could be reduced in those who are less socially competent. Indeed, reduced frontal-posterior functional

connectivity is found in people with ASD (Just, Keller, Malave, Kana, & Varma, 2012). Additionally, where differences in social competence are found between males and females, such as in the present research, endogenous levels of oxytocin might influence findings. Oxytocin levels are higher in females than in males (Carter, 2007). Accordingly, with saturated levels of oxytocin females may be unlikely to benefit from additional oxytocin, whereas males with lower levels of oxytocin would be more likely to benefit from oxytocin. Furthermore, differences in level and functioning of oxytocin depend on interactions with other hormones, such as oestrogen and testosterone, which also differ between males and females.

Participant age is another factor that has been shown in the present thesis to influence oxytocin effects, with older but not young males showing an effect after oxytocin administration, yet this factor has had little consideration in the literature (Huffmeijer et al., 2013). One study examined the effects of oxytocin administered over 10 days on older adults' wellbeing (Barraza et al., 2013). Participants administered oxytocin did not show decreases in physical functioning, fatigue, or dispositional gratitude that were seen in the placebo group over the time period (Barraza et al., 2013). Also, a genetic study has linked differences in the oxytocin receptor gene in both older and young adults to increased recruitment of the ACC when processing happy faces (Ebner et al., 2013). Notably, this increased recruitment of the ACC was more pronounced in older adults (Ebner et al., 2013). The current research extends these results to show that intranasal oxytocin can have a behavioral effect on emotion processing in older adults, particularly older males.

A gender difference in scanning of the face was found in older adults, with oxytocin increasing older males' visual scanning of the eyes, nose, and mouth as a proportion of scanning the total face, including cheeks, chin, and forehead. This

indicates that oxytocin increased their scanning of all areas of the face that might be important for the recognition of emotions, although this scanning result did not correlate with their increased recognition of emotions. Previous research has found that oxytocin increases scanning of the eye region of the face and this has been proposed as a mechanism for improved emotion recognition (Kemp & Guastella, 2011). However, this proposal is not supported by the current findings. Furthermore, other studies that have examined visual scanning of the face while participants recognise a range of emotions in faces (rather than assessing valence) have not found that oxytocin affects scanning of the eye region (Domes et al., 2010; Lischke et al., 2012a). It will be important in future research that scanning of a range of areas on emotional faces is examined, not solely scanning of the eyes.

Older females showed no change in visual scanning after oxytocin administration. Only one other study has examined eye tracking in females, and did not find an effect of oxytocin on scanning of the eye region during emotion recognition (Domes et al., 2010). However, this study only examined scanning of the eye region and had participants judge a number of different emotions in faces, so it was uncertain if the lack of results relates to participant gender or task methodology. In the current study, I examined other facial regions in addition to the eyes (the nose and mouth) yet still found no effect of oxytocin in either young or older females.

Oxytocin was also found to have an effect on the integration of gaze cues and emotional expression, which has not been studied before. Gaze cues and emotion combine to represent the motivational intent of the target face, with avoidance-related emotions (fear, sadness and disgust) deemed more intense with averted gaze and approach-related emotions (anger and happiness) deemed more intense with direct gaze (Adams & Kleck, 2005; Ruijten et al., 2013; Sander et al., 2007; Willis et al., 2011). In

the present study, young adults administered placebo integrated gaze direction cues with emotional expression to improve their recognition of emotions. They recognised sadness and anger more accurately with direct than averted gaze and recognised fear and disgust more accurately with averted than direct gaze. Except for the emotion of sadness (which is usually associated with averted gaze), this pattern of results fits with the previous literature and shows that gaze cues can facilitate the recognition of emotional expressions for young adults. Older adults in the placebo group did not integrate gaze and emotion cues, also consistent with previous studies (Slessor et al., 2010). Oxytocin administration impaired young adults' ability to integrate gaze cues with emotional expression. In contrast, for older adults oxytocin administration actually improved their integration of gaze direction cues for the expression of sadness.

The social-approach/withdrawal hypothesis, as described in the second chapter, states that oxytocin increases approach motivation and inhibits withdrawal motivation to influence the processing of social stimuli (Kemp & Guastella, 2011). This hypothesis could help to explain why older adults were able to recognise sadness better with direct gaze, if their motivation to approach others in distress was increased. However, it cannot explain why young adults' integration of cues was impaired after oxytocin administration. It is also unlikely that changes in the integration of gaze cues and emotional expression related to attention paid to the eye region of the face, because this was not shown in the eye tracking results. There was no interaction between age and face region or between gender and face region for visual scanning, indicating that older and young adults, as well as males and females, were looking to similar areas of the face stimuli. It seems more plausible that these results reflect changes in the processing of gaze or emotion information, although this change in processing might not be related to motivation.

A further test of the social-approach/withdrawal hypothesis comes from examining the effect of oxytocin on emotional experience. One's experience of emotion is thought to elicit approach and withdrawal tendencies more reliably than one's perception of emotion (Kemp & Guastella, 2011). On the basis that oxytocin influences motivational tendencies, it would be expected to have a larger effect on the experience of emotions than the perception of emotions. Older adults did appear to experience film-induced emotional changes during the study, especially for the relevant film clips of sadness and fear. However, oxytocin was found to have no influence on measures of emotional experience or responses. Motivational tendencies might have been enhanced if there was a more social aspect to the second task, rather than simply watching others interacting on film. Unlike other studies investigating oxytocin's effects on the experience of complex emotions like trust, participants in the current study had no interaction with other people. Oxytocin appears to change the processing of social cues in the environment and it is uncertain from the current studies if this change in processing is related to motivational tendencies or to some other mechanism.

The finding that oxytocin improved older males' emotion recognition ability suggests that changes in oxytocin (or more general neurotransmitter) functioning in older males' brains could be a partial mechanism for age-related emotion recognition difficulties. The neural decline theory, described in detail in the first chapter, posits that changes in structure and functioning in the ageing brain cause older adults to have difficulty recognising particular basic emotions (Ruffman et al., 2008). Structural changes in the areas of the brain associated with the recognition of particular emotions that older adults have more difficulty recognising (anger, sadness, and fear) gives support to this theory (Ruffman et al., 2008). Functional changes in neurotransmission are also hypothesised to play a role, with studies showing that altering optimal

neurotransmission in young adults changes the way that they recognise emotions (Harmer et al., 2003). Study 1 provides the first evidence that changes in neurotransmission can affect older adults' recognition of emotions. Oxytocin increases neurotransmission in the brain and improved basic emotion recognition in older males. Oxytocin did not influence the experience of emotions in older adults though, indicating that changes in neurotransmission might not be as important for the experience of emotions. Thus, the neural decline theory might provide a better explanation for changes in emotion recognition than changes in emotion experience with ageing.

It is unclear from the current study why neurotransmission changes after oxytocin administration might not have affected emotional experience. It is possible that the functional networks involved in emotion experience are different to those involved in recognition of emotions. At least one study has shown that functional connectivity between areas of the brain involved in the recognition and the experience of disgust are different (Jabbi, Bastiaansen, & Keysers, 2008). Another possibility is that changes in neurotransmission affected areas of the brain involved in decision-making. The emotion recognition task used in the current study involved a decision between the emotional expression labels given. Also, previous studies investigating the influence of oxytocin on trust in economic games have included a decision about financial investment (Baumgartner et al., 2008; Kosfeld et al., 2005). However, the emotion experience task used in the current study did not include a decision-making component. Participants watched the film clips passively and rated their subjective experience of emotion. During decision-making, particular areas of the brain, including the ACC and OFC, are functionally connected (Cohen, Heller, & Ranganath, 2005), and activity in these areas is affected by oxytocin (Petrovic et al., 2008; Singer et al., 2008).

The idea that changes in neurotransmission in older males after oxytocin administration contributed to their improved emotion recognition is supported by the model for endocrine regulation of human social-emotional behaviour, which provides a neural explanation for the effects of oxytocin (Bos et al., 2012). This neural explanation of the results is relevant because oxytocin has an effect on the brain and older adults' difficulties recognising emotions are likely linked to changes in the structure and function of the brain with age. However, only theoretical models can be discussed because the neurobiological mechanisms of oxytocin were not studied in the current research. The endocrine regulation model suggests that oxytocin works within a network of connected brain structures to modulate amygdala activity and shift neural output toward other brain regions. One of the ways in which oxytocin may have an effect is through a reduction in fear response and anxiety (Bethlehem, van Honk, Auyeung, & Baron-Cohen, 2013). The brain area mainly involved in producing a fear response is the amygdala. However, brain areas do not work alone and it is most likely that oxytocin has an effect on a range of interconnected brain areas, with the amygdala being a main component (Bethlehem et al., 2013). The amygdala shows connections with other regions of the brain important for emotion processing, including the thalamus, hypothalamus, septum, periaqueductal gray and the OFC, which has a modulating effect on the amygdala (Bos et al., 2012). The OFC is also connected to the anterior cingulate gyrus and superior temporal gyrus (Bos et al., 2012). Oxytocin increases functional connectivity between these regions and the amygdala (Riem et al., 2012; Sripada et al., 2013).

The idea that oxytocin may affect a network of interconnected brain areas is supported by the priming hypothesis (Bethlehem et al., 2013). Functional connectivity between areas of the network can be elicited through priming for oxytocin release

(Bethlehem et al., 2013). A signal, such as intranasal administration, can prime oxytocin release from the large dense-core vesicles that oxytocin is stored in within a cell. When oxytocin is released from these stores it causes a cascade that leads to more stores being primed for release, creating a loop (Bethlehem et al., 2013). This priming effect will initially occur at the areas of the brain that are sensitive to oxytocin, such as those described in the functional network above. This priming will help to temporarily change the functional neural connections between these areas (Bethlehem et al., 2013). Oxytocin administration may start this priming effect, changing the functional connectivity between brain areas to predispose the individual towards an affiliative response (Bethlehem et al., 2013). However, this response will also depend upon the stimulus presented, social context, and individual variation (Bethlehem et al., 2013).

In males, oxytocin reduces stress and fear by inhibiting the amygdala to increase proximity and bonding with others in the social environment and increase attention to social stimuli (Bos et al., 2012). In females, however, increases in amygdala activity are often found after oxytocin administration (Domes et al., 2010; Lischke et al., 2012b), indicating that changes in brain activity and connectivity might manifest differently in males and females. It is possible that this effect is due to differences in endogenous levels of oxytocin, because females have higher levels than males (Carter, 2007). Oxytocin also appears to influence responses to stress and challenge, and these responses are not the same in males and females. When under stress, females show a much larger desire to affiliate than males do, and oxytocin may lie at the heart of this affiliative process (Taylor et al., 2000). Males respond to threat with challenge behaviour, related to testosterone and the fight or flight response (Taylor et al., 2000). Oxytocin might enhance the affiliative response to threat through its effect on approach

motivation, which will have a different effect in females, who already react in this way, compared to males who usually react with a fight or flight response.

The endocrine regulation model explains that oxytocin works to increase functional connectivity in the brain (Bos et al., 2012). This relates to older adults because functional connectivity in the default network at rest and task-relevant functional connections are reduced compared to young adults (Grady, 2012; Grady, Grigg, & Ng, 2012). This reduction in functional connectivity might make it more difficult for older adults to allocate appropriate neural resources to the task at hand, affecting performance (Grady et al., 2012). For older males, oxytocin may increase functional connectivity between emotion processing areas in the brain, allowing them to better recognise emotions. Nevertheless, brain activity in older adults was not assessed in the current study so that future research using imaging techniques with older adults would help to provide more information on the effects of oxytocin on brain functioning and functional connectivity.

Oxytocin also interacts with a number of other hormones, and differences in brain activity or behaviour are not likely to be the result of changes in one hormone, but rather reflect changes in multiple systems and in the interactions between them. Oxytocin interacts with gonadal steroid hormones, oestrogen and testosterone, which decline with age and are related to socioemotional functioning (Ebner et al., 2013). In the emotion recognition task, oxytocin improved older males' performance to the level of older females' performance, ameliorating this gender difference. Interactions with gonadal hormones could help to explain the reduction in gender differences in recognition of emotions after oxytocin administration. Oestrogen and testosterone have both been implicated in the recognition of emotions. Different recognition ability is found for females at different stages of the menstrual cycle, when oestrogen is lower or

higher, and oestrogen levels have been related to the recognition of negative emotions such as anger, sadness and fear (Derntl, Kryspin-Exner, Fernbach, Moser, & Habel, 2008; Guapo et al., 2009). Also, testosterone has been implicated in the processing of threat cues, specifically anger and fear (Derntl et al., 2009; Little, 2013). Therefore, it is possible that differences in levels of gonadal hormones contribute to differences between males and females in the recognition of emotions. Furthermore, oestrogen up-regulates the production of oxytocin and its receptors, whereas testosterone promotes the production of vasopressin, which has been shown to have some opposite effects to oxytocin in terms of social behaviours (Macdonald, 2012). If the female advantage found in recognising emotions is due to having greater oxytocin levels through its interaction with oestrogen, then administering oxytocin to males might be expected to decrease this advantage because males can actually benefit from an increase in oxytocin levels.

No effects of oxytocin administration on emotion recognition ability were found for young adults or older females. Oxytocin, because it acts to increase neurotransmission, likely follows the Yerkes-Dodson law similar to neurotransmitters, whereby both too little and too much is detrimental to functioning (Honey & Bullmore, 2004). Therefore, if a person has near optimal oxytocin levels an increase in oxytocin will cause levels to be too high and functioning will not be enhanced and could be impaired. However, if a person's oxytocin levels are low then an increase in oxytocin will bring them to a more optimal level and they will show an increase in functioning. Higher or lower doses of oxytocin might be required to create optimal levels in different individuals. A dose-response relationship was not examined in this study; therefore, it is unclear whether young adults or older females might show improved emotion recognition with different (i.e., smaller) doses of oxytocin. Likewise, the majority of

the oxytocin literature has been conducted with an oxytocin dose similar to that used in the current study (20-24 IU: Weisman et al., 2012). Research examining different doses of oxytocin in different groups would be beneficial to determine whether the effects of oxytocin in females, or other groups, are dose-dependent.

Oxytocin did not fully account for age differences in emotion recognition, with older adults in the oxytocin group still significantly worse than younger adults, indicating that other structural and functional brain changes discussed in the neural decline theory might also be important in explaining emotion recognition difficulties in older adults. That is, declines in cell volumes, white matter and other neurotransmitters might also contribute to age-related emotion recognition declines (Ruffman et al., 2008). With regard to volume, grey matter predominantly forms cortical structures within the brain and its reduction is related to the shrinkage of large neurons (Ge et al., 2002), and in emotion processing areas of the brain, include the OFC, ACC and prefrontal cortices. White matter is involved in the transmission of information within and between these areas, by using myelin around neuron axons to speed the transmission of electrical signals (Ruffman et al., 2008). Grey matter begins to decline in a linear fashion from about age 20 (Taki et al., 2013), whereas white matter follows a non-linear pattern, with increases until around 45 years, then decreases (Ge et al., 2002). White matter loss occurs later in life, but at a higher rate than grey matter loss and so become more pronounced by age 70 (Ge et al., 2002). Grey matter reduction is particularly rapid in the frontal areas of the brain, which are central to emotion recognition (Raz et al., 2005; Taki et al., 2013). Interestingly, declines in grey matter volume in the medial prefrontal cortex are related to the decline in recognition of facial expressions of fear with age (Williams et al., 2006). This indicates that grey matter loss alone can explain aspects of declining emotion recognition. It is likely that these

structural declines, along with declines in white matter that affect the transmission of information to emotion processing areas of the brain, affect older adults' ability to recognise emotions.

The present study has examined oxytocin, which facilitates neurotransmission. However, there are a host of other neurotransmitters such as serotonin, noradrenaline, and dopamine that all decline with age (Kaasinen et al., 2000; Mukherjee et al., 2002) and have been shown in young adults to have an influence on the recognition of emotions (Blair & Curran, 1999; Zangara et al., 2002). Changes in the levels of these neurotransmitters can also be predicted to affect older adults' recognition of emotions. Overall, the recognition of an emotion appears to involve a complex neural circuit involving different brain areas and the functional connections between them. Altered ability of these areas to connect and communicate, as well as structural declines, influences emotion recognition and likely contributes to age-related changes in recognition ability.

There are some limitations to the current research that need to be mentioned. Participants' levels of oxytocin were not measured. Currently there is no simple and effective way to measure oxytocin because central levels of oxytocin are difficult to measure and it is unclear if peripheral and central levels are related (Weisman et al., 2012). However, there are some promising avenues for the peripheral measurement of oxytocin, such as in saliva (Weisman et al., 2012). It would be valuable to be able to measure oxytocin levels at baseline and after administration, and to determine differences in oxytocin levels between groups. It will be important for future studies to develop a comprehensive view of how different hormones change with ageing and how they interact with each other (Ebner et al., 2013). Future research needs to not only determine the influence of individual hormones on aspects of socioemotional

functioning in older adults, but also determine how changes in one hormone affects other hormones. Thus, it would also be useful to compare oxytocin levels with levels of other hormones, such as oestrogen and testosterone.

Some specific moderators of oxytocin effects were not measured in this study. A review on the moderating effects of oxytocin identified gender, genetic variation in oxytocin receptors and attachment history as important moderators of the way in which oxytocin will influence an individual (Macdonald, 2012). The current study is in agreement with Macdonald's review in showing that gender is an important moderator of oxytocin effects and should be included in future research. Further, it also demonstrates that age is another factor that is important in determining oxytocin effects that needs to be considered in future research. It will be important to clearly define moderators of oxytocin effects so that they can be systematically controlled in future research.

Finally, young adults were not included in the second study because of the focus on emotion processing in older adults and the findings from the first study that oxytocin had the largest effects in older males. Therefore, it is unknown whether oxytocin would have an effect of measures of emotional experience and response in young adults. Replication of this methodology with young adults, and replication of the novel findings in older adults would be beneficial to the field.

In conclusion, the current research shows that oxytocin influences emotion processing in older adults, specifically by improving emotion recognition in older males. No effects were found for oxytocin influencing the experience of emotion. This research provides clear evidence that changes in brain functioning contribute to age-related emotion recognition differences and supports the neural decline theory. However, it indicates that perhaps older adults' experience of emotion is not affected by

brain changes in the same way that their recognition of emotions is. The endocrine regulation model of oxytocin effects can explain these results in terms of an increase in functional connectivity after oxytocin administration, which could increase processing between emotion recognition areas of the brain in older males, leading to improved emotion recognition.

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Appendix

Means (*SD*s) of Film Clip CERT Measurements for Participant Groups for Each Film Clip

	Placebo		Oxytocin	
	Female	Male	Female	Male
Anger Film Clip				
AU1 Inner Brow Raise	0.63 (0.60)	0.78 (0.59)	0.65 (0.82)	0.93 (0.54)
AU2 Outer Brow Raise	0.11 (0.18)	0.29 (0.21)	0.15 (0.30)	0.33 (0.26)
AU4 Brow Lower	0.45 (0.23)	0.47 (0.16)	0.47 (0.22)	0.53 (0.17)
AU5 Eye Widen	0.58 (0.13)	0.63 (0.10)	0.56 (0.18)	0.60 (0.09)
AU9 Nose Wrinkle	0.30 (0.07)	0.28 (0.04)	0.28 (0.11)	0.29 (0.06)
AU10 Lip Raise	0.06 (0.10)	0.04 (0.05)	0.03 (0.09)	0.06 (0.08)
AU12 Lip Corner Pull	0.78 (0.20)	0.81 (0.63)	0.89 (0.67)	0.92 (0.57)
AU14 Dimpler	0.86 (0.50)	1.31 (0.38)	1.03 (0.53)	1.01 (0.34)
AU15 Lip Corner Depressor	2.24 (0.33)	2.47 (0.31)	2.13 (0.65)	2.37 (0.38)
AU17 Chin Raise	1.23 (0.57)	1.76 (0.42)	0.97 (0.50)	1.68 (0.48)
AU20 Lip stretch	1.64 (0.38)	1.63 (0.39)	1.50 (0.52)	1.63 (0.33)
AU6 Cheek Raise	0.11 (0.20)	0.10 (0.11)	0.14 (0.18)	0.09 (0.21)
AU7 Lids Tight	0.21 (0.11)	0.10 (0.08)	0.17 (0.11)	0.10 (0.07)
AU18 Lip Pucker	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)
AU23 Lip Tightener	1.14 (0.24)	1.36 (0.17)	1.04 (0.35)	1.26 (0.22)
AU24 Lip Presser	0.01 (0.06)	0.03 (0.06)	0.01 (0.05)	0.03 (0.06)
AU25 Lips Part	0.75 (0.34)	0.48 (0.27)	0.55 (0.30)	0.43 (0.20)
AU26 Jaw Drop	0.35 (0.23)	0.20 (0.17)	0.39 (0.25)	0.28 (0.24)
AU28 Lips Suck	0.15 (0.22)	0.10 (0.28)	0.14 (0.23)	0.10 (0.23)
AU45 Blink Eye Closure	0.20 (0.27)	0.39 (0.23)	0.15 (0.30)	0.34 (0.38)
Disgust Film Clip				
AU1 Inner Brow Raise	0.65 (0.61)	0.70 (0.52)	0.92 (0.86)	0.92 (0.64)
AU2 Outer Brow Raise	0.16 (0.17)	0.27 (0.18)	0.34 (0.33)	0.32 (0.29)
AU4 Brow Lower	0.48 (0.20)	0.48 (0.21)	0.58 (0.14)	0.53 (0.19)
AU5 Eye Widen	0.59 (0.11)	0.64 (0.07)	0.58 (0.11)	0.62 (0.08)
AU9 Nose Wrinkle	0.30 (0.07)	0.28 (0.04)	0.32 (0.08)	0.31 (0.07)
AU10 Lip Raise	0.06 (0.10)	0.05 (0.05)	0.02 (0.10)	0.06 (0.09)
AU12 Lip Corner Pull	0.89 (0.32)	0.69 (0.58)	0.89 (0.61)	0.87 (0.59)
AU14 Dimpler	0.79 (0.52)	1.23 (0.35)	1.10 (0.39)	1.04 (0.31)
AU15 Lip Corner Depressor	2.22 (0.18)	2.50 (0.30)	2.34 (0.29)	2.37 (0.34)

AU17 Chin Raise	1.20 (0.48)	1.78 (0.53)	1.11 (0.44)	1.65 (0.40)
AU20 Lip stretch	1.61 (0.37)	1.63 (0.40)	1.82 (0.27)	1.58 (0.28)
AU6 Cheek Raise	0.16 (0.20)	0.15 (0.10)	0.16 (0.17)	0.14 (0.18)
AU7 Lids Tight	0.23 (0.11)	0.12 (0.08)	0.20 (0.08)	0.13 (0.07)
AU18 Lip Pucker	0.01 (0.01)	0.01 (0.01)	0.02 (0.01)	0.01 (0.01)
AU23 Lip Tightener	1.11 (0.23)	1.34 (0.17)	1.17 (0.22)	1.24 (0.22)
AU24 Lip Presser	0.02 (0.06)	0.02 (0.05)	0.01 (0.04)	0.04 (0.05)
AU25 Lips Part	0.79 (0.33)	0.48 (0.24)	0.66 (0.26)	0.44 (0.23)
AU26 Jaw Drop	0.36 (0.28)	0.18 (0.20)	0.44 (0.31)	0.25 (0.30)
AU28 Lips Suck	0.17 (0.27)	0.14 (0.20)	0.18 (0.25)	0.08 (0.26)
AU45 Blink Eye Closure	0.22 (0.26)	0.44 (0.35)	0.21 (0.28)	0.35 (0.38)
Fear Film Clip				
AU1 Inner Brow Raise	0.66 (0.57)	0.83 (0.59)	0.79 (0.87)	0.97 (0.55)
AU2 Outer Brow Raise	0.18 (0.14)	0.30 (0.20)	0.32 (0.32)	0.35 (0.25)
AU4 Brow Lower	0.48 (0.19)	0.50 (0.18)	0.55 (0.14)	0.52 (0.21)
AU5 Eye Widen	0.58 (0.12)	0.62 (0.07)	0.60 (0.10)	0.61 (0.07)
AU9 Nose Wrinkle	0.29 (0.07)	0.29 (0.04)	0.31 (0.08)	0.29 (0.05)
AU10 Lip Raise	0.05 (0.11)	0.05 (0.07)	0.02 (0.10)	0.07 (0.08)
AU12 Lip Corner Pull	0.89 (0.29)	0.78 (0.48)	0.96 (0.63)	0.91 (0.52)
AU14 Dimpler	0.92 (0.44)	1.19 (0.38)	1.14 (0.37)	1.05 (0.39)
AU15 Lip Corner Depressor	2.21 (0.23)	2.48 (0.32)	2.30 (0.30)	2.44 (0.35)
AU17 Chin Raise	1.33 (0.55)	1.88 (0.40)	1.11 (0.46)	1.76 (0.47)
AU20 Lip stretch	1.64 (0.31)	1.61 (0.37)	1.71 (0.27)	1.66 (0.28)
AU6 Cheek Raise	0.09 (0.18)	0.11 (0.08)	0.15 (0.17)	0.11 (0.20)
AU7 Lids Tight	0.19 (0.10)	0.12 (0.08)	0.19 (0.10)	0.11 (0.08)
AU18 Lip Pucker	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)
AU23 Lip Tightener	1.10 (0.22)	1.39 (0.19)	1.14 (0.24)	1.29 (0.17)
AU24 Lip Presser	0.01 (0.05)	0.03 (0.04)	0.01 (0.05)	0.04 (0.06)
AU25 Lips Part	0.76 (0.30)	0.48 (0.20)	0.61 (0.26)	0.45 (0.21)
AU26 Jaw Drop	0.27 (0.31)	0.15 (0.26)	0.43 (0.24)	0.26 (0.23)
AU28 Lips Suck	0.15 (0.25)	0.15 (0.22)	0.19 (0.21)	0.08 (0.23)
AU45 Blink Eye Closure	0.21 (0.30)	0.39 (0.30)	0.25 (0.34)	0.33 (0.29)
Happiness Film Clip				
AU1 Inner Brow Raise	0.74 (0.59)	0.83 (0.52)	0.78 (0.83)	0.88 (0.59)

AU2 Outer Brow Raise	0.20 (0.20)	0.31 (0.17)	0.29 (0.30)	0.30 (0.27)
AU4 Brow Lower	0.43 (0.27)	0.46 (0.16)	0.49 (0.16)	0.48 (0.19)
AU5 Eye Widen	0.58 (0.13)	0.61 (0.10)	0.59 (0.08)	0.61 (0.08)
AU9 Nose Wrinkle	0.29 (0.06)	0.28 (0.04)	0.30 (0.08)	0.29 (0.05)
AU10 Lip Raise	0.04 (0.10)	0.05 (0.06)	0.04 (0.10)	0.05 (0.08)
AU12 Lip Corner Pull	0.59 (0.33)	0.72 (0.57)	0.70 (0.67)	0.77 (0.57)
AU14 Dimpler	0.84 (0.50)	1.20 (0.35)	1.16 (0.43)	1.04 (0.39)
AU15 Lip Corner Depressor	2.19 (0.25)	2.44 (0.28)	2.19 (0.32)	2.28 (0.36)
AU17 Chin Raise	1.22 (0.53)	1.72 (0.38)	0.95 (0.48)	1.49 (0.44)
AU20 Lip stretch	1.68 (0.36)	1.63 (0.38)	1.68 (0.29)	1.63 (0.33)
AU6 Cheek Raise	0.19 (0.17)	0.12 (0.11)	0.21 (0.22)	0.11 (0.19)
AU7 Lids Tight	0.21 (0.09)	0.12 (0.09)	0.18 (0.10)	0.12 (0.07)
AU18 Lip Pucker	0.01 (0.01)	0.01 (0.01)	0.02 (0.01)	0.01 (0.01)
AU23 Lip Tightener	1.04 (0.19)	1.40 (0.20)	1.12 (0.27)	1.23 (0.19)
AU24 Lip Presser	0.01 (0.05)	0.00 (0.05)	0.02 (0.04)	0.02 (0.04)
AU25 Lips Part	0.83 (0.38)	0.49 (0.24)	0.73 (0.24)	0.49 (0.20)
AU26 Jaw Drop	0.34 (0.21)	0.18 (0.24)	0.47 (0.26)	0.29 (0.26)
AU28 Lips Suck	0.10 (0.19)	0.14 (0.21)	0.17 (0.25)	0.10 (0.24)
AU45 Blink Eye Closure	0.16 (0.38)	0.51 (0.29)	0.17 (0.30)	0.28 (0.42)
Sadness Film Clip				
AU1 Inner Brow Raise	0.78 (0.50)	0.91 (0.56)	0.87 (0.86)	0.92 (0.60)
AU2 Outer Brow Raise	0.15 (0.18)	0.34 (0.19)	0.28 (0.38)	0.33 (0.29)
AU4 Brow Lower	0.42 (0.20)	0.47 (0.16)	0.53 (0.14)	0.52 (0.21)
AU5 Eye Widen	0.60 (0.14)	0.62 (0.08)	0.60 (0.09)	0.61 (0.08)
AU9 Nose Wrinkle	0.30 (0.07)	0.28 (0.03)	0.30 (0.09)	0.29 (0.05)
AU10 Lip Raise	0.04 (0.10)	0.06 (0.08)	0.02 (0.10)	0.05 (0.06)
AU12 Lip Corner Pull	0.75 (0.17)	0.80 (0.56)	0.97 (0.61)	0.87 (0.52)
AU14 Dimpler	0.89 (0.46)	1.17 (0.41)	1.13 (0.47)	1.03 (0.38)
AU15 Lip Corner Depressor	2.20 (0.24)	2.50 (0.32)	2.28 (0.36)	2.41 (0.38)
AU17 Chin Raise	1.03 (0.44)	1.87 (0.34)	1.10 (0.44)	1.73 (0.44)
AU20 Lip stretch	1.58 (0.34)	1.59 (0.34)	1.73 (0.34)	1.59 (0.33)
AU6 Cheek Raise	0.14 (0.18)	0.12 (0.12)	0.15 (0.17)	0.12 (0.19)
AU7 Lids Tight	0.21 (0.10)	0.11 (0.08)	0.17 (0.09)	0.12 (0.08)
AU18 Lip Pucker	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)

AU23 Lip Tightener	1.06 (0.14)	1.37 (0.15)	1.13 (0.25)	1.26 (0.16)
AU24 Lip Presser	0.03 (0.05)	0.02 (0.05)	0.01 (0.04)	0.03 (0.06)
AU25 Lips Part	0.71 (0.29)	0.41 (0.21)	0.59 (0.27)	0.46 (0.26)
AU26 Jaw Drop	0.36 (0.27)	0.15 (0.25)	0.37 (0.33)	0.32 (0.25)
AU28 Lips Suck	0.14 (0.22)	0.06 (0.22)	0.15 (0.20)	0.08 (0.22)
AU45 Blink Eye Closure	0.16 (0.25)	0.43 (0.27)	0.22 (0.35)	0.31 (0.37)