THE EFFECT OF THE SOCIAL REGULATION OF EMOTION ON EMOTIONAL MEMORY

BY

LUIS E. FLORES, JR.

DISSERTATION

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Doctoral Committee:

Professor Aaron S. Benjamin, Chair
Professor Howard Berenbaum, Director of Research
Professor R. Chris Fraley
Professor Paul E. Gold
Professor Wendy Heller
Associate Professor Donna L. Korol

ABSTRACT

This dissertation consists of two projects that examine the effect of the social regulation of emotion (in the form of handholding) on two types of emotional memory (i.e., emotional long-term memory and emotional working memory). Participants in both projects completed questionnaires regarding their desire for emotional closeness and attachment style. In the long-term memory project, participants viewed a series of negative, neutral, and positive images. Each participant held a stress ball for half of the slide show and held someone's hand for the other half. Participants returned one week later to complete a recognition task. The handholding condition reduced memory for negative but not positive images compared to the stress ball condition. Neither desired emotional closeness nor attachment style moderated the effect of the social regulation of emotion. The working memory project consisted of two similar studies, in which participants completed an emotional working memory task that measured the ability to remove irrelevant information from working memory. In Study 1, the emotional working memory task consisted only of negative images, and each participant did half of the task while holding someone's hand and half of the task while not holding someone's hand. In Study 2, the emotional working memory task consisted of both negative and neutral images, and each participant completed the entire task while either holding a stress ball or holding someone's hand. Overall, there appeared to be better ability to update negative contents of working memory in the handholding condition of each study than the control condition among people with high desired emotional closeness, but not among people with low desired emotional closeness. The present findings provide evidence that the social regulation of emotion can help weaken memory for negative information. In the case of working memory, this effect may only be present among those with high desired emotional closeness.

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I thank my parents for supporting and encouraging me my entire life. My family helped me persevere through the most difficult portions of my education by making me feel loved and supported even when I was far from home. I am grateful that I had such caring and supportive friends in graduate school who made it a second home for me. I especially thank Sima Finy, Eishita Manjrekar, Ida Sheila Salusky, Angela Walden, Alice Huang, and Lushima Flinyman.

TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

Emotional events (both positive and negative) are typically remembered better than neutral events (see Hamann, 2001, for a review). Having greater levels of arousal during these events has been demonstrated to play an important role in enhancing memory for these events (Hamann, 2001). Given that the emotional response of an individual to an event appears to play a big role in memory enhancement, emotion regulation may decrease the memory enhancement for negative events. One form of emotion regulation that may serve this function is the social regulation of emotion, which refers to interpersonal interactions that influence an individual's affect.

Emotional Memory

Although some have argued against memory enhancement for emotional events (Dougal & Rotello, 2007; Windmann & Kutas, 2001), emotional memory enhancement has been demonstrated in a variety of methodologies in both human and animal research. Emotional memory enhancement has been found consistently for emotional stimuli in free recall studies but inconsistently in recognition studies (Grider & Malmberg, 2008). A bias toward responding to emotional stimuli in recognition tasks has been posited to be an alternative explanation for the emotional memory enhancement in recognition studies (Dougal & Rotello, 2007; Leiphart, Rosenfeld, & Gabrieli, 1993; Windmann & Kutas, 2001). Receiver operating characteristic (ROC) analyses, however, are able to separately measure accuracy and bias differences between emotional and non-emotional stimuli in recognition studies, and have demonstrated an emotional memory enhancement (Grider & Malmberg, 2008). Grider and Malmberg (2008) suggest that the failure to distinguish differences in bias and accuracy may help explain the inconsistencies that have been found in the literature. Another source of controversy comes from studies conducted on flashbulb memories, which are vivid and highly detailed accounts for a highly emotional and consequential event (e.g., memory of hearing about September 11, 2011 terrorist attacks). These studies have found that although confidence for the accuracy of these vivid details is higher than for everyday memories, they are generally inaccurate and no more accurate than for everyday memories (Talarico & Rubin, 2003). It is worth noting that although these memories are not more accurate than everyday memories, they are quite strong and relatively fixed compared to everyday memories. Aside from the controversy evoked by response bias and flashbulb memory research, an emotional memory enhancement for episodic memory in humans has been found consistently with different stimuli, including emotional images, words, and scenarios (Phelps, 2006).

Arousal-related hormones and the amygdala appear to play important roles in enhancing the memory for emotional events (e.g., McGaugh, 2003; Gold & Van Buskirk, 1975; McEwen & Sapolsky, 1995). During an emotional event, arousal-related hormones (e.g., epinephrine and glucocorticoids) are released from the adrenal glands and influence brain areas that are considered to be storage sites (e.g., hippocampus, caudate) both directly and via the basolateral amygdala (McGaugh, 2003; Quirarte, Galvez, Roozendaal, & McGaugh, 1998). Naturally, this memory modulation pathway would not work for events that do not lead to the release of arousal-related hormones, such as neutral, low-arousal events. In other words, the memory modulation provided by arousal-related hormones and the amygdala demonstrates further evidence for emotional memory enhancement.

Emotion can also influence working memory, which is an executive function characterized as having a limited capacity to temporarily hold information for the purpose of performing a variety of other complex cognitive functions (Baddeley, 2003). One way that emotions influence working memory is by impairing working memory performance for neutral information when an individual is in a negative mood (Cheng & Holyoak, 1985; Spies et al., 1996; Mitchell & Phillips, 2007). An explanation for this impairment in working memory performance is that task-irrelevant intrusive thoughts and worries arise from the negative mood and cause a distraction (Eysenck & Calvo, 1992; Seibert & Ellis, 1991). The effect of emotional contents on working memory performance, however, has been mixed. Kensinger and Corkin (2003), for example, found that whereas working memory accuracy for emotional contents did not differ compared to neutral contents, speed was impaired for an *n*-back task using fearful faces but not negative words. Two other studies, on the other hand, have found the opposite effect, such that emotional contents improved working memory in terms of accuracy and speed (Lindström & Bohlin, 2011) and in terms of reducing proactive interference (i.e., interference from preceding trials; Levens & Phelps, 2008). Overall, emotion appears to hamper working memory performance if attention needs to be given to non-emotional details, but may improve working memory performance if attention needs to be given to the emotional details (Vuilleumier, 2005). Further evidence for this explanation can be found in research on the effect of emotion on attention. Impairment is demonstrated when attention to non-emotional details is more important; for example, impairment is found on the Emotional Stroop task (a task where participants need to report the color of a word) for negative words compared to neutral words (Williams, Mathews, & Macleod, 1996). In contrast, improvement is found when attention to emotional details is beneficial; for example, improved performance on the Attentional Blink paradigm (a paradigm that examines perception for a second target stimulus after a first target stimulus in a rapid serial visual presentation) is found for emotional words compared to neutral words (Anderson & Phelps, 2001).

The ability to hold information in working memory is an important component of working memory, but so is the ability to remove information that is no longer important. The purpose of temporarily holding information in working memory is to have it available for a task at hand; consequently, it is not necessary to maintain irrelevant information active in working memory (Hasher, Zacks, & May 1999). In addition, having difficulty in updating working memory can restrict the storage space available in working memory for other more relevant material. The attentional and memory enhancement associated with emotional information (Lindström & Bohlin, 2011; Vuilleumier, 2005) may make it more difficult to remove negative information from working memory compared to neutral contents. Thus, the emotional nature of information may impair working memory performance when focusing on the ability to deactivate memoranda.

Emotion Regulation

Emotion regulation refers to the process of influencing which emotions we have, when we have them, and how we experience and express them (Gross & Thompson, 2007). Effective emotion regulation tends to be composed of maintaining or increasing positive emotions and/or decreasing negative emotions. It is worth noting that effective emotion regulation may include increasing negative emotions and/or decreasing positive emotions if doing so would help accomplish a present goal (e.g., increasing anger to help with a confrontation; Tamir, Mitchell, & Gross, 2007). Maladaptive emotion regulation techniques tend to decrease positive emotions and/or increase or maintain negative emotions. Importantly, some conceptualizations describe emotion regulation techniques as lying on a continuum ranging from being automatic to being effortful (e.g., Gross & Thompson, 2007). In addition, forms of emotional regulation can be differentiated between being intrapersonal or interpersonal.

Interestingly, most of emotion regulation research focuses on intrapersonal strategies, such as cognitive reappraisal and emotional suppression (e.g., Aldao, Nolen-Hoeksema, & Schweizer, 2010; Gross & John, 2003; Ochsner, Bunge, Gross, & Gabrieli, 2002). However, there has recently been more exploration of interpersonal strategies of emotion regulation (e.g., Coan, Schaefer, & Davidson, 2006; Marroquín, 2011; Rimé, 2007; Shaver & Mikulincer, 2007). The social regulation of emotion is another term for interpersonal emotion regulation strategies and it refers to how others intentionally or unintentionally help individuals alter their affective response to stressors (Coan, 2008). Coan's (2008) social baseline model of emotion regulation proposes load sharing as an evolutionarily developed strategy of expending less energy and experiencing less negative emotion in a distressing situation when in the presence of another person. The presence of, and especially support from, another individual sends a message that an individual is not alone in facing the threat and can, therefore, rely on the other individual to share some of the burden of the threat. To demonstrate this process, Coan et al. (2006) had married women become threatened with the potential of being shocked under three conditions: (a) holding their husband's hand, (b) holding a male stranger's hand, and (c) not holding anyone's hand. Compared to the control condition, the married women self-reported lower levels of bodily arousal in each of the handholding conditions and lower levels of negative mood in the husband handholding condition. Similar effects were found in the activation of neural systems associated with emotional and behavioral threat responses. Thus, handholding, as a form of the social regulation of emotion, helped attenuate the emotional response to the threat and resulted in less energy expenditure, as measured by neural activation.

Emotional Closeness

Emotional closeness is an important aspect of interpersonal interactions and relationships. Flores and Berenbaum (2012) define emotional closeness as the degree to which individuals perceive others to have caring feelings for them and to be physically affectionate, verbally affectionate, and emotionally supportive. The focus on the reception, rather than delivery, of emotional closeness is based largely on interest in how the behaviors and perceived caring feelings of others may be a form of the social regulation of emotion. Emotional closeness may reinforce signals to the individual that they do not have to address stressors alone and, thus, stressors may be perceived as less threatening. In other words, emotional closeness may help regulate the distress that results from a stressor by providing an increase in perception of another person’s presence. One way that emotional closeness, including physical affection, may be associated with the alleviation of stress is through stress-related biochemical changes (e.g., increase in oxytocin and decrease in cortisol; Field, 2010).

Importantly, the degree to which a person responds to emotional closeness behaviors (e.g., handholding) is moderated by how much a person desires emotional closeness (Flores & Berenbaum, 2012; Flores & Berenbaum, 2014). Specifically, the reduction of facial expressivity, but not self-reported affective response, to negative images when holding someone’s hand compared to a control condition (no handholding) was larger among individuals with greater levels of desired emotional closeness. Thus, individual differences in desired emotional closeness may be important for understanding the impact of the social regulation of emotion on psychological and behavioral outcomes. Considering emotional closeness as a strategy to regulate emotions, one reason why desired emotional closeness may alter these outcomes is that the psychological impact of successfully using a given type of strategy for achieving a goal (e.g., using an approach or avoidance strategy) will often be moderated by an individual's desirability for utilizing the given type of strategy (Tamir & Diener, 2008).

A construct that is related to perceived emotional closeness, but which has received substantially more attention, is social support. Emotional closeness and social support have similarities, such as the inclusion of provision of emotional support by others. In fact, if one defines social support broadly enough (e.g., any interpersonal process that enhances well-being; Cohen, Gottlieb, & Underwood, 2000), then emotional closeness is technically one of many forms of social support.

In addition, our conceptualization of desired emotional closeness is related to several psychological constructs, including attachment (Bowlby, 1969/1982). Although attachment style is undoubtedly relevant to desired emotional closeness, it has a different focus that does not capture, or at least does not fully capture, desired emotional closeness. In fact, Flores and Berenbaum (2012) found that desired emotional closeness moderated the effectiveness of handholding as a form of the social regulation of emotion even when including attachment style in the same model. Further, despite being significantly correlated with desired emotional closeness, attachment style was not found to moderate the effectiveness of handholding (Flores & Berenbaum, 2012). Aside from empirical evidence, there are also some conceptual differences. For example, although a preference for emotional distance is considered to be an aspect of attachment avoidance, the discomfort and reluctance to trust and rely on an attachment figure are also central to attachment avoidance (Shaver & Mikulincer, 2007). Consequently, some individuals who have a low desire for emotional closeness may not have high levels of attachment avoidance if they are not uncomfortable when they do trust or rely on attachment figures. Thus, desired emotional closeness should be expected to be associated with, yet distinct from, attachment avoidance. Finally, most central to attachment anxiety are a strong preference for protection and an extreme worry about whether an attachment figure is available (Shaver & Mikulincer, 2007). Consequently, many individuals with a high desire for emotional closeness will not have high levels of attachment anxiety because they trust their attachment figures and do not worry about whether they will be available.

Social Regulation of Emotion and Memory

In addition to helping down-regulate negative emotions, the social regulation of emotion may also influence memory for emotional information. For instance, reducing the affective response to negative situations may reduce emotional memory enhancement. In fact, emotion regulation has been found to result in less activation of the amygdala while viewing negative images (Ochsner & Gross, 2005; Phillips, Ladouceur, & Drevets, 2008). Considering that the amygdala plays a role in emotional memory enhancement, it makes sense to expect emotion regulation to reduce this enhancement. Surprisingly, cognitive reappraisal (i.e., changing how one interprets a situation to change how one feels about it) has previously been found to either have no effect or to improve memory in a few studies (Dillon, Ritchey, Johnson, & LaBar, 2007; Erk, von Kalckreuth, & Walter, 2010; Kim & Hamann, 2012; Richards & Gross, 2000). One possibility for why this effective emotion regulation strategy leads to increased memory is that the act of changing how one interprets a situation involves elaboration, which tends to improve memory (Stark, Perfect, & Newstead, 2005). Expressive suppression, on the other hand, has been found to impair long-term memory (Dillon et al., 2007; Richards & Gross, 2000, 2006). Although both cognitive reappraisal and expressive suppression require cognitive resources, expressive suppression uses cognitive resources on efforts that do not engage with the stimulus. Thus, fewer cognitive resources are devoted to learning while engaging in expressive suppression. One key difference between the social regulation of emotion and the intrapersonal strategies of cognitive reappraisal and expressive suppression is that cognitive reappraisal and expressive suppression are consciously effortful. As previously described, the nature of the conscious efforts associated with these emotion regulation strategies appear to be important in determining if memory is enhanced or impaired when using them. Given that the social regulation of emotion does not require conscious effort, the direction in which memory will be affected will likely be based on other factors. One potential factor is that the social regulation of emotion reduces the perception of threat (Coan, 2008) without the conscious elaboration present in cognitive reappraisal. Subsequently, perceiving a negative stimulus as less threatening may reduce emotional arousal, which may decrease emotional memory enhancement. This effect may be seen for negative but not positive information since the social regulation of emotion down-regulates threat responses and not likely pleasant responses.

Overall, the ability to remove irrelevant negative information from working memory may benefit similarly from the social regulation of emotion as emotional long-term memory. However, there may be one important difference in how the two types of emotional memory are affected by the social regulation of emotion. The conservation of cognitive resources as a result of the social regulation of emotion may facilitate conducting the demanding task of updating contents of working memory. In contrast, having more cognitive resources available may not necessarily help in weakening the strength of long-term memories. Thus, investigating both the reduction of emotional long-term memory enhancement and the improvement in updating negative contents of working memory is helpful since they differ in how much they may benefit from the conservation of cognitive resources. In addition, no previous studies have examined the effect of any form of emotion regulation on updating negative contents of working memory.

Present Studies

This dissertation includes two related projects that investigated the effect of the social regulation of emotion on two types of memory. The emotional long-term memory project (Chapter 2) examined the effect of the social regulation of emotion on emotional long-term memory. I hypothesized that the social regulation of emotion, in the form of handholding, would reduce long-term memory for negative but not positive and neutral images (i.e., a condition × valence interaction). I further hypothesized that desired emotional closeness would moderate the relation between the social regulation of emotion and emotional memory, such that the weakening effect of the social regulation of emotion on negative emotional memory would be stronger or only present among those with high desired emotional closeness (i.e., a condition × valence × desired emotional closeness interaction).

The emotional working memory project (Chapter 3) consists of two studies and focused on the influence of the social regulation of emotion on the ability to update negative contents of working memory (i.e., the ability to remove irrelevant, negative information from working memory). I hypothesized that the social regulation of emotion, in the form of handholding, would improve the ability to update negative but not neutral contents of working memory (i.e., a condition × valence interaction). I further hypothesized that desired emotional closeness would moderate the relation between the social regulation of emotion and emotional working memory, such that the effect of the social regulation of emotion on updating negative contents from working memory would be stronger or only present among those with high desired emotional closeness (i.e., a condition × valence × desired emotional closeness interaction).

CHAPTER 2

EMOTIONAL LONG-TERM MEMORY

Emotional events (both positive and negative) are typically remembered better than neutral events (see Hamann, 2001, for a review). Having greater levels of arousal during these events has been demonstrated to play an important role in enhancing memory for these events (Hamann, 2001). Given that the emotional response of an individual to an event appears to play a big role in memory enhancement, emotion regulation may decrease the memory enhancement for negative events. One form of emotion regulation is the social regulation of emotion, which refers to interpersonal interactions that influence an individual's affect. The social regulation of emotion may help reduce the negative emotional response to the event by signaling the simultaneous presence of social support and physical proximity.

Emotional Memory

Overall, an emotional memory enhancement for episodic memory has been found consistently with different stimuli, including emotional images, words, and scenarios (Phelps, 2006). Evolutionarily, it is adaptive to remember emotionally arousing events since they can contain useful information for survival and/or reproductive success (Hamann, 2001). A biological explanation for this memory enhancement is that during an emotional event, arousal-related hormones (e.g., epinephrine and glucocorticoids) are released from the adrenal glands and influence brain areas that are considered to be storage sites (e.g., hippocampus, caudate) both directly and via the basolateral amygdala (McGaugh, 2003; Quirarte, Galvez, Roozendaal, & McGaugh, 1998).

An issue with emotional memory research is that emotional memory enhancement has been found consistently for emotional stimuli in free recall studies but inconsistently in recognition studies (Grider & Malmberg, 2008). A bias towards responding to emotional stimuli in recognition tasks has been posited to be an alternative explanation for the emotional memory enhancement in recognition studies (Dougal & Rotello, 2007; Leiphart, Rosenfeld, & Gabrieli, 1993; Windmann & Kutas, 2001). Receiver operating characteristic (ROC) analyses, however, are able to separately measure accuracy and bias differences between emotional and non-emotional stimuli in recognition studies, and have demonstrated an emotional memory enhancement (Grider & Malmberg, 2008). Grider and Malmberg (2008) suggest that the failure to distinguish differences in bias and accuracy may help explain the inconsistencies that have been found in the literature.

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Importantly, the degree to which a person responds to emotional closeness behaviors (e.g., handholding) is moderated by how much a person desires emotional closeness (Flores & Berenbaum, 2012; Flores & Berenbaum, 2014). For example, Flores and Berenbaum (2012) found that the reduction of facial expressivity, but not self-reported affective response, to negative images when holding someone's hand compared to a control condition (no handholding) was larger among individuals with greater levels of desired emotional closeness. Thus, individual differences in desired emotional closeness may be important for understanding the impact of the social regulation of emotion on psychological and behavioral outcomes. Considering the social regulation of emotion as a strategy to regulate emotions, one reason why desired emotional closeness may alter these outcomes is that the psychological impact of successfully using a given type of strategy for achieving a goal (e.g., using an approach or avoidance strategy) will often be moderated by an individual's desirability for utilizing the given type of strategy (Tamir & Diener, 2008).

Our conceptualization of desired emotional closeness is related to several psychological constructs, including attachment (Bowlby, 1969/1982). Although attachment style is undoubtedly relevant to desired emotional closeness, it has a different focus that does not capture, or at least does not fully capture, desired emotional closeness. In fact, Flores and Berenbaum (2012) found that desired emotional closeness moderated the effectiveness of handholding as a form of the social regulation of emotion even when including attachment style in the same model. Further, despite being significantly correlated with desired emotional closeness, attachment avoidance was not found to moderate the effectiveness of handholding (Flores & Berenbaum, 2012).

Social Regulation of Emotion and Memory

In addition to helping down-regulate negative emotions, the social regulation of emotion may also influence memory for emotional information. For instance, reducing the affective response to negative situations may reduce emotional memory enhancement. In fact, emotion regulation has been found to result in less activation of the amygdala while viewing negative images (Ochsner & Gross, 2005; Phillips, Ladouceur, & Drevets, 2008). Considering that the amygdala plays a role in emotional memory enhancement, it makes sense to expect emotion regulation to reduce this enhancement. Surprisingly, cognitive reappraisal (i.e., changing how one interprets a situation to change how one feels about it) has previously been found to either have no effect or to improve memory in a few studies (Dillon, Ritchey, Johnson, & LaBar, 2007; Richards & Gross, 2000; Erk, von Kalckreuth, & Walter, 2010; Kim & Hamann, 2012). One possibility for why this effective emotion regulation strategy leads to increased memory is that the act of changing how one interprets a situation involves elaboration, which tends to improve memory (Stark, Perfect, & Newstead, 2005). Expressive suppression, on the other hand, has been found to impair long-term memory (Dillon et al., 2007; Richards & Gross, 2000, 2006). Although both cognitive reappraisal and expressive suppression require cognitive resources, expressive suppression uses cognitive resources on efforts that do not engage with the stimulus. Thus, fewer cognitive resources may be devoted to learning while engaging in expressive suppression.

One key difference between the social regulation of emotion and the intrapersonal strategies of cognitive reappraisal and expressive suppression is that cognitive reappraisal and expressive suppression are consciously effortful. As previously described, the nature of the conscious efforts associated with these emotion regulation strategies appear to be important in determining if memory is enhanced or impaired when using them. Given that the social regulation of emotion does not require conscious effort, the direction in which memory will be affected will likely be based on other factors. One potential factor is that the social regulation of emotion reduces the perception of threat (Coan, 2008) without the conscious elaboration present in cognitive reappraisal. Subsequently, perceiving a negative stimulus as less threatening may reduce emotional arousal, which may decrease emotional memory enhancement. This effect may be seen for negative but not positive information since the social regulation of emotion down-regulates threat responses and not likely pleasant responses. It is worth noting, however, that the down-regulation of pleasant responses would also likely decrease emotional memory enhancement.

I hypothesized that the social regulation of emotion, in the form of handholding, would reduce the memory enhancement for negative images but not neutral and positive images. I further hypothesized that desired emotional closeness would moderate this relation, such that emotional memory enhancement would only be reduced among those with high desired emotional closeness. I also explored whether individuals with more secure attachment styles benefit more, to ensure that the potential role of desired emotional closeness is not due to its relation to attachment style.

Method

Participants were 219 undergraduate students. They were 58.3% female and had an average age of 19.2 (SD = 1.5). Forty-four percent self-identified as Asian, 34% as White, 11% as Latino, 8% as Black, and 3% as other or multiracial. Participants received credit for a research participation requirement or extra credit opportunity for a psychology course.

The study was composed of two sessions. In the first session, participants completed a packet of questionnaires and then completed the first part of the long-term memory task (i.e., the training portion). The second session occurred one-week later at the same time (93% of the participants returned for the second session). In the second session, participants completed a different packet of questionnaires and then completed the second part of the long-term memory task (i.e., the testing portion).

To determine if at least 200 participants would be an adequate sample size for the hypothesized two-way and three-way interactions, I conducted a simulation that estimated power for a linear regression model. I used standardized beta weights of .2 and 200 simulation trials. I found that 200 participants would provide at least 80% power to detect the effects of that size using two-tailed tests.

Measures

Desired Emotional Closeness. The 15-item self-report Desired Emotional Closeness Questionnaire (D-ECQ) was used to measure desired emotional closeness (Flores & Berenbaum, 2012). Items were selected from measures of related constructs that targeted feelings of emotional closeness that others have for the respondent, and behaviors that others direct towards the respondent that promote emotional closeness. Further items were written to fully capture the construct. In summary, items were written by the authors (4 items) or chosen, and modified if necessary, from the International Personality Item Pool (IPIP; Goldberg et al., 2006; 3 items), the COPE Inventory (Carver, Scheier, & Weintraub, 1989; 2 items), Affection Communication Index (ACI; Floyd & Morman, 1998; 1 item), the Trait Affection Scale (TAS; Floyd, 2002; 4 items) and the Interpersonal Support Evaluation List (ISEL; Cohen & Hoberman, 1983). For each item in the D-ECQ, participants rated "how true [they] would like each behavior, feeling, or circumstance to be, regardless of its feasibility" using a 6-point rating scale from 1 (*Definitely not true*) to 6 (*Definitely true*). The internal consistency was acceptable (see Table 1).

Attachment style. The 36-item Experiences with Close Relationships-Revised scale (ECR-R; Fraley, Waller, & Brennan, 2000) was used to measure attachment style; participants were asked to indicate how much they agree or disagree with items based on their emotionally intimate relationships, including those with romantic partners, close friends, and/or family members. The ECR-R measures attachment style through the dimensional subscales of attachment avoidance (e.g., "It's easy for me to be affectionate with close others") and attachment anxiety (e.g., "I often worry that close others don't really love me"). Each item was scored on a 7-point scale from 1 (*Strongly Disagree)* to 7 (*Strongly Agree*). Internal consistencies were good (see Table 1).

Emotional Long-Term Memory. Long-term memory for negative, positive, and neutral images was measured using an emotional long-term memory task. The long-term memory task was composed of two parts. The first part was the training portion. Each participant completed the training portion of the emotional memory task under two different conditions. During the control condition, the participant completed the task while holding a stress ball. The stress ball was used to help reduce differences between the control and handholding conditions (for example, both the hand hold and the stress ball provide something for the participant to squeeze when distressed). In the handholding condition, the participant held the hand of a female research assistant who was not visible to the participant. During each condition, the emotional memory task was composed of 6 blocks. Two blocks consisted of neutral images, two blocks consisted of positive images, and two blocks consisted of negative images. The order of these blocks was randomized. Each block consisted of 10 images, which were each presented for 3000 ms preceded by an interstimulus interval of 1000 ms. Therefore, each block had a total duration of 40 seconds. Participants rated the valence and arousal of their emotions, using the Self-Assessment Mannequin (SAM; Bradley & Lang, 1994), after each block. After the training portion, the participant answered a brief questionnaire about their experience holding a stress ball in the control condition and someone's hand in the handholding condition. The testing portion occurred during the second session of the study. In the testing portion of the emotional memory task, the participant viewed an image and determined whether the image appeared in the training portion, on a scale of 1-4 (e.g., 1 = very confident image was shown; 2 = less confident image was shown; 3 = less confident image was *not* shown; and 4 = very confident image was *not* shown). Each image may have appeared in the training portion or may have been a new image. All 120 images from the training portion were presented and 120 additional new images were presented (whether an image was assigned to be "trained" or "new" was counterbalanced across participants). The images were chosen from the International Affective Picture System (IAPS; Lang et al., 2008). Images were chosen by attempting to have similar levels of arousal and "absolute values" of valence for positive and negative images (i.e., positive images were just as pleasant as negative images were unpleasant). Negative images were low in valence (i.e., highly unpleasant; $M = 2.53$, $SD = 0.4$) and high in arousal ($M = 5.39$, $SD = 0.8$). Positive images are high in valence (i.e., highly pleasant; $M = 7.44$, $SD = 0.7$) and arousal ($M = 5.29$, $SD = 0.9$). When reverse-scoring the valence of negative images (a low score in valence means unpleasant and a high score means pleasant), there is no significant difference in valence ($t(158) = .58$, $p = .57$) or arousal ($t(158) = 0.79$, $p = .43$) between the positive and negative images. Neutral images were medium in valence (i.e., neither pleasant nor unpleasant; $M = 5.13$, $SD = 0.4$) and low in arousal ($M = 3.65$, $SD = 0.7$).

Affective Measurements. Subjective experience of the valence and arousal of each participant's emotions was measured using the SAM at the end of each block of pictures (as mentioned above). Throughout the task, the participants were also videotaped from behind a discreet one-way mirror. For each participant, five undergraduate research assistants, who were unaware of the questionnaire scores of the participants or the condition, made a rating on the level of both positive and negative facial expressivity during each block. Ratings were made on a 7-point scale from 0 (*absence of facial expressivity*) to 6 (*extremely facially expressive*). The five facial coders' scores were averaged. A similar method for coding facial expressivity has previously been used effectively (Flores & Berenbaum, 2012; Berenbaum & Williams, 1995). The research assistants coded a practice tape together at a lab meeting each week to help prevent rater drift. The facial coding was completed over the course of two semesters by two groups of five facial coders. The first group of facial coders rated 123 participants, and the interrater reliability of the ratings, measured using the intraclass correlation with coders treated as random effects and the mean of the coders used as the unit of reliability, was .94 for negative facial expressivity and .95 for positive facial expressivity. The second group of facial coders rated 71 participants and the intraclass correlation for their ratings was .91 for negative facial expressivity and .92 for positive facial expressivity. To ensure that the two groups of facial coders were reliable, I had the second group code 12 participants that the first group had already coded. I averaged the scores of the coders for each group to calculate intraclass correlations between the two groups. The intraclass correlation was .96 for negative facial expressivity and .95 for positive facial expressivity.

Comfort and Distraction. Participants' perceived levels of comfort and distraction while holding someone's hand or a stress ball was measured at the end of the training session with the following four questions: (1) "How comfortable did it feel to hold the stress ball during the task?"; (2) "How distracting did it feel to hold the stress ball during the task?"; (3) "How comfortable did it feel to hold the person's hand during the task?"; and (4) "How distracting did it feel to hold the person's hand during the task?". Participants rated these questions on a 5-point scale (1 = *Very uncomfortable* or *Not at all distracting*; 5 = *Very comfortable* or *Very distracting*).

Results

To help distinguish memory accuracy from response bias (Grider & Malmberg, 2008), ROC analyses based on signal detection theory was used. Participants' ability to discriminate trained versus new pictures was measured by the distance-based metric d_a (Green & Swets, 1966; Benajmin & Diaz, 2008; Matzen & Benjamin, 2009). The average and range of memory accuracy scores (d_a) for images of each valence and condition are reported in Table 2. Original confidence ratings were reverse-scored to produce positive memory accuracy scores. The average and range of the affective measurements for blocks of each valence and condition are also reported in Table 2.

I used multilevel modeling for our analyses since our data included both within-participant (Level 1) and between-participant (Level 2) variables. Multilevel modeling does not assume that data points are independent and can handle missing data points (Snijder & Bosker, 1999). For each of the analyses below, I used the MIXED procedure of the SAS 9.3 software. I report parameter estimates with standard errors. I included random intercepts in each model and used unstructured covariance structures. Condition is dummy-coded in each model (0 = stress ball condition; 1 = handholding condition).

Checking Emotion Elicitation Effectiveness

I first checked the effectiveness of the training session at eliciting emotion. I conducted multilevel models, which accounted for the data being nested within participants, with each of the affective measurements as the outcome variables and valence (neutral valence as the reference group; valence is dummy-coded as 0 = neutral, 1 = negative or positive) as the dependent variable[1]. Below is a representative model[2]:

Level 1:

$$\text{Affective Measurement}_{ij} = \beta_{0j} + \beta_{1j}(\text{Valence: Negative vs. Neutral})_{ij} + \beta_{2j}(\text{Valence: Positive vs. Neutral})_{ij} + r_{ij}$$

Level 2:

$$\beta_{0j} = \gamma_{00} + U_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20}$$

As expected, the negative segments elicited more highly negative self-report mood valence (γ_{10} = -2.17, SE = 0.06, $t(2407) = -38.86$, $p < .0001$), higher levels of self-report arousal (γ_{10} = 0.91, SE = 0.07, $t(2407) = 13.05$, $p < .0001$), higher levels of negative facial expressivity (γ_{10} = 0.47, SE = 0.03, $t(2061) = 13.76$, $p < .0001$), and lower levels of positive facial expressivity (γ_{10} = -0.07, SE = 0.03, $t(2062) = -2.40$, $p = .0166$) than did neutral segments. Also, positive segments elicited more highly positive self-report mood valence (γ_{20} = 1.44, SE = 0.06, $t(2407) = 25.79$, $p < .0001$), higher levels of self-report arousal (γ_{20} = 0.94, SE = 0.07, $t(2407)$ = 13.46, $p < .0001$), higher levels of positive facial expressivity (γ_{20} = 0.26, SE = 0.03, $t(2062)$ =

9.43, $p < .0001$), and lower levels of negative facial expressivity ($\gamma_{20} = -0.16$, SE = 0.03, $t(2061) = -4.78$, $p < .0001$) than neutral segments.

I then conducted the same analyses with negative valence as the reference group (valence is dummy-coded as 0 = negative, 1 = neutral or positive) to compare positive and negative valence. As expected positive segments elicited more highly positive self-report mood valence ($\gamma_{20} = 3.62$, SE = 0.06, $t(2407) = 64.64$, $p < .0001$), higher levels of positive facial expressivity ($\gamma_{20} = 0.33$, SE = 0.03, $t(2063) = 11.82$, $p < .0001$), and lower levels of negative facial expressivity ($\gamma_{20} = -0.63$, SE = 0.03, $t(2062) = -18.53$, $p < .0001$) than did negative segments. Importantly, there was no significant effect of positive versus negative valence on self-report arousal ($\gamma_{20} = 0.03$, SE = 0.07, $t(2407) = 0.42$, $p = .6744$). Thus, segments with positive and negative pictures were similarly effective at eliciting self-report arousal.

Checking Emotion Regulation Effectiveness

To check whether handholding was effectively helping participants regulate their emotions during the training session, I examined whether handholding changed the association between image valence and the affective measurements (i.e., a condition × valence interaction). I conducted multilevel models with each of the affective measurements as the outcome variable and with the following predictor variables: condition, valence, and condition × valence. I first used neutral valence as the reference group (valence was dummy-coded as 0 = neutral, 1 = negative or positive) and then conducted the same model with negative valence as the reference group (valence was dummy-coded as 0 = negative, 1 = neutral or positive). A representative model can be seen below:

Level 1:

$$\text{Affective Measurement}_{ij} = \beta_{0j} + \beta_{1j}(\text{Condition})_{ij} + \beta_{2j}(\text{Valence: Negative vs. Neutral})_{ij} + \beta_{3j}(\text{Valence: Positive vs. Neutral})_{ij} + \beta_{4j}(\text{Condition} \times \text{Valence: Negative vs. Neutral})_{ij} + \beta_{5j}(\text{Condition} \times \text{Valence: Positive vs. Neutral})_{ij} + r_{ij}$$

Level 2:

$\beta_{0j} = \gamma_{00} + U_{0j}$

$\beta_{1j} = \gamma_{10}$

$\beta_{2j} = \gamma_{20}$

$\beta_{3j} = \gamma_{30}$

$\beta_{4j} = \gamma_{40}$

$\beta_{5j} = \gamma_{50}$

There were significant condition × valence interactions (negative vs. neutral: $\gamma_{40} = 0.23$, SE = 0.07, $t(2061) = 3.38$, $p = .0007$; positive vs. negative: $\gamma_{50} = -0.15$, SE = 0.07, $t(2062) = -2.27$, $p = .0232$) with negative facial expressivity as the outcome variable, such that there were higher levels of negative facial expressivity in the handholding condition compared to the control condition among negative segments and the opposite pattern occurred in the neutral and positive segments. The valence × condition interactions (positive vs. neutral: $\gamma_{50} = -0.12$, SE = 0.06, $t(2062) = -2.09$, $p = .0370$; positive vs. negative: $\gamma_{50} = -0.12$, SE = 0.06, $t(2063) = -2.23$, $p = .0258$) were also significant with positive facial expressivity as the outcome variable, such that there were lower levels of positive facial expressivity in the handholding condition compared to the control condition among positive but not negative and neutral segments. Neither of these interactions, however, provided evidence for handholding effectively regulating emotion during the task. No other condition × valence interactions were found to be significant, including when using self-report valence (negative vs. neutral: γ_{40} = -0.11, SE = 0.11, $t(2407) = -1.00$, $p = .3152$; positive vs. neutral: γ_{50} = -0.14, SE = 0.11, $t(2407) = -1.25$, $p = .2115$; positive vs. negative: γ_{50} = -0.03, SE = 0.11, $t(2407) = -0.25$, $p = .8062$) or self-report arousal as outcome variables (negative vs. neutral: γ_{40} = 0.18, SE = 0.14, $t(2407) = 1.29$, $p = .1968$; positive vs. neutral: γ_{50} = 0.10, SE = 0.14, $t(2407) = 0.73$, $p = .4646$; positive vs. negative: γ_{50} = -0.08, SE = 0.14, $t(2407) = -0.56$, $p = .5760$).

Association between Emotion and Memory Accuracy

Our next goal was to examine whether the emotion elicited by the training session was associated with memory accuracy during the testing session. I conducted multilevel models with memory accuracy as the outcome variable and each of the affective variables as the predictor variable. For these models, means of the affective measurements for the two segments that were of the same valence and condition were used since there was only one memory accuracy score for the two segments. Random slopes for the predictor variables were included in these models. Below is a representative model:

Level 1:

$$\text{Memory Accuracy}_{ij} = \beta_{0j} + \beta_{1j}(\text{Affective Measurement})_{ij} + r_{ij}$$

Level 2:

$$\beta_{0j} = \gamma_{00} + U_{0j}$$

$$\beta_{1j} = \gamma_{10} + U_{1j}$$

As expected, memory accuracy was negatively associated with subjective mood valence and positively associated with subjective arousal and negative facial expressivity (see Table 3). Memory accuracy was not significantly associated, however, with positive facial expressivity. These associations demonstrate that memory accuracy was generally related to the participants' emotional experience during the training session. I then continued to conduct further multilevel models to examine the associations among the different affective measurements. For each analysis demonstrated in Table 3, the outcome variable is noted at the beginning of the row and the predictor variable is noted at the top of the column. Positive and negative facial expressivity were negatively associated with each other and significantly associated with self-report mood valence in their respective directions. Self-report arousal was not significantly associated with negative facial expressivity and its positive association with positive facial expressivity fell shy of statistical significance.

The Effect of the Social Regulation of Emotion on Emotional Long-Term Memory

I conducted a two-level multilevel model with a random intercept. Desired emotional closeness was standardized. Neutral valence was used as the reference group (valence was dummy-coded as 0 = neutral, 1 = negative or positive). The model can be seen below:

Level 1:

$$\text{Memory Accuracy}_{ij} = \beta_{0j} + \beta_{1j}(\text{Condition})_{ij} + \beta_{2j}(\text{Valence: Negative vs. Neutral})_{ij} + \beta_{3j}(\text{Valence: Positive vs. Neutral})_{ij} + \beta_{4j}(\text{Condition} \times \text{Valence: Negative vs. Neutral})_{ij} + \beta_{5j}(\text{Condition} \times \text{Valence: Positive vs. Neutral})_{ij} + r_{ij}$$

Level 2:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Desired Emotional Closeness})_j + U_{0j}$$

$\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{Desired Emotional Closeness})_j$

$\beta_{2j} = \gamma_{20} + \gamma_{21}(\text{Desired Emotional Closeness})_j$

$\beta_{3j} = \gamma_{30} + \gamma_{31}(\text{Desired Emotional Closeness})_j$

$\beta_{4j} = \gamma_{40} + \gamma_{41}(\text{Desired Emotional Closeness})_j$

$\beta_{5j} = \gamma_{50} + \gamma_{51}(\text{Desired Emotional Closeness})_j$

As can be seen in Table 4, there was a main effect of valence, such that negative but not positive pictures were remembered better than neutral pictures. There was also a main effect of condition, such that pictures learned during the handholding condition were remembered less well. Contrary to part of our primary hypotheses, there was not a significant condition × valence interaction or a significant desired emotional closeness × condition × valence interaction.

I then conducted a similar multilevel model with negative valence as the reference group (valence was dummy-coded as 0 = negative, 1 = neutral or positive) to compare differences in memory accuracy between positive and negative pictures. There was a main effect of valence, such that negative pictures were remembered better than both neutral and positive pictures (see Table 4). Aligned with part of our primary hypotheses, there was a significant condition × valence interaction. I performed follow-up paired-samples t-tests to better understand the nature of this interaction. The negative ($t(198) = -4.16$, $p < .0001$) but not positive ($t(198) = -0.93$, $p = .3545$) pictures were remembered significantly less accurately when they were learned during the handholding condition than when they were learned during the control condition (see Figure 1). There was not a significant desired emotional closeness × condition × valence interaction.

Accounting for Attachment Style

I conducted the same two sets of multilevel models reported above with attachment avoidance and attachment anxiety as potential between-participant moderators in replacement of desired emotional closeness. Correlations between these between-participant variables are displayed in Table 5. Not surprisingly, attachment avoidance was positively correlated with attachment anxiety and negatively correlated with desired emotional closeness. Attachment anxiety and attachment avoidance were standardized in these models. Below is the model with neutral valence as the reference group (valence was dummy-coded as 0 = neutral, 1 = negative or positive):

Level 1:

$$\text{Memory Accuracy}_{ij} = \beta_{0j} + \beta_{1j}(\text{Condition})_{ij} + \beta_{2j}(\text{Valence: Negative vs. Neutral})_{ij} + \beta_{3j}(\text{Valence: Positive vs. Neutral})_{ij} + \beta_{4j}(\text{Condition} \times \text{Valence: Negative vs. Neutral})_{ij} + \beta_{5j}(\text{Condition} \times \text{Valence: Positive vs. Neutral})_{ij} + r_{ij}$$

Level 2:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Attachment Anxiety})_j + \gamma_{02}(\text{Attachment Avoidance})_j + U_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{Attachment Anxiety})_j + \gamma_{12}(\text{Attachment Avoidance})_j$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}(\text{Attachment Anxiety})_j + \gamma_{22}(\text{Attachment Avoidance})_j$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31}(\text{Attachment Anxiety})_j + \gamma_{32}(\text{Attachment Avoidance})_j$$

$$\beta_{4j} = \gamma_{40} + \gamma_{41}(\text{Attachment Anxiety})_j + \gamma_{42}(\text{Attachment Avoidance})_j$$

$$\beta_{5j} = \gamma_{50} + \gamma_{51}(\text{Attachment Anxiety})_j + \gamma_{52}(\text{Attachment Avoidance})_j$$

As can be seen in Table 5, there were not any significant attachment style × condition × valence interactions. For the model with negative valence as the reference group (valence was dummy-coded as 0 = negative, 1 = neutral or positive), there were two significant two-way interactions that are not directly relevant to our hypotheses. One was a significant attachment avoidance × condition interaction, such that there was less memory accuracy in the handholding condition compared to the control condition at high but not low levels of attachment avoidance. The other was a significant attachment anxiety × condition interaction, such that there was a greater reduction in memory accuracy in the handholding condition compared to the control condition at low but not high levels of attachment anxiety. Neither of these significant interactions is present when neutral valence is used as the reference group, suggesting that these are not robust findings.

The Effect of Comfort and Distraction on Emotional Memory

I investigated the roles of self-report comfort and distraction while holding someone's hand or a stress ball to ensure that the effect of handholding in the main analysis was not an artifact of being distracted by holding someone's hand. This was a potential concern since higher levels of distraction were reported in the handholding condition compared to the control condition (see Table 2; $t(209) = 10.96$, $p < .0001$).

I conducted multilevel models with memory accuracy and the affective measurements as the outcome variables and the level of comfort and distraction participants felt while holding a stress ball or a person's hand as the predictor variables (see Table 3). Below is a representative model:

Level 1:

$$(\text{Memory Accuracy or Affective Measurement})_{ij} = \beta_{0j} + \beta_{1j}(\text{Comfort or Distraction})_{ij} + r_{ij}$$

Level 2:

$\beta_{0j} = \gamma_{00} + U_{1j}$

$\beta_{1j} = \gamma_{10}$

Memory accuracy was positively associated with perceived levels of comfort holding the stress ball or hand and negatively associated with perceived levels of distraction while holding the stress ball or hand. Perceived levels of distraction was positively associated with self-report arousal, negatively associated with negative and positive facial expressivity, and not significantly associated with self-report mood valence. Perceived levels of comfort was not significantly associated with any of the affective variables. Perceived levels of comfort and distraction were negatively associated.

I then conducted a multilevel model predicting memory accuracy that included condition, valence, comfort, and distraction as predictor variables. I conducted one model with neutral valence as the reference group (valence was dummy-coded as 0 = neutral, 1 = negative or positive) and another with negative valence (valence was dummy-coded as 0 = negative, 1 = neutral or positive) as the reference group. Comfort and distraction were standardized in these models. A representative model with neutral valence as the reference group can be seen below:

Level 1:

$$\text{Memory Accuracy}_{ij} = \beta_{0j} + \beta_{1j}(\text{Condition})_{ij} + \beta_{2j}(\text{Valence: Negative vs. Neutral})_{ij} + \beta_{3j}(\text{Valence: Negative vs. Positive})_{ij} + \beta_{4j}(\text{Condition} \times \text{Valence: Negative vs. Neutral})_{ij} + \beta_{5j}(\text{Condition} \times \text{Valence: Negative vs. Positive})_{ij} + \beta_{60}(\text{Comfort})_{ij} + \beta_{70}(\text{Distraction})_{ij} + \beta_{80}(\text{Comfort} \times \text{Condition})_{ij} + \beta_{90}(\text{Comfort} \times \text{Condition})_{ij} + \beta_{10\,0}(\text{Comfort} \times \text{Valence: Negative vs. Neutral})_{ij} + \beta_{11\,0}(\text{Comfort} \times \text{Valence: Negative vs. Positive})_{ij} + \beta_{12\,0}(\text{Distraction} \times$$

Valence: Negative vs. Neutral$)_{ij}$ + $\beta_{13\,0}$(Distraction × Valence: Negative vs. Positive$)_{ij}$ + r_{ij}

Level 2:

$\beta_{0j} = \gamma_{00} + U_{0j}$

$\beta_{1j} = \gamma_{10}$

$\beta_{2j} = \gamma_{20}$

$\beta_{3j} = \gamma_{30}$

$\beta_{4j} = \gamma_{40}$

$\beta_{5j} = \gamma_{50}$

$\beta_{6j} = \gamma_{60}$

$\beta_{7j} = \gamma_{70}$

$\beta_{8j} = \gamma_{80}$

$\beta_{9j} = \gamma_{90}$

$\beta_{10j} = \gamma_{10\,0}$

$\beta_{11j} = \gamma_{11\,0}$

$\beta_{12j} = \gamma_{12\,0}$

$\beta_{13j} = \gamma_{13\,0}$

As can be seen in Table 6, the condition × valence (positive vs. negative) interaction remained significant when also including comfort and distraction along with their respective interactions with condition and image valence. Further, comfort and distraction no longer significantly predicted memory accuracy when also including condition in the model. Thus, it appears that the level of comfort and distraction participants felt when holding someone's hand during the task did not account for the condition × valence (positive vs. negative) interaction found in the main analysis.

Discussion

The present findings suggest that physical touch reduces the strength of emotional memory for negative information but not for positive information. Both negative and positive pictures elicited higher levels of self-report mood valence (in their respective directions), self-report arousal, and facial expressivity than did neutral pictures. Thus, the training task appeared to be effective at eliciting emotion. In addition, higher negative affective responses (i.e., self-report mood valence, self-report arousal, and negative facial expressivity) were broadly related to higher levels of memory accuracy among negative pictures. Surprisingly, there was no evidence of handholding reducing subjective or observable affective responses in the current study even though handholding has previously been found to decrease affective responses to different types of negative stimuli (Coan et al., 2006; Flores & Berenbaum, 2012). A possible contributor to handholding not reducing affective response is that the negative stimuli used by Flores and Berenbaum (2012) were more negative and arousing than the stimuli used in the current study. The current study required the use of fewer highly negative and arousing stimuli in order to match the valence and arousal of the positive stimuli. Regardless, handholding did significantly reduce memory for negative but not positive pictures, thus implying an emotion-related mechanism, or more specifically, differential effects depending on direction of emotional valence.

One potential explanation for the effect of handholding on emotional memory is that physical touch did serve as a form of the social regulation of emotion during a negative experience despite the lack of support in our findings of this explanation. It is possible that although there was not a decrease in subjective or observable affective response in the handholding condition, there may still have been physiological changes (e.g., reduction of arousal-related hormones, amygdala reactivity) that contributed to the reduction of memory for negative stimuli. Physical touch, for example, has been found to increase levels of oxytocin (Field, 2010), which has been demonstrated to reduce cortisol (an arousal-related hormone) in humans and corticosterone (an arousal-related hormone) in rodents (Neumann, 2002; Heinrichs et al., 2003) and, subsequently, memory of negative information in rodents (Boccia, Kopf, & Baratti, 1998; Boccia & Baratti, 2000). If the handholding condition indeed affects emotional memory through reducing cortisol, this may explain why there is a reduction in memory for negative but not positive pictures. Given that cortisol is generally released during unpleasant rather than pleasant events, the oxytocin released with physical touch is unlikely to attenuate memory for positive pictures. It is still unclear though why a reduction was also seen in memory for neutral pictures.

It is worth noting that the effect of handholding on negative memory does not appear to be explained by distraction that may come from physical touch. This was a concern since higher levels of distraction were reported in the handholding condition compared to the control condition, and since distraction was negatively associated with memory accuracy. Inconsistent with this alternative explanation, there is an effect of the handholding condition but not distraction when they were both included in the same model. In addition, if distraction fully explained the present findings, memory for positive pictures should also have been similarly affected by the handholding condition as memory for negative and neutral pictures.

Previous studies on the effect of emotion regulation on emotional memory have focused on the effect of emotion regulation on cognitive resources (e.g., expressive suppression expends cognitive resources, so less is available for learning; Dillon et al., 2007; Richards & Gross, 2000, 2006). Handholding and the social regulation of emotion more broadly, in contrast, are notable for expending less energy than intrapersonal emotion regulation strategies (Coan, 2008). Thus, even though expressive suppression and handholding were both found to impair emotional memory, their pathways are likely to be different. Whereas the social regulation of emotion and cognitive reappraisal are both adaptive emotion regulation strategies, expressive suppression is a maladaptive emotion regulation strategy. An important difference though between handholding and cognitive reappraisal is that handholding does not appear to increase elaboration, which may be the mechanism for memory enhancement with the use of cognitive reappraisal. Another key difference between the social regulation of emotion and cognitive reappraisal regards the involvement of oxytocin. As described previously, social behaviors, such as the social regulation of emotion, leads to increases in levels of oxytocin and reduces the affective response to a stressor (Heinrichs et al., 2003). Therefore, the present findings suggest that not all adaptive emotion regulation strategies have the same outcome on memory.

Unlike previous studies investigating the social regulation of emotion and desired emotional closeness (Flores & Berenbaum, 2012; Flores & Berenbaum, 2014), the present study did not find that desired emotional closeness moderated the effect of the social regulation of emotion. Flores and Berenbaum (2012) found that desired emotional closeness moderated effect of handholding emotion on negative facial expressivity, and Flores and Berenbaum (2014) found that desired emotional closeness moderated the prospective association between perceived emotional closeness (a form of the social regulation of emotion) and worry and depressive symptoms. It is possible that desired emotional closeness moderates specific types of outcomes of the social regulation of emotion that do not include emotional long-term memory. Alternatively, future studies may demonstrate that desired emotional closeness does indeed broadly moderate outcomes of the social regulation of emotion that include long-term emotional memory.

The findings of the present study are not only helpful to better understand the relationship between emotion regulation and memory, but also to better understand the emotional benefits of close relationships. A particularly important benefit of close relationships is the protection against depression (Brown & Harris, 1978). The present findings suggest that behaviors that accompany close relationships, such as physical touch, can help reduce the strength of negative memories. This is relevant to depression because among the cognitive biases that are present in depression are mood-congruent memory biases (Matthews & MacLeod, 2005; Matt, Vázquez, & Campbell, 1992; Williams, Watts, MacLeod, & Mathews, 1997). Future research is needed to clarify how the social regulation of emotion may help reduce risk for depression and other forms of psychopathology (e.g., PTSD) by reducing the strength of negative memories.

In order to better understand the mechanism of the effect of physical touch on long-term emotional memory, it would be helpful to place further focus on oxytocin and amygdala reactivity. Although it is extremely difficult to measure endogenous levels of central oxytocin, studies simultaneously using intranasal-administered oxytocin and handholding could help demonstrate the role of oxytocin. Neuroimaging studies could also be helpful by measuring amygdala and hypothalamus activity during the training session to investigate if handholding attenuates activity in these regions and if attenuation of their activity is associated with long-term memory. Overall, the present research has demonstrated that there appears to be an effect of the social regulation of emotion on long-term emotional memory, and future research is needed to better understand the nature of this effect including its potential mechanisms.

CHAPTER 3

EMOTIONAL WORKING MEMORY

Negative events are part of everyday life, but not being able to remove these negative events from working memory once the event is no longer relevant has been found to be associated with maladaptive outcomes (Joormann & Gotlib, 2008). Therefore, improving the ability to remove irrelevant negative contents from working memory can be beneficial. Considering the importance of interpersonal relationships in handling stressors (Cohen, Gottlieb, & Underwood, 2000), to the present research investigated whether the social regulation of emotion – which refers to interpersonal interactions that influence an individual's affect – may promote the removal of negative contents from working memory.

Emotion and Working Memory

Emotion has been found to influence working memory, which is an executive function characterized as having a limited capacity to temporarily hold information for the purpose of performing a variety of other complex cognitive functions (Baddeley, 2003). One way that emotions influence working memory is by impairing working memory performance for neutral information when an individual is in a negative mood (Cheng & Holyoak, 1985; Spies et al., 1996; Mitchell & Phillips, 2007). The effect of emotional contents on working memory performance, however, has been mixed. Kensinger and Corkin (2003), for example, found that whereas working memory accuracy for emotional contents did not differ compared to neutral contents, speed was impaired for an *n*-back task using fearful faces but not negative words. Two other studies, on the other hand, have found the opposite effect, such that emotional contents improved working memory in terms of accuracy and speed (Lindström & Bohlin, 2011) and in terms of reducing proactive interference (i.e., interference from preceding trials; Levens & Phelps, 2008). Overall, emotion appears to hamper working memory performance if attention needs to be given to non-emotional details, but may improve working memory performance if attention needs to be given to the emotional details (Vuilleumier, 2005).

The ability to hold information in working memory is an important component of working memory, but so is the ability to remove information that is no longer important. The purpose of temporarily holding information in working memory is to have it available for a task at hand; thus it is not necessary to maintain irrelevant information active in working memory (Hasher, Zacks, & May 1999). In addition, having difficulty in updating working memory can restrict the storage space available in working memory for other more relevant material. The attentional and memory enhancement associated with emotional information (Vuilleumier, 2005; Lindström & Bohlin, 2011) may make it more difficult to remove negative information from working memory compared neutral contents. Thus, the emotional nature of information may impair working memory performance when focusing on the ability to deactivate memoranda.

Social Regulation of Emotion and Desired Emotional Closeness

The social regulation of emotion is another term for interpersonal emotion regulation strategies, and it refers to how others intentionally or unintentionally help individuals alter their affective response to stressors (Coan, 2008). Coan's (2008) social baseline model of emotion regulation proposes load sharing as an evolutionarily developed strategy of expending less energy and experiencing less negative emotion in a distressing situation when in the presence of another person. The presence of, and especially support from, another individual sends a message that an individual is not alone in facing the threat and can, therefore, rely on the other individual to share some of the burden of the threat. To demonstrate this process, Coan et al.

(2006) had married women become threatened with the potential of being shocked under three conditions: (a) holding their husband's hand, (b) holding a male stranger's hand, and (c) not holding anyone's hand. Compared to the control condition, the married women self-reported lower levels of bodily arousal in each of the handholding conditions and lower levels of negative mood in the husband handholding condition. Similar effects were found in the activation of neural systems associated with emotional and behavioral threat responses. Thus, handholding, as a form of the social regulation of emotion, helped attenuate the emotional response to the threat and resulted in less energy expenditure, as measured by neural activation.

Emotional closeness is an important aspect of interpersonal interactions and relationships. Flores and Berenbaum (2012) define emotional closeness as the degree to which individuals perceive others to have caring feelings for them and to be physically affectionate, verbally affectionate, and emotionally supportive. The focus on the reception, rather than delivery, of emotional closeness is based largely on interest in how the behaviors and perceived caring feelings of others may be a form of the social regulation of emotion. Emotional closeness may reinforce signals to the individual that they do not have to address stressors alone and, thus, stressors may be perceived as less threatening. In other words, emotional closeness may help regulate the distress that results from a stressor by providing an increase in perception of another person's presence. One way that emotional closeness, including physical affection, may be associated with the alleviation of stress is through stress-related biochemical changes (e.g., increase in oxytocin and decrease in cortisol; Field, 2010).

Importantly, the degree to which a person responds to emotional closeness behaviors (e.g., handholding) is moderated by how much a person desires emotional closeness (Flores & Berenbaum, 2012; Flores & Berenbaum, 2014). For example, the reduction of facial expressivity, but not self-reported affective response, to negative images when holding someone's hand compared to a control condition (no handholding) was larger among individuals with greater levels of desired emotional closeness (Flores & Berenbaum, 2012). Thus, individual differences in desired emotional closeness may be important for understanding the impact of the social regulation of emotion on psychological and behavioral outcomes. Considering emotional closeness as a strategy to regulate emotions, one reason why desired emotional closeness may alter these outcomes is that the psychological impact of successfully using a given type of strategy for achieving a goal (e.g., using an approach or avoidance strategy) will often be moderated by an individual's desirability for utilizing the given type of strategy (Tamir & Diener, 2008).

Our conceptualization of desired emotional closeness is related to several psychological constructs, including attachment (Bowlby, 1969/1982). Although attachment style is undoubtedly relevant to desired emotional closeness, it has a different focus that does not capture, or at least does not fully capture, desired emotional closeness. In fact, Flores and Berenbaum (2012) found that desired emotional closeness moderated the effectiveness of handholding as a form of the social regulation of emotion even when including attachment style in the same model. Further, despite being significantly correlated with desired emotional closeness, attachment avoidance was not found to moderate the effectiveness of handholding (Flores & Berenbaum, 2012).

Social Regulation of Emotion and Working Memory

In addition to helping down-regulate negative emotions, the social regulation of emotion may also influence memory for emotional information. Although research has yet to examine the effect of emotion regulation on updating negative contents of working memory, there have been studies that investigated the effect of emotion regulation on long-term memory. Cognitive reappraisal (i.e., changing how one interprets a situation to change how one feels about it) has previously been found to either have no effect or improve memory in a few studies (Dillon, Ritchey, Johnson, & LaBar, 2007; Erk, von Kalckreuth, & Walter, 2010; Kim & Hamann, 2012; Richards & Gross, 2000). Expressive suppression, on the other hand, has been found to impair long-term memory (Dillon et al., 2007; Richards & Gross, 2000, 2006).

I conducted two studies to examine the hypothesis that the social regulation of emotion, in the form of handholding, will facilitate the elimination of irrelevant negative material in an emotional working memory task. I further hypothesized that desired emotional closeness would moderate this relation, such that this relation may only be present among those with high desired emotional closeness.

Study 1

Method

Participants were 106 undergraduate students (62% female) who ranged in age from 18 to 25 years (M = 19.7, SD = 1.4). Forty-nine percent identified themselves as Asian, 37% as White, 9% as Latino or Hispanic, 3% as Black or African American, and 3% as other or multiracial. Participants received credit for a research participation requirement for a psychology course.

In a single session, participants completed questionnaires and an emotional working memory task, which included both a control condition and a handholding condition (order counterbalanced across participants).

Measures

Desired Emotional Closeness. The 15-item self-report Desired Emotional Closeness Questionnaire (D-ECQ) was used to measure desired emotional closeness (Flores & Berenbaum, 2012). Items were selected from measures of related constructs that targeted feelings of emotional closeness that others have for the respondent, and behaviors that others direct towards the respondent that promote emotional closeness. Further items were written to fully capture the construct. In summary, items were written by the authors (4 items) or chosen, and modified if necessary, from the International Personality Item Pool (IPIP; Goldberg et al., 2006; 3 items), the COPE Inventory (Carver, Scheier, & Weintraub, 1989; 2 items), Affection Communication Index (ACI; Floyd & Morman, 1998; 1 item), the Trait Affection Scale (TAS; Floyd, 2002; 4 items) and the Interpersonal Support Evaluation List (ISEL; Cohen & Hoberman, 1983). For each item in the D-ECQ, participants rated "how true [they] would like each behavior, feeling, or circumstance to be, regardless of its feasibility" using a 6-point rating scale from 1 (*Definitely not true*) to 6 (*Definitely true*). The mean and standard deviation of the questionnaire in this sample was 5.1 (0.7), and the internal consistency was acceptable (α=.89).

Updating Negative Contents of Working Memory. The ability to update negative contents of working memory was measured using an emotional working memory task. The emotional working memory task was a modified Sternberg task with the use of emotional images as the targets. This task was a further modification of the modified Sternberg task used by Joormann and Gotlib (2008). Figure 2 provides an illustration of a sample trial of the task. Emotional images were used in order to assess working memory performance during a distressing situation. Broadly in this task, participants viewed two sets of two negatively-valenced images. After studying both sets of images, their goal for each trial was to remember one set ("the relevant set") and forget the other set ("the irrelevant set") in order to later most effectively determine if an image is from the relevant set. Describing the task in more detail, each trial began with a 500ms fixation cross. The participant would then view two sets of images that they were supposed to study for 7.8 seconds. The set on the upper half of the screen had a blue frame around the images and the set on the lower half of the screen had a red frame around the images. Afterward, the participants would try to keep the sets of images in their working memory as they viewed a blank screen for 800ms. Then a blue or red frame would appear to let them know which set of images will be relevant for this trial. The other set would now be considered irrelevant. After 1000ms, an image (the probe) would appear that would be from the relevant set, irrelevant set, or an entirely new image. The participant would then be asked to determine if this image was from the relevant set. The extent to which participants continued holding the irrelevant set in their working memory is reflected by a longer response time when the image is from the irrelevant set. The added difficulty in determining that an image from the irrelevant set is not from the relevant set is called the intrusion effect. The intrusion effect is calculated by subtracting the response times of trials when the probe is from the irrelevant set by the response times of trials when the probe is a new image. The emotional working memory task was divided into three blocks, which each consisted of 12 trials and lasted 2.4 minutes for a total of 36 trials and 7.2 minutes. Each block had 4 of each of the following types of trials: (a) the probe is from the relevant set; (b) the probe is from the irrelevant set; and (c) the probe is a new image. The task was presented at full screen on an 18-inch monitor, which was 54-inches away from the eyes of the participant. The images were chosen from the International Affective Picture System (IAPS; Lang et al., 2008). Images were chosen by taking those with the rated low in valence (i.e., the negatively valenced images; $M = 2.8$, $SD = 0.7$). These images also tended to be rated high in level of arousal ($M = 5.6$, $SD = 0.9$). Images were pre-assigned into each of the blocks (order of the blocks were random) and the valence (F(5, 234) = 0.00, p = 1.00) and arousal (F(5, 234) = 0.22, p = .95) of the images did not significantly differ.

Social Regulation of Emotion. Participants completed the emotional working memory task under two different conditions reflecting the presence or absence of the social regulation of emotion. In the handholding condition, the participants held the hand of an anonymous female research assistant who sat behind a curtain and was not visible at any time to the participants. In the control condition, the participants did not hold anyone's hand. Research assistants were trained to provide a firm, supportive handhold for each participant. Handholding circles were conducted at weekly meetings to maintain similar handholding strengths among the research assistants. I have decided not to include a close other handholding condition for two reasons: (a) I am most interested in responsiveness to interpersonal emotion regulation outside the context of close relationships; and (b) to prevent biasing the sample, as I am interested in including participants with low emotional closeness in their real lives. Participants rated their mood and level of arousal ratings on a 9-point scale using the Self-Assessment Mannequin (SAM; Bradley & Lang, 1994) after each block of trials. Throughout the task, the participants were videotaped from behind a discreet one-way mirror. Five undergraduate research assistants, who were unaware of the questionnaire scores of the participants or the condition, were trained to make a single rating on the overall facial expressivity of the participant during each block. Ratings were made on a 7-point scale from 0 (*absence of facial expressivity*) to 6 (*extremely facially expressive*). The average of the five facial coders' scores were used. A similar method for coding facial expressivity has previously been used effectively (Flores & Berenbaum, 2012; Berenbaum & Williams, 1995). The research assistants coded a practice tape together at a lab meeting each week to help prevent rater drift. Interrater reliability was measured using the intraclass correlation with coders treated as random effects and the mean of the coders used as the unit of reliability. The interrater reliability for all four coders was .89. These data were used as a way to check the effectiveness of the social regulation of emotion strategy.

Results and Discussion

I used multilevel modeling for our analyses in both Study 1 and Study 2 since our data included both within-participant (Level 1) and between-participant (Level 2) variables. Multilevel modeling does not assume that data points are independent and can handle missing data points (Snijder & Bosker, 1999). For each of the analyses below, I used the MIXED procedure of the SAS 9.3 software. I report parameter estimates with standard errors. I included random intercepts in each model and used unstructured covariance structures. In addition, desired emotional closeness and attachment styles were standardized, and condition (control = 0; handholding = 1) was dummy-coded.

Checking Emotion Regulation Effectiveness of Handholding

I first examined the effectiveness of handholding at reducing affective response to the emotional working memory task. Descriptive statistics of the affective variables (i.e., self-report mood valence, self-report arousal, and facial expressivity) by condition (i.e., control and handholding condition) are shown in Table 7. I conducted multilevel models in order to examine the significance of the differences between conditions and whether participants with higher levels of desired emotional closeness experienced a greater reduction in affective response than those with lower levels of desired emotional closeness[3]. A model was conducted for each of the three affective variables (i.e., self-report mood valence, self-report arousal, and facial expressivity). A representative model is presented below[4].

$$\text{Level 1: Affect}_{ij} = \beta_{0j} + \beta_{1j}(\text{Condition})_{ij} + R_{ij}$$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Desired Emotional Closeness})_{j} + U_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{Desired Emotional Closeness})_{j}$$

As shown in Table 8, handholding significantly altered mood valence to be less negative and not quite significantly reduced subjective reports of arousal. Handholding, however, did not appear to alter facial expressivity during the task. As indicated by the lack of significant Condition × Desired Emotional Closeness interactions, participants with higher levels of desired emotional closeness did not appear to obtain a greater emotion regulation benefit from handholding than those with lower levels of desired emotional closeness. An additional finding was that those with higher levels of desired emotional closeness had significantly greater negative mood during the emotional working memory task those with lower levels of desired emotional closeness.

Descriptive Statistics and Associations of Emotional Working Memory Task Variables

Descriptive statistics of the task variables, including the average response times and accuracy rates, for each of the different types of trials are shown in Table 9. The relevant trials are those where the probe was from the relevant set, the intrusion trials are those where the probe was from the irrelevant set, and the new trials are those where the probe is a new image. Intrusion effect is the difference between the response times from the intrusion trials and the new trials. Longer response times in the intrusion trials and, subsequently, the intrusion effect reflect the continued strength of the memory for the pictures from the irrelevant set in the participants' working memory.

I conducted multilevel models to examine the associations between the working memory task and affective variables (Table 10). For each model, I included the variable labeled at the beginning of the row as the outcome variable and the variable labeled at the top of the column as the predictor variable. A representative model is shown below.

$$\text{Level 1: Row Variable}_{ij} = \beta_{0j} + \beta_{1j}(\text{Column Variable})_{ij} + R_{ij}$$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + U_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

Not surprisingly, the accuracy of the intrusion trials was positively associated with the accuracy of the relevant trials and not quite significantly associated with the accuracy of the new trials. Accuracy of new trials was generally negatively associated with response times to the different types of trials. As expected, the response times for the different types of trials were positively associated with each other. Both response times to relevant and intrusion trials were positively associated with the intrusion effect. Given that response times to intrusion trials but not new trials were significantly associated with intrusion effect, it seems that changes to intrusion trial response times contributed more than new trial response times to changes in intrusion effect. Intrusion effect was also significantly associated with mood valence, but surprisingly, more negative mood was associated with less intrusion effect. More negative mood was also associated with higher levels of arousal. Contrary to expectations, the affect variables were mostly not significantly associated with the working memory task accuracy rates and response times.

Effect of the Social Regulation of Emotion on Emotional Working Memory Task Accuracy

To investigate the effect of handholding on accuracy rates on the emotional working memory task I conducted multilevel models that included condition and desired emotional closeness as predictor variables for accuracy rates of each type of trial. A representative model is shown below.

Level 1: $\text{Accuracy}_{ij} = \beta_{0j} + \beta_{1j}(\text{Condition})_{ij} + R_{ij}$

Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Desired Emotional Closeness})_j + U_{0j}$

$\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{Desired Emotional Closeness})_j$

As shown in Table 11, there was a main effect of condition on accuracy rates on intrusion trials, such that accuracy on intrusion trials was unexpectedly lower during the handholding condition compared to the control condition. Contrary to hypotheses, desired emotional closeness did not moderate the effect of condition on intrusion trial accuracy rates.

Effect of the Social Regulation of Emotion on Emotional Working Memory Task Response Times

I conducted multilevel models in order to test whether the social regulation of emotion affected the response times for each type of trial and whether this effect was moderated by desired emotional closeness. Following Oberauer (2001) and Joormann and Gotlib (2008), the intrusion effect for each condition for each participant was also investigated and was measured by subtracting the average of the irrelevant trials (probe is from irrelevant set) from the average of the relevant trials (probe is a new image). Trials with incorrect responses or with response times less than 300ms or more than 5000ms (10.1% of trials) were excluded. A representative model can be seen below.

Level 1: $\text{Response Time}_{ij} = \beta_{0j} + \beta_{1j}(\text{Condition})_{ij} + R_{ij}$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Desired Emotional Closeness})_j + U_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{Desired Emotional Closeness})_j$$

There was not a main effect of condition or desired emotional closeness on the response times on any of the types of trials (Table 12). The condition × desired emotional closeness interaction (i.e., desired emotional closeness as an explanatory variable for condition) fell shy of statistical significance in predicting intrusion trial response times, such that handholding reduced response times to intrusion trials among those with high desired emotional closeness and increased response times to intrusion trials among those with low desired emotional closeness.

As can be seen in Table 12, there was not a main effect of condition or desired emotional closeness on the intrusion effect. However, the hypothesized condition × desired emotional closeness interaction was significant, such that there was a reduction of the intrusion effect in the handholding condition among those with high desired emotional closeness and an opposite pattern among those with low desired emotional closeness (see Figure 3). A follow-up simple slopes test (see Preacher, Curran, & Bauer, 2006) demonstrated that the effect of condition at one standard deviation below the mean of desired emotional closeness ($t(107) = 1.63$, $p = .1051$) and at one standard deviation above the mean ($t(107) = -1.40$, $p = .1651$) did not reach statistical significance.

Overall some evidence was found demonstrating that desired emotional closeness moderated the effect of the social regulation of emotion on the ability to update negative contents of working memory. Handholding was mostly demonstrated to be effective as a type of the social regulation of emotion by significantly reducing self-report levels of negative mood and not quite significantly reducing self-report levels of arousal. Supporting the primary hypothesis, desired emotional closeness moderated the effect of handholding, such that lower levels of the intrusion effect was demonstrated in the handholding condition compared to the control condition at high desired emotional closeness but not low desired emotional closeness. It is worth noting, however, that the change in intrusion effect at one standard deviation above and below the mean of desired emotional closeness did not reach statistical significance. A similar pattern was demonstrated in predicting response times to intrusion trials even though the interaction did not reach statistical significance.

Study 2

Study 2 was conducted to address some unanswered questions from Study 1. Since all of the pictures used in Study 1 were negative, it was unclear if handholding reduced the effect of the negative emotional nature of the pictures. Considering that handholding serves as an example of the social regulation of emotion, it is informative if handholding alters the effect of negative emotion (i.e., neutral vs. negative) on working memory. Study 2 also considers the possibilities that attachment style or the comfort and distraction that a participant felt during the task might better account for the moderating role of desired emotional closeness. Considering that comfort and distraction while holding someone's hand may explain the findings from Study 1, the control condition was altered to holding a stress ball to make it more similar to the handholding condition. In addition, each participant completed the emotional working memory task under just one of the two conditions to reduce expectancy effects.

Method

Participants were 195 undergraduate students. Demographics of the participants in each condition can be found in Table 13. There were no significant differences in gender, race/ethnicity, or attachment style. Participants in the stress ball condition had slightly higher levels of desired emotional closeness than those in the handholding condition, but this difference did not quite reach statistical significance ($t(193) = 1.86$, $p = .06$). Participants received credit for a research participation requirement for a psychology course.

To determine if 195 participants would be an adequate sample size for the hypothesized two-way and three-way interactions, I conducted simulations that estimated power for a linear regression model. I used standardized beta weights of .2 and 200 simulation trials. I found that 200 participants would provide at least 80% power to detect the effects of that size using two-tailed tests.

In a single session, participants completed questionnaires and a similar emotional working memory task as Study 1. Each participant completed the emotional working memory task in either a stress ball or a handholding condition.

Attachment style. The 36-item Experiences with Close Relationships-Revised scale (ECR-R; Fraley, Waller, & Brennan, 2000) was used to measure attachment style; participants were asked to indicate how much they agree or disagree with items based on their emotionally intimate relationships, including those with romantic partners, close friends, and/or family members. The ECR-R measures attachment style through the dimensional subscales of attachment avoidance (e.g., "It's easy for me to be affectionate with close others") and attachment anxiety (e.g., "I often worry that close others don't really love me"). Each item was scored on a 7-point scale from 1 (*Strongly Disagree)* to 7 (*Strongly Agree*). Internal consistencies were good (see Table 14).

Updating Negative and Neutral Contents of Working Memory. The primary difference of the emotional working memory task in Study 2 is that half of the 6 blocks of trials consisted of neutral images rather than negative images. Images for the negative blocks were chosen by taking those rated low in valence in the IAPS database (i.e., the negatively valenced images; $M = 2.5$, $SD = 0.6$). These images also tended to be rated high in level of arousal ($M = 5.8$, $SD = 0.8$). Images for the neutral blocks were chosen by taking those rated moderately in valence (i.e., neither positive nor negative; $M = 5.2$, $SD = 0.6$). Images in the neutral blocks were generally rated low in level of arousal ($M = 3.2$, $SD = 0.5$). As expected, images in the negative blocks have been rated significantly more negative ($t(310) = 39.74$, $p < .0001$) and higher in arousal ($t(310) = 33.50$, $p < .0001$) than images in the neutral blocks. Images were pre-assigned into each of the 3 negative blocks and 3 neutral blocks (order of the blocks were random). The valence (negative blocks: $F(2, 153) = 0.00$, $p = 1.00$; neutral blocks: $F(2, 153) = 0.02$, $p = .98$) and arousal (negative blocks: $F(2, 153) = 0.04$, $p = .96$; neutral blocks: $F(2, 153) = 0.65$, $p = .52$) of the images did not significantly differ between the blocks of the same valence.

Social Regulation of Emotion. Each participant completed the emotional working memory task under just one of the two conditions. In the stress ball condition, participants held a stress ball during the task. The handholding condition in Study 2 was the same as in Study 1. A short break of a few minutes was given to participants after the first 3 blocks during which they did not hold a stress ball or someone's hand. As with Study 1, participants rated their mood and level of arousal ratings on a 9-point scale using the Self-Assessment Mannequin (SAM; Bradley & Lang, 1994) after each block of trials. Also like Study 1, participants were videotaped throughout the task from behind a discreet one-way mirror. Four undergraduate research assistants, who were unaware of the questionnaire scores of the participants or the condition, were trained to make a single rating on the overall facial expressivity of the participant during each block. Ratings were made on a 7-point scale from 0 (*absence of facial expressivity*) to 6 (*extremely facially expressive*). Most videos were rated by two of the four raters (24 of 148 videos were rated by all four raters to measure interrater reliability between all 4 raters). A subset of 47 participants either declined to have their videotapes coded or participated after the raters were no longer available. The average of the two or four facial coders' scores were used. The research assistants coded a practice tape together at a lab meeting each week to help prevent rater drift. Interrater reliability was measured using the intraclass correlation with coders treated as random effects and the mean of the coders used as the unit of reliability. The interrater reliability for all four coders was .91. The interrater reliability for each pair of coders was an average of .81 (SD = .06) and ranged from .70 to .86. These data were used as a way to check the effectiveness of the social regulation of emotion strategy.

Comfort and Distraction. Participants' perceived levels of comfort and distraction while holding someone's hand or a stress ball was measured at the end of the session with the following two questions: (1) "How comfortable did it feel to hold [the stress ball/someone's hand] during the task?"; and (2) "How distracting did it feel to hold [the stress ball/someone's hand] during the task?" Participants rated these questions on a 5-point scale (1 = *Very uncomfortable* or *Not at all distracting*; 5 = *Very comfortable* or *Very distracting*).

Results and Discussion

Correlations between desired emotional closeness and attachment style are displayed in Table 14. As expected, attachment avoidance was positively associated with attachment anxiety and negatively associated with desired emotional closeness. The strong correlation between desired emotional closeness and attachment avoidance highlights the importance of ensuring that any effect of desired emotional closeness is not primarily due to its association with attachment avoidance.

Checking Emotion Elicitation and Effectiveness of the Social Regulation of Emotion

Descriptive statistics of the affective variables and the comfort and distraction variables can be found in Table 15. In order to examine whether the negative blocks elicited negative emotion and whether handholding served effectively as the social regulation of emotion, I conducted multilevel models to predict each affective variables. Valence was dummy-coded in all multilevel models in Study 2 (0 = Neutral; 1 = Negative). A representative model is demonstrated below.

$$\text{Level 1: Affect}_{ij} = \beta_{0j} + \beta_{1j}(\text{Valence})_{ij} + R_{ij}$$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Condition})_j + \gamma_{02}(\text{Desired Emotional Closeness})_j + \gamma_{03}(\text{Condition} \times \text{Desired Emotional Closeness})_j + U_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{Condition})_j + \gamma_{12}(\text{Desired Emotional Closeness})_j + \gamma_{13}(\text{Condition} \times \text{Desired Emotional Closeness})_j$$

As shown in Table 16, participants displayed more facial expressivity and reported more negative mood and arousal during the negative blocks compared to the neutral blocks (i.e., main effect of valence). Unexpectedly, no evidence was found of handholding effectively reducing any of the affective variables as none of the condition × valence interactions were statistically significant.

Task Variables Descriptive Statistics and Associations

Descriptive statistics of the task variables divided by both valence of the trials and the condition are displayed in Table 17. Associations between these variables, along with the affective variables, were calculated by conducting multilevel models (see Table 18). For each model, I included the variable labeled at the beginning of the row as the outcome variable and the variable labeled at the top of the column as the predictor variable. A representative model is shown below.

$$\text{Level 1: Row Variable}_{ij} = \beta_{0j} + \beta_{1j}(\text{Column Variable})_{ij} + R_{ij}$$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + U_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

Accuracy rates of the relevant trials were significantly associated with accuracy rates of intrusion trials and not quite significantly associated with accuracy rates of new trials. Accuracy rates between intrusion and new trials, however, were not significantly associated. Accuracy rates of intrusion trials were negatively associated with response times of intrusion and new trials and the intrusion effect. Accuracy rates of intrusion trials – and to a lesser extent accuracy rates of relevant trials – were significantly associated with each of the affective variables, such that accuracy was worse at greater levels of negative mood, arousal, and facial expressivity. Response times to the different types of trials were each positively associated. As with Study 1, response times to intrusion trials appeared to be more strongly associated with intrusion effect than response times to new trials. Response times of each type of trial were each significantly associated with mood valence, such that response times were longer at greater levels of negative mood. Response times to relevant trials were also significantly slower at higher levels of arousal, and response times to new trials were significantly slower at higher levels of facial expressivity.

Each of the affective variables was significantly associated with others in the expected directions. The level of comfort and distraction participants experienced while holding either a stress ball or someone's hand was negatively associated. Higher levels of distraction was significantly associated with greater negative mood and facial expressivity, and higher levels of comfort was associated with less negative mood.

Accuracy Rates on Emotional Working Memory Task

Multilevel models were conducted to examine the effect of handholding on accuracy rates on each of the three types of trials on the emotional working memory task. A representative model is shown below.

$$\text{Level 1: Accuracy}_{ij} = \beta_{0j} + \beta_{1j}(\text{Valence})_{ij} + R_{ij}$$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Condition})_j + \gamma_{02}(\text{Desired Emotional Closeness})_j + \gamma_{03}(\text{Condition} \times \text{Desired Emotional Closeness})_j + U_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{Condition})_j + \gamma_{12}(\text{Desired Emotional Closeness})_j + \gamma_{13}(\text{Condition} \times \text{Desired Emotional Closeness})_j$$

As demonstrated in Table 19, there was a main effect of image valence on intrusion trial accuracy rates, such that there were lower accuracy rates for negative pictures compared to neutral pictures. There was also a significant valence × condition × desired emotional closeness interaction in predicting accuracy rates of intrusion trials. Among those with high desired emotional closeness, the effect of negative pictures was lower in the handholding condition compared to the stress ball condition (see Figure 4). The opposite pattern was evident among those with low desired emotional closeness. Follow-up simple slopes tests (Preacher et al., 2006) demonstrated that the effect of negative emotion was significant in the stress ball condition ($t(195) = -2.53$, $p = .0121$) but not the handholding condition ($t(195) = -1.57$, $p = .1189$) at one standard deviation above the mean of desired emotional closeness. In contrast, the effect of negative emotion was significant in both the stress ball condition ($t(195) = -2.15$, $p = .0326$) and the handholding condition ($t(195) = -6.02$, $p < .0001$) at one standard deviation below the mean of desired emotional closeness[5].

Response Times and Intrusion Effect on Emotional Working Memory Task

Multilevel models were conducted to examine the effect of handholding on response times on each of the three types of trials and the intrusion effect in the emotional working memory task. Trials with incorrect responses or with response times less than 300ms or more than 5000ms (9.9% of trials were excluded). A representative model is shown below.

$$\text{Level 1: Response Time}_{ij} = \beta_{0j} + \beta_{1j}(\text{Valence})_{ij} + R_{ij}$$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Condition})_j + \gamma_{02}(\text{Desired Emotional Closeness})_j + \gamma_{03}(\text{Condition} \times \text{Desired Emotional Closeness})_j + U_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{Condition})_j + \gamma_{12}(\text{Desired Emotional Closeness})_j + \gamma_{13}(\text{Condition} \times \text{Desired Emotional Closeness})_j$$

As demonstrated in Table 20, there was a main effect of valence, such that participants generally responded more slowly to negative pictures than neutral pictures. There were also significant valence × condition × desired emotional closeness interactions in predicting response times of intrusion trials and new trials. As seen in Figure 5, among those with high desired emotional closeness, the effect of negative pictures on intrusion trial response times was lower in the handholding condition compared to the stress ball condition. The opposite pattern was found among those with low desired emotional closeness. Follow-up simple slopes tests (Preacher et al., 2006) demonstrated that the effect of valence was significant in the stress ball condition ($t(195) = 3.95$, $p = .0001$) but not the handholding condition ($t(195) = 1.09$, $p = .2777$) at one standard deviation above the mean of desired emotional closeness. In contrast, the effect of valence was not significant in the stress ball condition ($t(195) = 0.62$, $p = .5393$) but was significant in the handholding condition ($t(195) = 3.96$, $p = .0001$) at one standard deviation below the mean of desired emotional closeness[6].

As seen in Figure 6, among those with high desired emotional closeness, the effect of negative pictures on new trial response times was lower in the handholding condition compared to the stress ball condition. This pattern was not found among those with low desired emotional closeness. Follow-up simple slopes tests (Preacher et al., 2006) demonstrated that the effect of valence was significant in both the stress ball condition ($t(195) = 8.27$, $p < .0001$) and the handholding condition ($t(195) = 3.40$, $p = .0008$) at one standard deviation above the mean of desired emotional closeness. Similarly, the effect of valence was significant in both the stress ball condition ($t(195) = 3.33$, $p = .0010$) and the handholding condition ($t(195) = 5.89$, $p < .0001$) at one standard deviation below the mean of desired emotional closeness.

Accounting for Attachment Style

Given the theoretical and empirical association between desired emotional closeness and attachment avoidance, it was worth investigating whether attachment style accounted for the findings related to desired emotional closeness. I added attachment avoidance and attachment anxiety along with their respective interactions with valence and condition to the three previously run multilevel models that resulted in significant valence × condition × desired emotional closeness interactions (i.e., those that predicted intrusion trial accuracy, intrusion trial response times, and new trial response times). A representative model is shown below.

$$\text{Level 1: Task Variable}_{ij} = \beta_{0j} + \beta_{1j}(\text{Valence})_{ij} + R_{ij}$$

Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Condition})_j + \gamma_{02}(\text{Attachment Anxiety})_j + \gamma_{03}(\text{Attachment Avoidance})_j + \gamma_{04}(\text{Desired Emotional Closeness})_j + \gamma_{05}(\text{Condition} \times \text{Attachment Anxiety})_j + \gamma_{06}(\text{Condition} \times \text{Attachment Avoidance})_j + \gamma_{07}(\text{Condition} \times \text{Desired Emotional Closeness})_j + U_{0j}$

$\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{Condition})_j + \gamma_{12}(\text{Attachment Anxiety})_j + \gamma_{13}(\text{Attachment Avoidance})_j + \gamma_{14}(\text{Desired Emotional Closeness})_j + \gamma_{15}(\text{Condition} \times \text{Attachment Anxiety})_j + \gamma_{16}(\text{Condition} \times \text{Attachment Avoidance})_j + \gamma_{17}(\text{Condition} \times \text{Desired Emotional Closeness})_j$

None of the interactions including attachment anxiety or attachment avoidance was found to be significant or just shy of significance (i.e., p <.10). The valence × condition × desired emotional closeness interaction remained significant in predicting intrusion trial response time (γ_{17} = -112.82, t(195) = -2.15, p = .0325) and new trial response time (γ_{17} = -93.82, t(195) = -2.87, p = .0045). In addition the valence × condition × desired emotional closeness interaction was just shy of statistical significance in predicting intrusion trial accuracy rates (γ_{17} = 4.92, t(195) = -1.91, p = .0581).

Accounting for Comfort and Distraction

Although participants in the handholding condition did not report significantly lower levels of comfort (t(194) = -1.34, p = .1827) than participants in the stress ball condition, they did report significantly higher levels of distraction (t(194) = 4.14, p = .0001). Thus, a potential explanation for the present findings is that handholding reduces the effect of intrusion trials by distracting participants away from the images. Thus, I added comfort and distraction along with their respective interactions with valence and condition to the three previously run multilevel models that resulted in significant valence × condition × desired emotional closeness interactions (i.e., those that predicted intrusion trial accuracy, intrusion trial response times, and new trial response times). Comfort and distraction, along with desired emotional closeness, were standardized. A representative model is shown below.

$$\text{Level 1: Task Variable}_{ij} = \beta_{0j} + \beta_{1j}(\text{Valence})_{ij} + R_{ij}$$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Condition})_j + \gamma_{02}(\text{Comfort})_j + \gamma_{03}(\text{Distraction})_j + \gamma_{04}(\text{Desired Emotional Closeness})_j + \gamma_{05}(\text{Condition} \times \text{Comfort})_j + \gamma_{06}(\text{Condition} \times \text{Distraction})_j + \gamma_{07}(\text{Condition} \times \text{Desired Emotional Closeness})_j + U_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{Condition})_j + \gamma_{12}(\text{Comfort})_j + \gamma_{13}(\text{Distraction})_j + \gamma_{14}(\text{Desired Emotional Closeness})_j + \gamma_{15}(\text{Condition} \times \text{Comfort})_j + \gamma_{16}(\text{Condition} \times \text{Distraction})_j + \gamma_{17}(\text{Condition} \times \text{Desired Emotional Closeness})_j$$

Only one of the interactions including comfort or distraction was found to be significant. There was a significant valence × condition × distraction interaction in predicting new trial response times ($\gamma_{17} = -67.55$, $t(195) = -2.28$, $p = .0238$). As can be seen in Figure 7, valence appeared to have less of an effect in the handholding condition than the stress ball condition among those who experienced high levels of distraction. Condition did not seem to matter, however, among those with low levels of distraction. Follow-up simple slopes tests (Preacher et al., 2006) demonstrated that the effect of valence was significant in the stress ball condition ($t(195) = 5.80$, $p < .0001$) but not the handholding condition ($t(195) = 1.59$, $p = .1132$) at one standard deviation above the mean of distraction. In contrast, the effect of valence was significant in both the stress ball condition ($t(195) = 6.01$, $p < .0001$) and the handholding condition ($t(195) = 3.88$, $p = .0001$) at one standard deviation below the mean of distraction.

The valence × condition × desired emotional closeness interaction remained significant in predicting intrusion trial accuracy rates ($\gamma_{17} = 2.20$, $t(195) = 2.31$, $p = .0217$), intrusion trial response time (γ_{17} = -116.92, $t(195) = -2.61$, p = .0099) and new trial response time (γ_{17} = -91.55, $t(195) = -3.30$, p = .0011). Thus, neither the comfort nor distraction that participants felt during the stress ball and handholding conditions appeared to account for the present findings.

Summary of Study 2 Findings

Although there was not a hypothesized valence × condition × desired emotional closeness interaction in predicting the intrusion effect, there were hypothesized valence × condition × desired emotional closeness interactions in predicting related task variables. Specifically, the effect of negative valence on intrusion trial accuracy and response times was no longer significant in the handholding condition at high levels of desired emotional closeness. A similar finding was evident in Study 1 in regards to intrusion trial response times, but it did not quite reach statistical significance. Longer response times and lower accuracy rates in intrusion trials likely reflect a difficulty in removing no longer relevant information from working memory. It is likely that maintaining this information in working memory makes it more difficult to determine that an intrusion probe is not from the relevant set, resulting in longer response times and more errors.

Additional analyses accounting for attachment style demonstrated that the present findings with desired emotional closeness are not better accounted for by attachment style. Analyses accounting for the comfort and distraction while holding either a stress ball or someone’s hand also provided evidence that the present findings are not an artifact of increased levels of distraction and decreased levels of comfort in the handholding condition compared to the stress ball condition.

General Discussion

Overall the findings from the two studies support the hypothesis that desired emotional closeness moderates the effect of the social regulation of emotion on the ability to update negative contents of working memory. In Study 1, there was a stronger effect of handholding on reducing the intrusion effect of negative images among people with higher levels of desired emotional closeness compared to those with lower levels of desired emotional closeness. There was also a trend for a similar interaction in predicting response times for trials with an intrusion probe. The primary goal of Study 2 was to investigate whether handholding reduced the effect of negative valence on the updating of negative contents of working memory. Although handholding did not reduce the effect of emotional content on intrusion as measured by the intrusion effect, it did when defining intrusion as lower accuracy rates and higher response times to intrusion trials. As expected, this effect was found among participants with higher levels of desired emotional closeness but not among those with lower levels of desired emotional closeness. Although the present findings broadly support the primary hypotheses, it is worth noting that the present evidence should be interpreted with some caution since the supporting evidence in Study 1 and Study 2 are not based on the identical outcome variables.

Interestingly, participants with high levels of desired emotional closeness appeared to benefit from the social regulation of emotion in terms being better able to remove negative contents of working memory, whereas participants with low levels of desired emotional closeness did not appear to benefit. In fact, the social regulation of emotion often resulted in worse intrusion from irrelevant information among people with low levels of desired emotional closeness. This finding suggests that not everyone may benefit from the social regulation of emotion and that benefiting from it is dependent on valuing close interactions highly. Flores and

Berenbaum (2012) also demonstrated reduced emotion regulation benefit from holding a stranger's hand among people with low desired emotional closeness. This finding is not limited, however, to interactions with strangers. People with low desired emotional closeness have also been found to benefit less – in regards to worry and depressive symptoms – from emotional closeness interactions in their daily lives (Flores & Berenbaum, 2014). Coan's (2008) social baseline theory posits that the presence of others signals that there are others to share the load of a threat and reduces risk perception. Perhaps those who do not highly value close relationships do not interpret the presence of others as supportive and, thus, do not experience a threat less severely. It is worth noting that the role of desired emotional closeness is not better accounted for by attachment style, which corroborates similar findings from previous studies (Flores & Berenbau, 2012; Flores & Berenbaum, 2014).

Handholding has been found to be an effective form of the social regulation of emotion in previous studies (Coan et al., 2006; Flores & Berenbaum, 2012). Study 1 mostly replicated these previous studies in that participants reported significantly lower levels of negative mood and not quite significantly lower levels of arousal in the handholding condition compared to the control condition. Study 2, however, did not demonstrate any reduction of self-report affective response to the emotional stimuli in the handholding condition compared to the control condition. Thus, it seems unlikely that the effect of handholding on updating working memory is due to a reduction in the subjective experience of emotion. Considering that handholding still had a differential effect between negative and neutral information in Study 2 on updating working memory, handholding does seem to affect the removal of negative contents of working memory via an emotion-specific mechanism.

Perhaps physiological measures of emotion may better elucidate mechanisms than subjective experience and observable expression of emotion. For example, Coan et al. (2006) demonstrated that handholding during a stressful situation alters neural activity in various brain regions broadly associated with emotion. In addition, physical touch increases levels of oxytocin (Field, 2010; Holt-Lunstad, Birmingham, and Light, 2008), which has been associated with decreases in arousal-related hormones (e.g., cortisol; Heinrichs et al., 2003; Neumann, 2002). Importantly, both psychosocial stressors and cortisol administration have been found to impair working memory (Lupien, Gillin, & Hauger, 1999; Morgan et al., 2006; Oei et al., 2006; Schoofs, Preuß, & Wolf, 2008). Lupien and Lepage (2001) assert that the deleterious effects of cortisol on working memory are attributed to increased activity of glucocorticoid receptors in the prefrontal cortex as a response to acute elevations of cortisol. Qin et al. (2009) found support for this assertion by demonstrating less working memory-related activity in the dorsolateral prefrontal cortex after an induced acute stressor. Potentially the increase in oxytocin from physical touch may decrease activity of glucocorticoid receptors in the prefrontal cortex and, thus, decrease the impairing effect of a stressor on working memory. Therefore, future studies examining the roles of physiological changes may be helpful in elucidating the mechanisms in which the social regulation of emotion alters working memory.

An essential component of Coan's (2008) social baseline theory is that the social regulation of emotion requires less energy expenditure to conduct compared to most intrapersonal emotion regulation strategies. An important benefit from less energy expenditure is that more resources are available for better handling the threat and other unrelated tasks. Although Coan et al. (2006) has demonstrated that the social regulation of emotion reduces activity in brain regions associated with emotion regulation (e.g., dorsolateral prefrontal cortex) during a stressful situation, research has yet to examine whether the social regulation of emotion facilitates improved cognitive functioning. The present studies contribute to this line of research by demonstrating that the social regulation of emotion can improve at least one kind of cognitive function – in this case the ability to update working memory effectively. Potentially the cognitive resources conserved by handholding may aid in effectively completing the cognitively taxing task of updating negative contents of working memory. Supporting this possibility is that activity in the dorsolateral prefrontal cortex, which is attenuated by handholding during stress (Coan et al., 2006), plays an important role in both emotion regulation and working memory. Future research is necessary to further elucidate the cognitive benefits that can result from the social regulation of emotion and whether energy conservation is one of the mechanisms of these benefits.

The results of the present study suggests that one of the various ways that social relationships help with dealing with stressors is by being better able to deactivate the memory of the stressor once it is no longer relevant. Keeping stressors active in working memory is adaptive when facing the stressor, but it is no longer necessary to maintain the stressor active in working memory once it has past. The present results suggests that the social regulation of emotion helps with removing the additional strength that negative stimuli often commands (Vuilleumier & Huang, 2009) once the information is no longer important (i.e., the intrusion trials) while not affecting the removal of negative information when it is still important (i.e., the relevant trials). Maintaining irrelevant negative information in working memory is considered to be a mechanism of rumination (Joormann & Gotlib, 2008). In addition, relationship satisfaction has been found to be negatively associated with rumination (Preacher, Watkins, Kuyken, & Mullan, 2010). Thus, social relationships may help reduce rumination via the effect of the social regulation of emotion on updating negative contents of working memory. Investigating this link more directly, however, is essential to better understand this potential relation.

Although the current study provides suggestive evidence that the social regulation of emotion improves updating negative contents of working memory among people with high levels of desired emotional closeness, the results are not sufficiently consistent to definitively conclude this effect of the social regulation of emotion. The lack of consistency may suggest a weak effect. Further replications are necessary to more firmly establish a relation between desired emotional closeness, the social regulation of emotion, and updating negative contents of working memory. Future studies may be aided by attempting to strengthen the effect. Potential modifications include using a close friend, romantic partner, or family member as the hand holder to strengthen the benefits of the social regulation of emotion (Coan et al., 2006). The addition of positive stimuli to the emotional working memory task would help to better understand how the social regulation of emotion affects other types of emotional stimuli. In addition, if the effect of the social regulation of emotion is more dependent on the valence of the emotional content rather than the level of arousal the content produces – regardless of the valence associated with the arousal – then the effect of valence may become stronger since positive and negative are at opposite ends of the valence spectrum and neutral is in between the two valence types (Russell & Barrett, 1999).

In summary, the present studies provide initial evidence that the social regulation of emotion can provide cognitive benefits, such as updating negative contents of working memory, and that its effect depends on high levels of desired emotional closeness. Further investigation is imperative to more strongly establish the present findings and to elucidate potential mechanisms, which do not appear to include the reduction of subjective experience of emotion.

CHAPTER 4

DISCUSSION

The findings from the present projects provide evidence for the ability of the social regulation of emotion, in the form of handholding, to alter two types of emotional memory. Chapter 2 demonstrated that the social regulation of emotion significantly reduced long-term memory for negative but not positive pictures. In Study 1 of Chapter 3, the social regulation of emotion helped improve the ability to update negative contents of working memory among individuals with high levels of desired emotional closeness. More specifically, the social regulation of emotion helped reduce the intrusion effect at high levels of desired emotional closeness and helped increase the intrusion effect at low levels of desired emotional closeness. In Study 2 of Chapter 3, there was a significant valence × condition × desired emotional closeness interaction. At high levels of desired emotional closeness, there was significantly more difficulty in updating working memory (as measured by higher intrusion trial response time and lower intrusion trial accuracy) for negative contents than neutral contents in a control condition but not in the handholding condition. The opposite pattern was evident at low level of desired emotional closeness.

Although handholding has previously been demonstrated to be an effective form of the social regulation of emotion (Coan et al., 2006; Flores & Berenbaum, 2012), only one (i.e., Study 1 of Chapter 3) of the three present studies replicated these findings in terms of reducing the strength of affective response (i.e., subjective experience of emotion). It is still possible, however, that handholding reduced affective response in all three of these studies in terms of physiological changes. For example, physical touch has been found to reduce arousal-related hormone concentrations (Field, 2010) and neural activity in several brain regions (e.g., ventral anterior cingulate cortex, posterior cingulate) found to be associated with affective responses

(Coan et al., 2006). Alternatively, handholding may still be considered to have been an effective form of the social regulation of emotion in the other two studies since handholding altered the effect of emotional stimuli on memory. Regardless, the present findings suggest that a reduction in affective response, at least as measured by self-report and facial expressivity, does not mediate the effect of handholding on emotional memory. Thus, further investigation of other potential mediators, such as emotion-related physiological changes, are needed to better understand how the social regulation of emotion affects emotional memory.

Unexpectedly, desired emotional closeness moderated the effect of the social regulation of emotion on updating negative contents of working memory but not emotional long-term memory. Desired emotional closeness has previously been found to also moderate the effect of the social regulation of emotion on emotional facial expressivity (Flores & Berenbaum, 2012) and worry and depressive symptoms (Flores & Berenbaum, 2014). It is currently unclear why desired emotional closeness did not moderate the effect of the social regulation of emotion on emotional long-term memory. Potentially, future research may suggest that desired emotional closeness does tend to moderate the effect of the social regulation of emotion on emotional long-term memory and that there are factors specific to this study (e.g., the sample, the stimuli) that contributed to the lack of a significant desired emotional closeness interaction. Alternatively, future studies might reveal that emotional long-term memory is one of several related outcomes in which the effect of the social regulation of emotion is not affected by desired emotional closeness. Overall, the significant role of desired emotional closeness in both of the studies in Chapter 3 provide further evidence that desired emotional closeness is important to consider when investigating benefits of the social regulation of emotion.

Given the conceptual and empirical association between desired emotional closeness and attachment avoidance, there was a possibility that attachment avoidance may better account for the present findings. Multilevel models in Chapter 2 and Study 2 of Chapter 3, however, demonstrated that attachment style did not moderate the effect of the social regulation of emotion on either emotional long-term memory or updating negative contents of working memory. In addition, the valence × condition × desired emotional closeness interaction in these models remained significant when predicting intrusion trial response times and was just shy of significance when predicting intrusion trial accuracy in Study 2 of Chapter 3. These findings corroborate previous research that attachment avoidance does not account for the role of desired emotional closeness in moderating the effectiveness of the social regulation of emotion (Flores & Berenbaum, 2012; Flores & Berenbaum, 2014). One key difference between desired emotional closeness and attachment style is that they differ in their emphasis on either a person's own behavior or the behaviors of others. Whereas desired emotional closeness focuses on how much someone wants others to conduct emotional closeness behaviors (Flores & Berenbaum, 2012), attachment avoidance emphasizes how much someone does or feels comfortable doing behaviors that affect attachment bonds (Shaver & Mikulincer, 2007). Given that the social regulation of emotion examined in the present studies and the previous studies mentioned (i.e., Flores & Berenbaum, 2012; Flores & Berenbaum, 2014) concern the behaviors of others, it is reasonable to expect desired emotional closeness to play a distinct and prominent role.

Coan's (2008) social baseline theory posits that the social regulation of emotion may result in cognitive benefits compared to intrapersonal strategies, like cognitive reappraisal, that require more energy expenditure to regulate emotions. The energy conservation from the social regulation of emotion allows more cognitive resources to be available for both related and unrelated tasks. Conserving energy is beneficial since cognitive resources available to self-regulation are limited even though they can become replenished (Muraven & Baumeister, 2000). Although Coan et al. (2006) has previously demonstrated that the social regulation of emotion reduces neural activity in the caudate and the right dorsolateral prefrontal cortex (which have been associated with emotion regulation), research has yet to investigate improvements in cognitive functioning. The present studies are the first to test this possibility. The two studies of Chapter 3 provide evidence of the social regulation of emotion facilitating the ability to update negative contents of working memory among people with high desired emotional closeness. Updating working memory is a cognitively taxing task, which may be made more taxing when the contents are negative and command more attention (Vuilleumier, 2005). Possibly, the cognitive resources conserved by the social regulation of emotion facilitates the improved performance in updating negative contents of working memory. Chapter 4 also suggests that the social regulation of emotion helps weaken memory for negative but not positive information. Since having a bias for negative memories is related to depression (see Gotlib & Joormann, 2010 for a review), the ability to weaken negative memories may be adaptive. Overall, the present studies demonstrate that the social regulation of emotion can at least affect emotional memory-related cognitive functions. Future research is needed to further understand what other cognitive benefits can result from the social regulation of emotion.

Previous research examining the effect of emotion regulation on memory has been mixed. Expressive suppression has been found to impair long-term memory (Dillon et al., 2007; Richards & Gross, 2000, 2006), and the cognitive reappraisal has been found to either improve or have no effect on long-term memory (Dillon, Ritchey, Johnson, & LaBar, 2007; Erk, von Kalckreuth, & Walter, 2010; Kim & Hamann, 2012; Richards & Gross, 2000). These differential effects are thought to be due to maladaptive expressive suppression – but not the adaptive cognitive reappraisal – having cognitive costs (Richards & Gross, 2000, 2006). Chapter 2 suggests that impaired long-term memory may be considered to be a desirable outcome and not just a result of a cognitively taxing and ineffective emotion regulation strategy (i.e., expressive suppression). The studies of Chapter 3 further add to the literature of emotion regulation and memory by providing evidence that emotion regulation can also affect features of working memory, such as the ability to update negative contents of working memory. Research had yet to investigate how emotion regulation could affect this particular working memory function.

Although research on other types of emotion regulation has highlighted the focus of conscious effort to determine its effect on memory, there are likely other important mechanisms for the effect of the social regulation of emotion on memory. A likely integral and relatively unique pathway may be changes to central oxytocin levels. Physical touch, for example, has been found to increase levels of oxytocin (Field, 2010; Holt-Lunstad, Birmingham, & Light, 2008), which has been demonstrated to reduce arousal-related hormones in humans and rodents (e.g., cortisol; Neumann, 2002; Heinrichs et al., 2003) and, subsequently, memory in rodents (Boccia, Kopf, & Baratti, 1998; Boccia & Baratti, 2000). It is worth noting that the Yerkes-Dodson law states that the effect of arousal on memory is better described as an inverted-U shape rather than linear (Yerkes & Dodson, 1908). Specifically, increases in arousal improve memory at lower levels of arousal, but increases in arousal impair memory at higher levels of arousal. This U-shaped curve has also been found in research on arousal-related hormones and memory (Gold & Van Buskirk, 1975). The present studies likely only reached arousal levels of the lower end of this curve. If the social regulation of emotion affects memory based on decreases in arousal-related hormones, it is likely that the social regulation of emotion may improve memory at much higher levels of arousal. Future research incorporating the roles of social- and arousal-related hormones would help establish whether hormone level changes serve as the mechanism for the effect of the social regulation of emotion on emotional memory.

Close relationships provide numerous benefits, including helping to cope with stress (Cohen et al., 2000) and protecting people against depression (Brown & Harris, 1978). Perhaps the social regulation of emotion that close relationships provide is a mechanism for these benefits. In addition, the effect of the social regulation of emotion on emotional memory may further help to cope with stressors and to prevent depression. Considering that people with depression tend to have a negative memory bias (Gotlib & Joormann, 2010), reducing this negative memory bias by reducing the strength of negative memories through the social regulation of emotion may be one way that close relationships help protect against depression. The social regulation of emotion may also help protect against depression by facilitating the removal of negative contents from working memory, which is considered to be a mechanism of rumination (Joormann & Gotlib, 2008). The present findings also suggest that these benefits, or at least some of these benefits, may be limited to those with high desired emotional closeness. Future research that directly connects memory-related benefits of the social regulation of emotion and clinical depression is essential to support these hypotheses. Longitudinal studies would especially be helpful to determine if often experiencing the social regulation of emotion in everyday life and benefiting greatly from the social regulation of emotion predicts lower levels of depressive symptoms.

Overall, the present studies provide evidence that the social regulation of emotion, in the form of handholding, helps weaken negative memories in both long-term memory and working memory. As with other benefits of the social regulation of emotion, these memory-related benefits may be dependent on having a high desire for emotional closeness. Although it is not yet clear what contributes to the effect of the social regulation of emotion on emotional memory, the present studies suggest that further research that attempts to elucidate mechanisms for this effect is worthwhile. In addition, future studies are needed to help establish how the effect of the social regulation of emotion on emotional memory may promote well-being.

FOOTNOTES

[1] Gender and ethnicity are not presented in order simplify the multilevel models. When included, gender, and ethnicity (i.e., comparing Asian and White participants due to the ethnic composition of the sample) did not significantly predict long-term memory or significantly interact with any of the other predictor variables.

[2] Random slopes were not included in the multilevel models – unless otherwise specified – due to final hessian and estimated G matrix not being positive definite when they were included for the majority of the models.

[3] Gender and ethnicity are not presented in order simplify the multilevel models. When included, gender did not significantly predict any of the working memory task variables or significantly interact with any of the other predictor variables. Although there were a couple of significant interactions including ethnicity (i.e., comparing Asian and White participants due to the ethnic composition of the sample) when it was included in the models, these interactions were not directly relevant to the primary hypotheses (e.g., significant interaction between ethnicity and desired emotional closeness in predicting accuracy of relevant trials in Study 1).

[4] Random slopes were not included in the multilevel models – unless otherwise specified – due to final hessian and estimated G matrix not being positive definite when they were included for the majority of the models.

[5] Follow-up simple slopes tests focusing on the slopes of condition rather than valence were also conducted to help make more of a direct comparison to the analyses of Study 1. These tests demonstrated that there were lower accuracy rates for intrusion trials in the handholding condition compared to the stress ball condition for negative ($t(195) = -7.06$, $p = .0302$) but not

neutral pictures (*t*(195) = -0.28, *p* = .7782) at one standard deviation above the mean of desired emotional closeness. In contrast, there was no significant difference in intrusion trial accuracy rates for either negative (*t*(195) = -0.08, *p* = .9338) or neutral pictures (*t*(195) = -0.93, *p* = .7723) at one standard deviation below the mean of desired emotional closeness.

[6] Follow-up simple slopes tests focusing on the slopes of condition rather than valence demonstrated that at one standard deviation above the mean of desired emotional closeness, the effect of the handholding condition in decreasing intrusion trial response times was just shy of statistical significance for negative pictures (*t*(195) = -1.74, *p* = .0837) and not significant for neutral pictures (*t*(195) = -0.68, *p* = .5003). The effect of condition was not significant for either negative (*t*(195) = 0.05, *p* = .9579) or neutral pictures (*t*(195) = 1.43, *p* = .1544) at one standard deviation below the mean of desired emotional closeness.

TABLES

Table 1

Correlations among Between-Participant Variables

	1	2	3	Mean (SD)
1. Desired Emotional Closeness	*.93*	0.10	-0.44***	5.0 (0.8)
2. Attachment Anxiety		*.91*	0.30***	3.3 (1.1)
3. Attachment Avoidance			*.90*	3.1 (1.0)

Note. Internal consistencies are italicized and reported along the diagonal.

*** $p < .001$.

Table 2

Descriptive Statistics of Memory Accuracy, Emotion Variables, and Stress ball/Handholding Experience

		Negative Images		Neutral Images		Positive Images	
Condition	Variable	Mean	SD	Mean	SD	Mean	SD
Stress Ball	Memory Accuracy	1.3	0.7	0.9	0.6	0.9	0.6
Handholding		1.1	0.7	0.8	0.7	0.9	0.6
Stress Ball	Self-Report Mood Valence	3.2	1.4	5.3	0.9	6.8	1.2
Handholding		3.1	1.5	5.3	0.9	6.7	1.2
Stress Ball	Self-Report Arousal	4.3	1.9	3.4	1.6	4.3	1.9
Handholding		4.4	2.0	3.4	1.7	4.4	1.9
Stress Ball	Facial Expressivity - Negative	0.8	0.9	0.5	0.6	0.3	0.3
Handholding		0.9	1.0	0.3	0.4	0.2	0.3
Stress Ball	Facial Expressivity - Positive	0.1	0.3	0.2	0.4	0.5	0.8
Handholding		0.1	0.3	0.2	0.4	0.4	0.6
		Stress Ball		Handholding			
		Mean	SD	Mean	SD		
	Self-Report Comfort	3.6	1.0	3.2	1.1		
	Self-Report Distraction	1.8	1.0	2.8	1.0		

Table 3

Associations among Memory Accuracy, Emotion Variables, and Self-Report Stress Ball/Handholding Experience

	2	3	4	5	6	7
1. Memory Accuracy	-0.08***	0.03**	0.18***	-0.05	0.05**	-0.06***
2. Self-Report Mood Valence		-0.04	-0.96***	0.99***	0.01	0.01
3. Self-Report Arousal			0.05	0.18†	0.00	0.14***
4. Facial Expressivity – Negative				-0.23***	0.03	-0.04*
5. Facial Expressivity – Positive					0.02	-0.04**
6. Self-Report Comfort						-0.32***
7. Self-Report Distraction						

Note. The scores reported above are unstandardized coefficient estimates (γ).

† $p < .10$. *$p < .05$. ** $p < .01$. *** $p < .001$.

Table 4

Coefficient Estimates for Multilevel Models Including Desired Emotional Closeness for Predicting Memory Accuracy

	Neutral Reference		Negative Reference	
Variable	Estimate	SE	Estimate	SE
Level 1 (Within-participant)				
Condition	-0.16***	0.05	-0.18***	0.05
Valence (Negative vs. Neutral)	0.38***	0.05	-0.38***	0.05
Valence (Positive vs. Neutral)	-0.03	0.05		
Valence (Positive vs. Negative)			-0.41***	0.05
Condition × Valence (Negative vs. Neutral)	-0.02	0.06	0.02	0.06
Condition × Valence (Positive vs. Neutral)	0.12†	0.06		
Condition × Valence (Positive vs. Negative)			0.14*	0.06
Level 2 (Between-participant)				
Intercept	0.93***	0.05	1.30***	0.05
Desired Emotional Closeness	0.04	0.05	-0.01	0.05
Desired × Condition	0.02	0.05	0.09†	0.05
Desired × Valence (Negative vs. Neutral)	-0.06	0.05	0.06	0.05
Desired × Valence (Positive vs. Neutral)	-0.01	0.05		
Desired × Valence (Positive vs. Negative)			0.05	0.05

Table 4 (cont.)

Desired × Condition × Valence (Negative vs. Neutral)	0.06	0.07	-0.06	0.07
Desired × Condition × Valence (Positive vs. Neutral)	0.00	0.07		
Desired × Condition × Valence (Positive vs. Negative)			-0.06	0.07

Note. Desired = Desired emotional closeness; SE = Standard error

† $p < .10$. * $p < .05$. *** $p < .001$.

Table 5

Coefficient Estimates for Multilevel Models Including Attachment Style for Predicting Memory Accuracy

	Neutral Reference		Negative Reference	
Variable	Estimate	SE	Estimate	SE
Level 1 (Within-participant)				
Condition	-0.16	0.05	-0.18***	0.05
Valence (Negative vs. Neutral)	0.38	0.05	-0.38***	0.05
Valence (Positive vs. Neutral)	-0.03	0.05		
Valence (Positive vs. Negative)			-0.41***	0.05
Condition × Valence (Negative vs. Neutral)	-0.02	0.06	0.02	0.06
Condition × Valence (Positive vs. Neutral)	0.12†	0.06		
Condition × Valence (Positive vs. Negative)			0.14*	0.06
Level 2 (Between-participant)				
Intercept	0.93***	0.05	1.31***	0.05
Attachment Anxiety (AttAnx)	-0.05	0.05	-0.01	0.05
Attachment Avoidance (AttAv)	0.00	0.05	0.09†	0.05
AttAnx × Condition	0.00	0.05	0.10*	0.05
AttAv × Condition	0.02	0.05	-0.10*	0.05
AttAnx × Valence (Negative vs. Neutral)	0.04	0.05	-0.04	0.05

Table 5 (cont.)

AttAnx × Valence (Positive vs. Neutral)	0.04	0.05		
AttAnx × Valence (Positive vs. Negative)			0.00	0.05
AttAv × Valence (Negative vs. Neutral)	0.08†	0.05	-0.08†	0.05
AttAv × Valence (Positive vs. Neutral)	-0.01	0.05		
AttAv × Valence (Positive vs. Negative)			-0.09†	0.05
AttAnx × Condition × Valence (Negative vs. Neutral)	0.10	0.07	-0.10	0.07
AttAnx × Condition × Valence (Positive vs. Neutral)	-0.01	0.07		
AttAnx × Condition × Valence (Positive vs. Negative)			-0.11	0.07
AttAv × Condition × Valence (Negative vs. Neutral)	-0.11†	0.07	0.11†	0.07
AttAv × Condition × Valence (Positive vs. Neutral)	-0.07	0.07		
AttAv × Condition × Valence (Positive vs. Negative)			0.04	0.07

Note. AttAnx = attachment anxiety; AttAv = attachment avoidance; SE = standard error

† $p < .10$. * $p < .05$. *** $p < .001$.

Table 6

Coefficient Estimates for Multilevel Models Including Comfort and Distraction for Predicting Memory Accuracy

	Negative Reference		Neutral Reference	
Variable	Estimate	SE	Estimate	SE
Level 1 (Within-participant)				
Condition	-0.16**	0.06	-0.09	0.06
Valence (Neutral vs. Negative)	-0.41***	0.05	0.41***	0.05
Valence (Positive vs. Negative)	-0.44***	0.05		
Valence (Positive vs. Neutral)			-0.03	0.05
Comfort	0.05	0.04	0.04	0.03
Distraction	0.00	0.04	-0.04	0.04
Condition × Valence (Neutral vs. Negative)	0.08	0.08	-0.08	0.08
Condition × Valence (Positive vs. Negative)	0.18*	0.08		
Condition × Valence (Positive vs. Neutral)			0.10	0.08
Comfort × Condition	-0.04	0.04	-0.04	0.04
Distraction × Condition	-0.01	0.04	-0.01	0.04
Comfort × Valence (Neutral vs. Negative)	0.00	0.04	0.00	0.04
Comfort × Valence (Positive vs. Negative)	0.04	0.04		
Comfort × Valence (Positive vs. Neutral)			0.00	0.04
Distraction × Valence (Neutral vs. Negative)	-0.05	0.04	0.05	0.04

Table 6 (cont.)

Distraction × Valence (Positive vs. Negative)	-0.02	0.04		
Distraction × Valence (Positive vs. Neutral)			0.02	0.04
Level 2 (Between-participant)				
Intercept	1.30***	0.05	0.89***	0.05

Note. SE = standard error

* *p* < *.05*. ** *p* < *.01*. *** *p* < *.001*.

Table 7

Descriptive Statistics of Affective Variables in Study 1

	Control		Handholding	
Variable	M	SD	M	SD
Mood Valence	4.3	2.2	4.6	2.0
Arousal	4.3	2.1	4.0	1.9
Facial Expressivity	1.1	0.9	1.1	0.9

Note. Lower values of mood valence indicate more negative mood.

Table 8

Multilevel Models Predicting Affective Variables in Study 1

	Mood Valence		Arousal		Facial Expressivity	
	Coef.	SE	Coef.	SE	Coef.	SE
Intercept	4.30***	0.19	4.26***	0.19	1.14***	0.09
Condition	0.34**	0.12	-0.24+	0.14	0.00	0.07
Desired	-0.58**	0.19	-0.02	0.19	0.12	0.09
Cond*Desired	0.14	0.12	0.05	0.14	-0.08	0.06

Note. Lower values of mood valence indicate more negative mood. Coef. = Coefficient estimate; SE = Standard error; Desired = Desired Emotional Closeness; Cond = Condition.

Table 9

Accuracy and Response Times on Emotional Working Memory Task in Study 1

	Stress ball			Handholding		
Probe	M	SD	%	M	SD	%
Relevant	1,114	366	90	1,132	384	91
Intrusion	1,362	426	83	1,342	473	79
New	984	317	98	951	303	97
Intrusion Effect	378	301		385	294	

Table 10

Associations Between Task and Affective Variables in Study 1

	2	3	4	5	6	7	8	9	10
1. Acc - Rel	0.16***	0.13	0.00	0.00	0.00	0.00	0.60	-0.30	1.49
2. Acc - Int		0.34†	0.00	0.00	0.00	0.00	-0.06	-0.38	0.87
3. Acc - New			-0.002†	-0.003*	-0.004**	0.00	-0.34	-0.01	0.13
4. RT - Rel				0.65***	0.87***	0.45***	-4.89	2.28	14.24
5. RT - Int					1.01***	0.93***	16.26	11.08	-6.69
6. RT - New						-0.07	-2.80	27.20	-11.83
7. Intrusion Eff							21.26*	-8.28	17.12
8. Mood Val								-0.27***	-0.11
9. Arousal									-0.01
10. Facial									

Note. The scores reported above are unstandardized coefficient estimates (γ). Lower values of mood valence indicate more negative mood. Acc = Accuracy; RT = Response times; Rel = Relevant trials; Int = Intrusion trials; Intrusion Eff = Intrusion effect; Mood Val = Mood Valence; Facial = Facial expressivity.

† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table 11

Multilevel Models Predicting Accuracy Rates in Study 1

	Accuracy - Relevant		Accuracy - Intrusion		Accuracy - New	
	Coef.	SE	Coef.	SE	Coef.	SE
Level 1						
Condition	0.61	1.12	-3.75*	1.77	-0.54	0.63
Level 2						
Intercept	90.14***	1.12	82.87***	1.51	97.78***	0.60
Desired	0.47	1.12	1.42	1.51	0.20	0.60
Cond*Desired	-1.53	1.12	-2.75	1.77	-0.55	0.63

Note. Level 1 includes within-participant coefficients and Level 2 includes between-participant coefficients. Coef. = Coefficient estimate; SE = Standard error; Cond = Condition; Desired = Desired Emotional Closeness.

*$p < .05$. *** $p < .001$.

Table 12

Multilevel Models Predicting Response Times in Study 1

	RT - Relevant		RT - Intrusion		RT - New		Intrusion Effect (RT Int – RT New)	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Level 1								
Condition	21.83	29.71	-17.64	33.74	-24.07	20.46	4.46	31.30
Level 2								
Intercept	1113.96***	35.86	1362.06***	42.66	983.66***	30.12	378.40***	28.19
Desired	2.10	35.83	42.00	42.75	20.63	30.18	21.38	28.25
Cond*Desired	-39.49	29.53	-56.03†	33.74	9.74	20.48	-67.01*	31.27

Note. Level 1 includes within-participant coefficients and Level 2 includes between-participant coefficients. RT = Response times; Int = Intrusion trials; Coef. = Coefficient estimate; SE = standard error; Cond = Condition; Desired = Desired Emotional Closeness.

† $p < .10$. *$p < .05$. *** $p < .001$.

Table 13

Participant Characteristics of Study 2

	Stress ball Condition	Handholding Condition
N (% female)	99 (62)	96 (60)
Age	19.8 (1.4)	19.7 (1.1)
Race/Ethnicity (%)		
Asian	39	45
Black	7	6
Latino	9	15
White	44	31
Other or multiracial	1	3
Desired Emotional Closeness	5.2 (0.7)	5.0 (0.8)
Attachment Anxiety	3.4 (1.1)	3.4 (1.1)
Attachment Avoidance	3.2 (1.0)	3.4 (1.2)

Table 14

Correlations between Desired Emotional Closeness and Attachment Style in Study 2

	1	2	3
1. Desired Emotional Closeness	*.94*	.12	-.48***
2. Attachment Anxiety		*.91*	.36***
3. Attachment Avoidance			*.93*

*** $p < .001$.

Table 15

Affective Variables and Comfort/Distraction Descriptive Statistics for Study 2

		Stress ball		Handholding	
Valence	Variable	M	SD	M	SD
Negative	Mood Valence	3.4	1.5	3.3	1.7
Neutral		5.5	1.1	5.4	1.1
Negative	Arousal	4.6	1.9	4.2	2.0
Neutral		3.7	1.7	3.3	1.6
Negative	Facial Expressivity	1.0	1.0	0.9	1.0
Neutral		0.4	0.5	0.4	0.6
	Comfort	3.3	0.8	3.1	1.0
	Distraction	1.7	0.9	2.2	1.0

Table 16

Multilevel Models Predicting Affective Variables in Study 2

	Mood Valence		Arousal		Facial Expressivity	
	Coef.	SE	Coef.	SE	Coef.	SE
Level 1						
Valence	-2.13***	0.17	0.85***	0.21	0.60***	0.10
Level 2						
Intercept	5.37***	0.15	3.67***	0.21	0.39***	0.09
Condition	-0.01	0.21	-0.43	0.31	0.05	0.14
Desired	-0.04	0.16	-0.02	0.23	-0.01	0.10
Val*Cond	-0.16	0.24	0.18	0.31	-0.10	0.14
Val*Desired	-0.28	0.18	0.39†	0.23	-0.03	0.11
Cond*Desired	0.24	0.21	0.26	0.31	0.08	0.14
Val*Cond*Desired	-0.01	0.24	-0.42	0.30	0.21	0.14

Note. Level 1 includes within-participant coefficients and Level 2 includes between-participant coefficients. Lower values of mood valence indicate more negative mood. Coef. = Coefficient estimate; SE = standard error; Val = Valence; Cond = Condition; Desired = Desired emotional closeness

† $p < .10$. *** $p < .001$.

Table 17

Descriptive Statistics of Study 2 Emotional Working Memory Task

		Stress ball			Handholding		
Valence	Probe	M	SD	%	M	SD	%
Negative	Relevant	1,288	379	92	1,189	325	89
Neutral		1,205	359	93	1,130	314	93
Negative	Intrusion	1,553	462	81	1,458	482	77
Neutral		1,443	467	86	1,341	407	86
Negative	New	1,145	333	98	1,045	274	98
Neutral		976	252	98	943	261	99
Negative	Intrusion Effect	407	304		413	357	
Neutral		467	311		398	290	

Table 18

Associations Between Task and Affective Variables in Study 2

	2	3	4	5	6	7	8	9	10	11	12
1. Acc - Rel	0.17***	0.17†	-0.004*	0.00	0.00	0.00	0.68*	-0.62*	-1.24†	0.15	-0.18
2. Acc - Int		0.22	0.00	-0.01***	-0.01*	-0.01**	2.02***	-1.70***	-3.48**	-1.63	-0.33
3. Acc - New			0.00	0.00	0.00	0.00	0.03	-0.19	0.23	-0.13	0.13
4. RT - Rel				0.49***	0.75***	0.26***	-15.98*	18.01*	13.14	-38.22	-14.08
5. RT - Int					1.01***	0.95***	-26.99**	15.80	23.88	-6.18	-40.39
6. RT - New						-0.05	-29.86***	12.61	43.67*	-9.85	-14.08
7. Intrusion Eff							9.26	1.02	-33.81	3.67	-26.32
8. Mood Valence								-0.29***	-0.68***	0.29*	-0.29**
9. Arousal									0.49***	0.00	0.13
10. Facial										-0.03	0.13*
11. Comfort											r = -.30***
12. Distraction											

Table 18 (cont.)

Note. Lower values of mood valence indicate more negative mood. Acc = Accuracy; RT = Response times; Rel = Relevant trials; Int = Intrusion trials; Intrusion Eff = Intrusion effect; Facial = Facial expressivity.

† $p < .10$. *$p < .05$. ** $p < .01$. *** $p < .001$.

Table 19

Multilevel Models Predicting Accuracy Rates in Study 2

	Accuracy - Relevant		Accuracy - Intrusion		Accuracy - New	
	Coef.	SE	Coef.	SE	Coef.	SE
Level 1						
Valence	-1.14	1.26	-5.12***	1.48	-0.01	0.61
Level 2						
Intercept	92.95***	1.04	86.30***	1.67	97.87***	0.56
Condition	0.20	1.47	-0.60	2.27	0.90	0.79
Desired	-0.93	1.12	-0.99	1.73	0.22	0.60
Val*Cond	-3.35+	1.80	-2.48	2.13	-1.03	0.87
Val*Desired	-0.37	1.37	-0.11	1.62	0.14	0.66
Cond*Desired	0.21	1.49	-0.33	2.29	-0.38	0.80
Val*Cond*Desired	-0.20	1.82	4.31*	2.15	-0.18	0.88

Note. Level 1 includes within-participant coefficients and Level 2 includes between-participant coefficients. Val= Valence; Cond = Condition; Desired = Desired emotional closeness.

*$p < .05$. *** $p < .001$.

Table 20

Multilevel Models Predicting Response Times and Intrusion Effect in Study 2

	RT - Relevant		RT - Intrusion		RT - New		Intrusion Effect (RT Int – RT New)	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Level 1								
Valence	81.19**	27.12	100.38**	30.31	164.36***	18.94	-63.98*	30.69
Level 2								
Intercept	1199.82***	34.30	1440.51***	45.43	975.13***	27.93	465.38***	31.71
Condition	-63.39	48.85	-93.82	64.70	-24.15	39.78	-69.67	45.16
Desire	49.63	37.18	19.36	49.25	8.21	30.28	11.15	34.37
Val*Cond	-22.11	38.62	14.38	43.16	-66.29*	26.97	80.68†	43.71
Val*Des	14.68	29.40	92.79**	32.85	50.62*	20.53	42.17	33.27
Cond*Des	5.55	49.35	34.17	65.37	64.25	40.19	-30.09	45.63
Val*Cond*Des	-12.99	39.02	-118.65**	43.61	-89.64**	27.25	-29.01	44.16

Note. Level 1 includes within-participant coefficients and Level 2 includes between-participant coefficients. RT = Response times; Int = Intrusion trials; Val= Valence; Cond = Condition; Des = Desired emotional closeness.

† $p < .10$. *$p < .05$. ** $p < .01$. *** $p < .001$.

FIGURES

Figure 1. Graph based on multilevel model predicting memory accuracy.

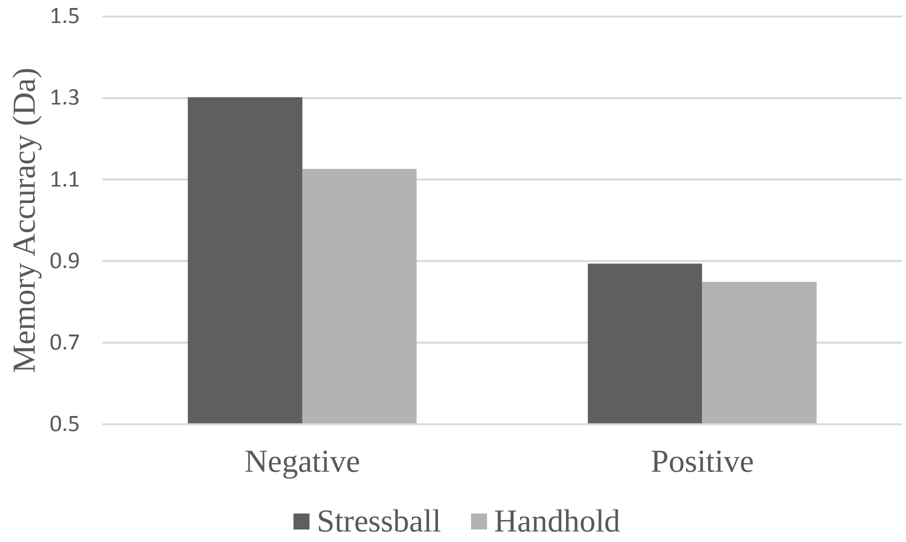


Figure 2. Example of an intrusion trial in the emotional working memory task.

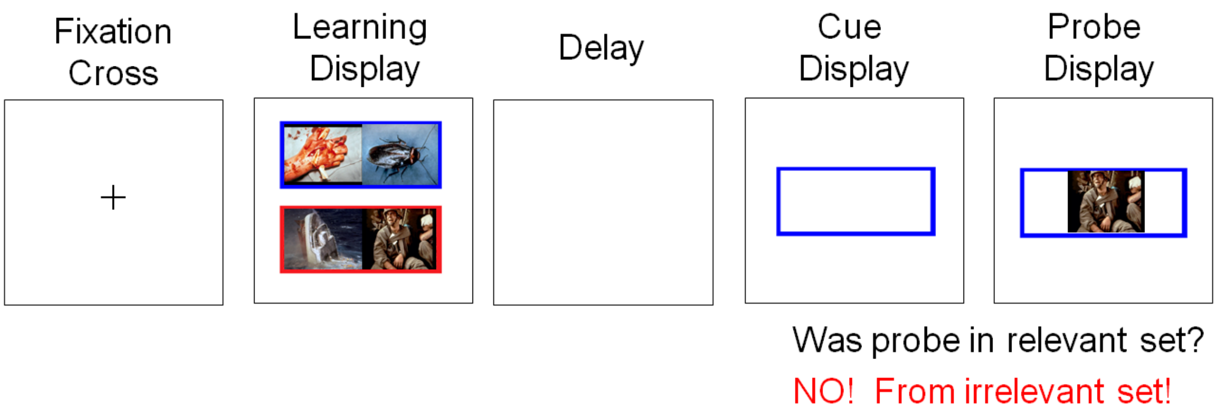


Figure 3. Graph based on multilevel model in Study 1 predicting intrusion effect at one standard deviation above and below the mean of desired emotional closeness.

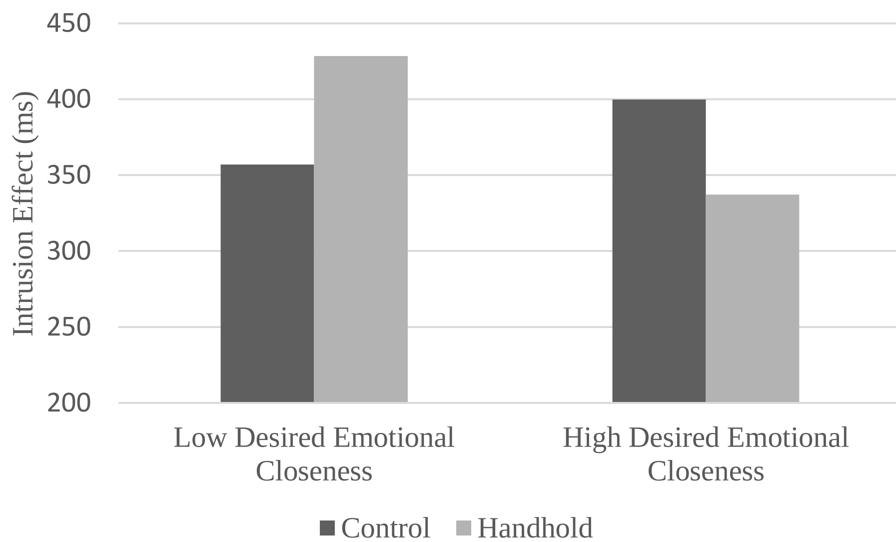


Figure 4. Graph based on multilevel model in Study 2 predicting intrusion trial accuracy rates at one standard deviation above and below the mean of desired emotional closeness.

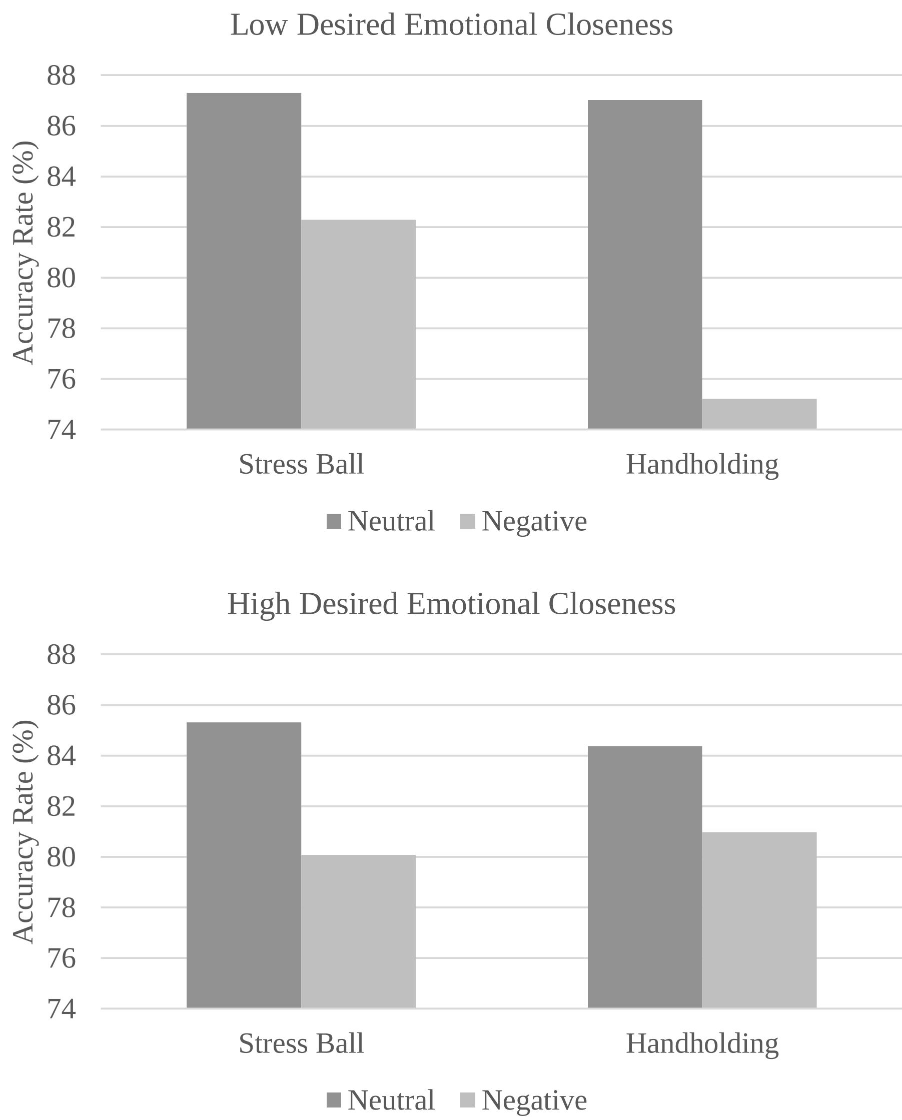


Figure 5. Graph based on multilevel model in Study 2 predicting intrusion trial response times at one standard deviation above and below the mean of desired emotional closeness.

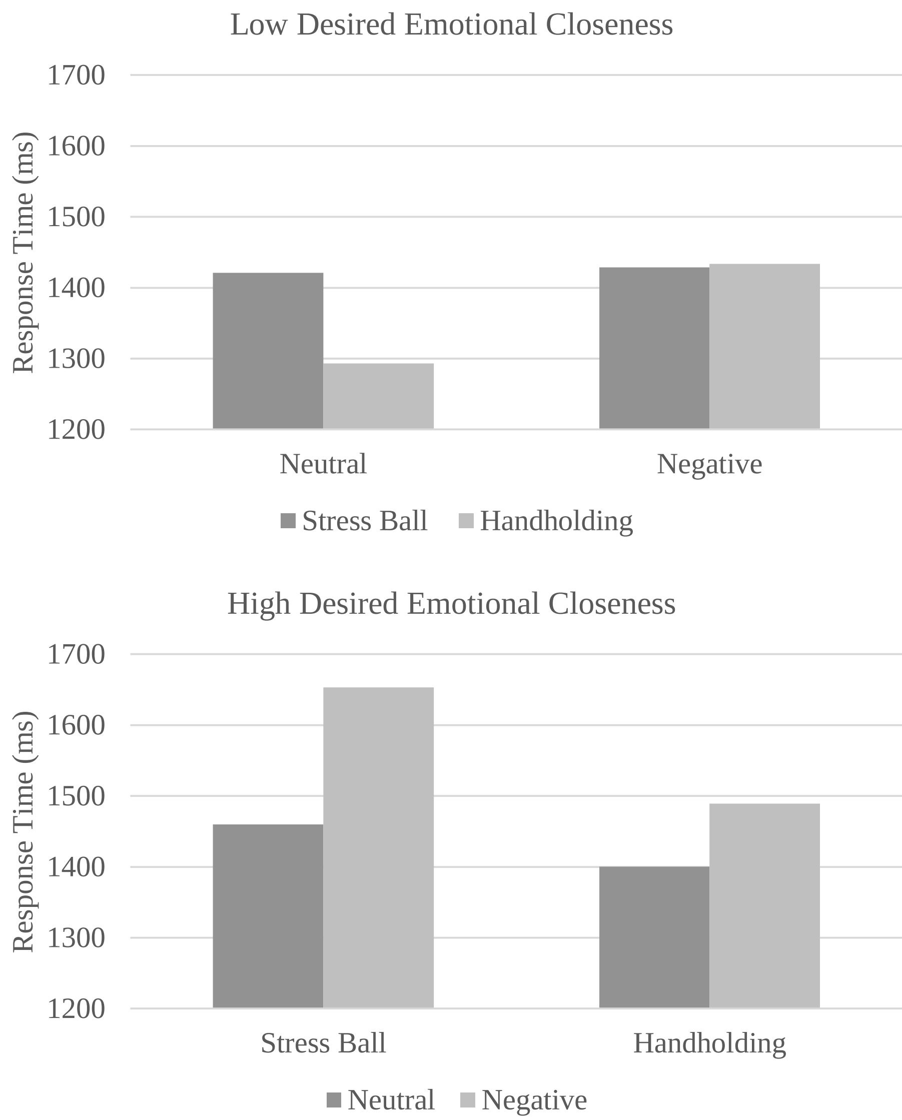


Figure 6. Graph based on multilevel model in Study 2 predicting new trial response times at one standard deviation above and below the mean of desired emotional closeness.

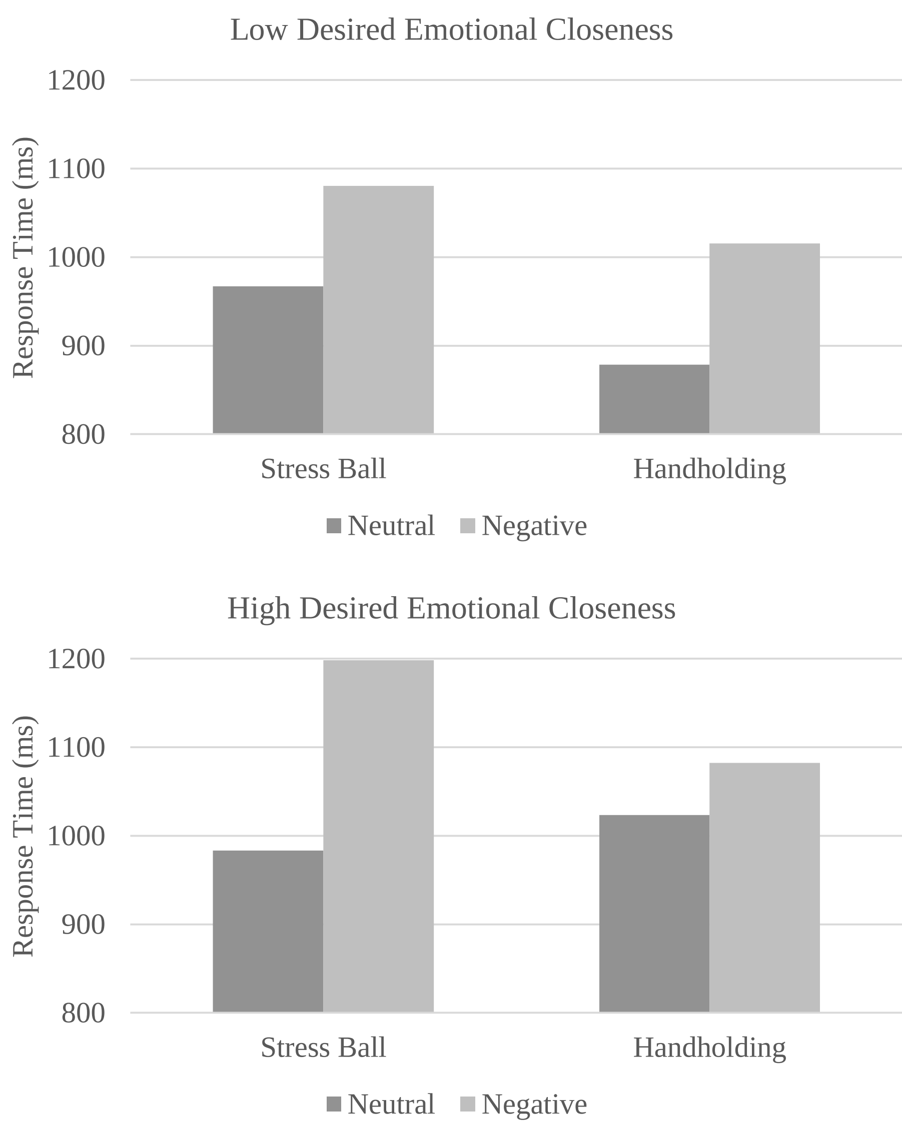
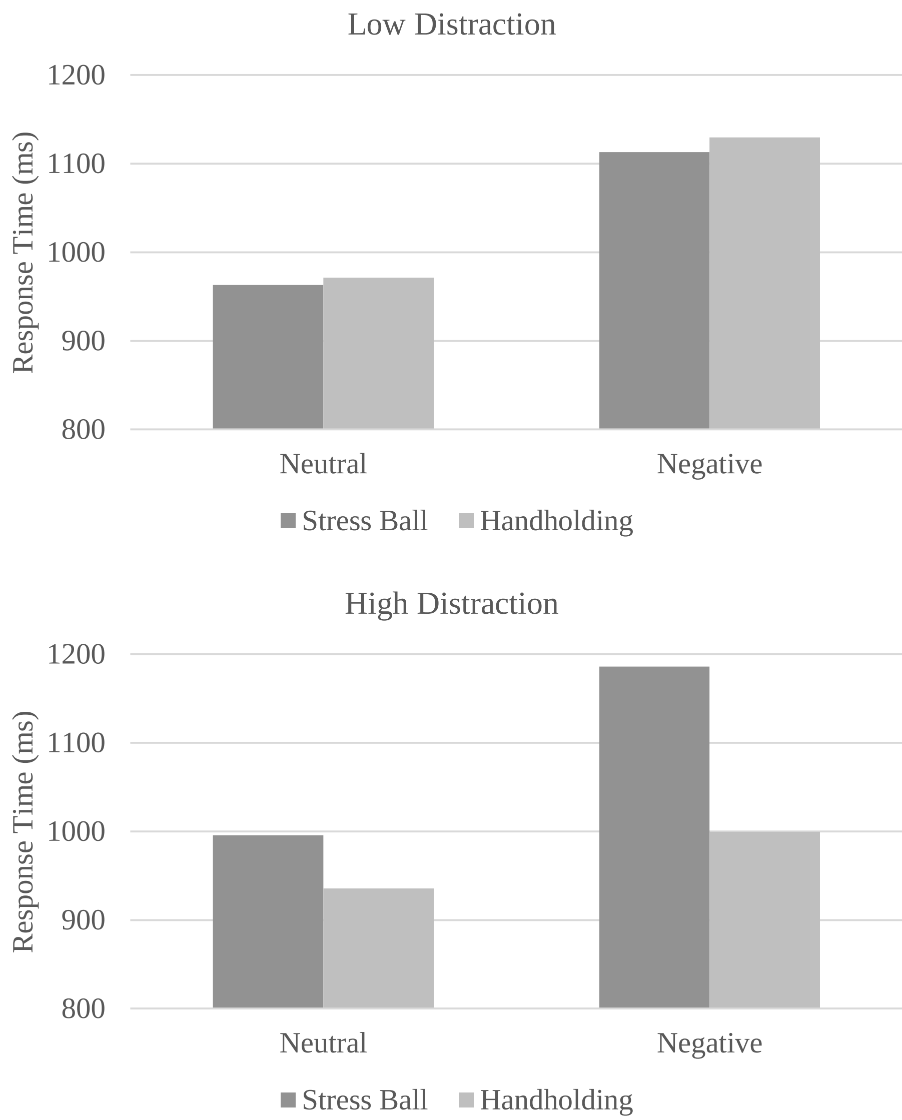


Figure 7. Graph based on multilevel model in Study 2 predicting new trial response times at one standard deviation above and below the mean of desired emotional closeness.



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