NEGATIVE EMOTION ENHANCES GIST: EVIDENCE FROM PICTURE RECOGNITION

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ABSTRACT

Although there has been prior work on how true and false memory are influenced by emotional valence and arousal, they have often been confounded. Thus, it is difficult to say whether specific effects are due to valence, arousal, or both. In the present research, I used a picture-memory paradigm that allowed emotional valence to be manipulated with arousal held constant. Negatively-valenced pictures elevated both true and false memory relative to positive and neutral pictures. Conjoint recognition modeling analyses revealed that negative valence (a) reduced erroneous recollection rejection for true memory and phantom recollection for false memory but (b) increased familiarity for both. Thus, negative valence reduced distortion in some ways but increased it in others, which cannot be detected without models that separate the effects of different retrieval processes. Discrete emotion analyses revealed that sadness increased false memory compared to joy, fear, and disgust due to elevated levels of familiarity. These data are consistent with the view that emotional valence strengthens conceptual gist that enhances the familiarity of presented and unpresented material.

BIOGRAPHICAL SKETCH

Sarah Bookbinder was born on June 10th, 1988 in New Haven, Connecticut and grew up in New Canaan, Connecticut. She attended Hamilton College where she received a Bachelor of Arts in psychology in 2010. After graduating she worked as a mental health worker at a psychiatric hospital in upstate New York, followed by several jobs in Connecticut and New York City before deciding to pursue a graduate career. She enrolled in Cornell University's graduate program in the Department of Human Development in the fall of 2012, where she is pursuing a doctorate degree. Her current work is focused on the relationship between emotion and false memory through a process-based approach. She hopes to pursue a career in academia, continuing this line of research while focusing on her passion for teaching.

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Overview

Personal experience and intuition tell us that our emotions affect the strength of our memories: it is typically easier to remember a birthday party or a funeral than what kind of sandwich one ate for lunch. For decades researchers have been interested in the way we remember emotional content and a particularly controversial line of focus within this research lies in the impact of emotion on false memory. As emotion affects memory for true events, it may similarly affect the presence of memory distortions and false memories based on the remembered emotional content or the mood of the rememberer. The importance of fully understanding the connection between emotion and false memory becomes particularly clear when one considers situations such as legal cases when the to-be-remembered event is highly emotionally charged and when one's memory is the only available record of the event. Basing decisions such as a conviction or length of a sentence on one or just a few eyewitness reports is risky when such reports have been shown to be unreliable, as will be discussed, and prone to false memory. However, there have been conflicting data in regards to exactly how emotion influences false memory: sometimes emotional *content* appears to increase false memory and on other occasions it seems to reduce it, whereas emotional *moods* have completely different effects. In the eyewitness case, emotional content, mood, or both could be at play. These differences in effects could be due to factors such as the confounding of emotional valence and arousal as well as variation in the types of stimuli and methodology used. The present study sought to further clarify the memory-emotion relationship by disentangling valence and arousal, identifying factors that moderate the way valence affects false memory, and identifying the underlying memory processes that valence influences.

Emotion and Episodic Memory

Prior to reviewing the extant literature regarding the relationship between emotion and episodic memory, I want to clarify precisely what I mean when I refer to "emotion;" that is, what are the different ways one can think about emotions theoretically and what are they ways one can manipulate those conceptions experimentally?

Conceptualizations of emotion. Russell (1991) proposed the circumplex model of emotion, suggesting a two-dimensional space containing emotions that are free to vary continuously on scales of both valence and arousal. Valence ranges from unpleasant to pleasant, reflecting the positivity or negativity of the emotion, whereas arousal ranges from calm to exciting, reflecting the intensity of the emotion. Other similar models have defined valence in other ways--as approach and withdrawal (Lang, Bradley, & Cuthbert, 1998) or positivity and negativity (Tellegen, Watson, & Clark, 1999)--but each model shares the same idea that two dimensions contribute to affective states. Later models (e.g., Bradley, Lange, & Cuthbert, 1999) have integrated a third dimension such as dominance, but the valence and arousal components remained. Although we have specific words and conceptualizations for individual emotions, several emotions are often experienced at the same time and different emotions may evoke similar physiological states, suggesting that emotions are not truly distinct. Emotions can be conceived of as any combination of possible values on the two aforementioned continuous scales and are thought to be caused by activation of two distinct yet connected neurological systems. Support for this two-systems approach comes from findings that, in terms of valence, the mesolimbic system is not only associated with both pleasure but also with displeasure, suggesting a unified system for the perception of valence (e.g., Diana, Pistis, Muntoni, & Gessa, 1996). As for arousal, it is now well known that the amygdala plays a role in arousal (e.g., Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003) and it seems that it works within the reticular network to control the arousal dimension of the model. Furthermore, additional evidence suggests that the amygdala is particularly sensitive to negative information via both episodic memory consolidation as well as perceptual encoding (Anderson and Phelps, 2001). In sum, there is much support for Russell's circumplex model of emotion, not only in the context of outward experience of emotion but also neurologically.

The theory of discrete emotions, however, suggests a slightly different view (e.g., Ekman, 1992). Discrete emotion theories suggest that each emotion is distinct from all others, has evolved for a particular function that is separate from those of other emotions, that these purposes are universal and biological, and that there are a finite number of these discrete emotions. Each emotion is thought to arise from an identifiable neurological pattern coupled with its own physiological expression. Most notably, facial expression research has been conducted to demonstrate this universality, providing evidence that different cultures express emotions similarly (e.g. Ekman & Friesen, 1971) and different emotional states can be differentiated by separate activity of the autonomic nervous system (e.g., Ekman, Levenson & Friesen, 1983).

In short, experimental evidence supports both discrete and continuous views of emotion, which may explain the development of theories that sought to combine the two views. One such theory, the psychoevolutionary theory (Plutchik, 2001), proposes that there are eight basic emotions, but that each represents a dimension in which there are many variations and which can be combined with others, as one might mix colors on a color wheel. Continuing the color analogy, one might say that there is a set number of basic colors (e.g., red, blue, yellow, orange, green, and purple) but that there are many variations of each of those colors as well as combinations among them (e.g., yellow-red, light blue, violet). We could make comparisons among the basic colors (e.g, red versus blue), we could make comparisons based on particular aspects of colors (e.g., brightness: light blue versus dark blue), or we could compare among colors that are similar in terms of a dimension of interest (e.g., low brightness: light blue vs. light purple). In Plutchik's view, we can look at emotions in the same way. We may compare basic emotions, but we could also compare the valence or intensity overall, or compare basic emotions within a given level of valence or arousal. Further support for this sort of combined model has been provided through computer recognition of facial expressions of emotions. In one such study (Susskind, Littlewort, Bartlett, Movellan, & Anderson, 2007) computers were able to recognize emotions as humans do, by recognizing discrete emotions as well as similarities among them suggestive of broader, continuous dimensions. The present study utilized all three means of comparison to investigate in detail how emotion affects true and false memory.

Experimental evidence. Experimentally, researchers have been interested in the effects of the emotionality of stimuli or the mood of participants, or, in some experiments, both (e.g., Ruci, Tomes, & Zelenski, 2009). Of particular relevance to the present study, emotion can affect memory in either form or in combination. This distinction is important to make for the purposes of the present study because content and mood effects on memory are not always the same given the same levels of valence and arousal and therefore mood effects may not predict content effects and vice versa.

Continuous emotions. Turning first to the idea of emotion-as-content, studies using continuous emotions (i.e., researchers compared general levels of valence and arousal as opposed to distinct emotions), many researchers have found enhanced memory for emotional content as compared to neutral content for stimuli that range from words to pictures to videos (e.g., Budson, Todman, Chong, Adams, Kensinger, Krangel, & Wright, 2006; Charles, Mather, & Carstensen, 2003; Maras, Gaigg, & Bowler, 2012, respectively). As will be discussed in more detail in a later section, valence and arousal were often confounded in such studies, resulting in enhanced memory for positive and negative arousing content compared to neutral, nonarousing content, which makes it difficult to conclude whether the memory enhancement for emotional stimuli is a result of valence, arousal, or both.

Furthermore, in addition to the valence-arousal confound, positive valence has often been ignored altogether. For example, Kensinger (e.g, Kensinger & Corkin, 2004; Kensinger & Schacter, 2007) has explored negative emotion extensively by comparing negative arousing stimuli with neutral stimuli, demonstrating greater recognition for negative arousing items compares to neutral items. This difference has been attributed to an arousal-induced memory enhancement and has been corroborated by other research demonstrating enhanced memory for arousing content (e.g., Block, Greenberg, & Goodman, 2009). Ignoring positive emotions has certainly not been an oversight. It is clearly of great importance to focus research on the high-stakes situations mentioned previously, such as legal cases, when moods and to-be remembered information are usually negative and arousing. However, the lack of inclusion of positive stimuli leaves unclear whether this arousal-induced memory enhancement functions the same way for both positive and negative stimuli.

Brainerd, Stein, Silveira, Rohenkohl, and Reyna (2008), however, provide evidence that even when arousal is controlled, valence affects memory. Using emotional word lists with equal arousal levels, they demonstrated that true memory was highest for negative words and lowest for positive words, suggesting that arousal is in fact not a necessary component of the emotional enhancement of memory. Other researchers have addressed the confound problem through factorial manipulation of valence and arousal. Van Damme and Smets (2014) found that negative valence reduced memory for peripheral details of pictures but arousal increased memory for central details, suggesting combined effects of valence and arousal on memory, but that the two dimensions may affect different components of the memory in different ways. Similarly, Brainerd, Holliday, Reyna, Yang, and Toglia (2010) demonstrated a valence-arousal interaction such that memory was better for arousing than nonarousing words and this effect was strengthened for positive compared to negative words. These findings from Van Damme and Smets and Brainerd et al., at least, seem to be in line with Kensinger's demonstration of an arousal-based memory enhancement, suggesting that when arousal is manipulated it always affects memory, but when it is held constant, the valence effect remains.

The continuous conceptualization of emotion has been applied to mood studies as well; however, induced mood does not appear to affect memory the way emotional content does. Storbeck (2013) induced positive and negative affect using music (arousal was not mentioned), but found no differences in word memory. Similarly, Van Damme (2013) manipulated both valence and arousal in her mood induction but found no effect of either on true recall or recognition of words. That being said, negative mood can provide a memory disadvantage when it is natural, rather than induced. For example, Emery and Hess (2012) compared positive and negative moods induced using video clips to natural positive and negative moods and found reduced word recall for adults whose natural mood was negative even though induced mood did not affect recall. This evidence of both a lack of effect (when experimenters induce affect in participants) and a reverse effect (when natural mood is measured), compared to emotional content studies, further demonstrates the wide range of effects of emotion depending on the form it takes and the experimental manipulations chosen as well as demonstrates that we cannot necessarily apply what we know about emotional mood to predict emotional content effects.

Discrete emotions. The relationship between discrete emotional content and memory has commonly been studied using facial expressions as stimuli. In line with the research previously discussed regarding continuous emotions, there tends to be a memory advantage for negative facial expressions compared to neutral ones. For example, Jackson, Wu, Linden, and Raymond (2009) compared visual short term memory for angry, happy, and neutral faces, and found an advantage for recognizing neutral faces that had made angry expressions as compared to those that had made neutral and happy expressions. Wang (2013) similarly found greater recognition accuracy for angry faces than happy faces. Righi et al. (2012) found a memory advantage for fearful expressions as compared to happy and neutral faces, further substantiating the idea that negative emotion enhances memory, although the results from these two studies leave unexplained whether there is a general advantage for negative facial expressions or whether discrete negative emotions have different effects. A study that compared memory for both angry and fearful faces might provide insight into whether distinct emotions function uniquely or whether general valence levels can sufficiently explain these effects.

When it comes to inducing discrete moods, there does not appear to be a comparable negative memory enhancement. For example, Corson and Verrier (2007) induced discrete positive and negative moods with varying levels of arousal (happy, serene, angry, and sad) and tested memory for neutral word lists, with no effects of mood on memory. Storbeck and Clore (2011) similarly did not find effects of induced discrete emotions (happy, sad, and neutral) on memory for neutral words. Van Damme (2013) used music and guided imagery to induce eight different moods (serene, happy, sad, angry, and neutral) and similarly found no effects. Taken together, these results suggest that mood induction, both in the form of continuous and discrete moods, and furthermore regardless of the types of discrete moods chosen, does not affect true memory as emotional content does.

Within-valence comparisons. To address the question of whether negative valence in general or specific negative emotions drives memory effects, a handful of researchers have made comparisons among discrete emotions of the same valence. In the case of content, Talarico, Berntsen, and Rubin (2009) compared recall of participant-generated positive and negative arousing and nonarousing autobiographical events. They found that out of all 8 emotions (positive surprise, happy, calm, in love, sad, negative surprise, afraid, and angry) anger produced recall of the fewest peripheral details. The authors noted that recall of peripheral details for anger-inducing events was lower than that of fear-inducing events, although a significance test was not reported. Thus, this research hints toward differences among negative emotions without a direct and concrete comparison.

In the case of mood, Levine and Burgess (1997) also attempted to compare discrete emotions, but only those of negative valence. They measured recall of goals and outcomes from a narrative after manipulating participants' moods and measuring self-report of happiness, anger, sadness, and neutrality. Participants who reported being happy recalled more goals and outcomes than those who felt neutral, participants who were sad recalled more outcomes than those who were angry and neutral, and those who were angry recalled more goals than those who felt neutral. In other words, sad and angry moods did not behave the same way in affecting recall despite their similar level of valence, suggesting that distinct emotions do indeed differ, at least on the negative side, in how they affect memory.

In sum, emotional content and mood do not appear to affect memory in identical ways. There appears to be an emotional memory enhancement effect for emotional or specifically negative stimuli, but mood does not seem to affect memory in such a way. Research comparing effects of distinct emotions of the same valence with each other has begun to indicate that not all negative discrete emotions, at least, affect memory the same way. The present study seeks to further investigate this topic from the content viewpoint by not only comparing memory for stimuli with differing general valence levels but also by comparing six different discrete emotions to facilitate within-valence comparisons.

Trends in true memory and emotion. As evidenced by the body of work discussed thus far, research on memory and emotion covers a broad range of experimental and conceptual variation, with results indicating several possible relations between emotion and episodic memory. I will now try to outline some general trends to date. First, researchers initially believed that the emotional enhancement of memory (EEM) (see Hamann, 2001, for a review) caused memory to be better for emotional stimuli than neutral stimuli. In support of the results discussed earlier regarding arousing content and memory, EEM could at least partially be due to greater attention given to emotional stimuli, based on greater amygdala activation during encoding of those stimuli (Cahill & McGaugh, 1998). The textbook example of this effect is flashbulb memory, in which people feel extremely confident in the accuracy of their memories for highly emotionally-charged events (Brown & Kulik, 1977). However, that is just it: a *feeling of confidence* despite evidence that flashbulb memories are in actuality not as accurate as they seem (e.g., Talarico & Rubin, 2003). Thus, one of the overarching themes of emotional memory research is that the emotion may enhance some aspects of a memory but be a detriment to others.

A second theme found in this body of research relates to confounding variables: at this point it seems clear that both valence and arousal affect memory, but as it is difficult to maintain constant arousal with positive and negative stimuli, and even more so when neutral stimuli are included, the majority of relevant research has not taken advantage of a factorial manipulation of valence and arousal that would enable one to make all comparisons. This trend of valence/arousal confounds was a driving force for the present study: because arousal and valence are different constructs that have not been extensively disentangled using a range of methodologies in the past, the present research used such a factorial manipulation within a paradigm that has yet to be used to address emotional memory.

Finally, a third theme, and another limitation, of emotion and memory research is that these studies rarely seek to identify the memory retrieval processes that emotion affects. Such an identification is important because, as demonstrated by researches such as Gomes, Brainerd, and Stein (2013), emotions affect types of retrieval during recall and recognition in varying ways. A complete understanding of how emotion affects memory thus necessitates taking these processes into consideration; however, as can be seen through the literature reviewed in the present paper, it is uncommon for retrieval processes to be included in analyses.

Applications and importance. The study of emotion and episodic memory has clear applications to situations, such as eyewitness testimony or spousal reporting of medical records, in which a person's memory for a highly emotional situation is the only record of said situation and is thus used to make important decisions, such as the conviction of criminals or medical treatments, respectively. As hinted at earlier, this reliance on memory becomes problematical when memories are distorted, inaccurate, or subject to forgetting. In the most extreme case, reports of these emotional situations may be subject to false memories. It is clear that a case in which false memories are being reported as truths (and, in fact, rememberers of false memories do, indeed, believe them to be true, see Loftus & Pickrell, 1995, for example), is a dangerous one due to the real consequences of making such a memory error and not knowing that an error is being made. Determining how and why these false memories occur, as well as how to prevent them, is why the study of false memory has become such a popular one and why it is the subject of the present study.

Emotion and False Memory

Measuring false memory. Possibly the most well-known and replicated method of experimental induction of false memory is the Deese-Roediger McDermott (DRM) procedure, which draws on semantic relationships among words to elicit false recall or recognition of an unpresented critical word to which all the presented words relate (Roediger & McDermott, 1995). Participants are presented with lists of words that all relate to an unpresented critical word (e.g., the "sleep" list contains the words bed, rest, awake, etc., but not the word sleep). They then complete a recognition memory test on presented list words as well as the critical words. Generally, the DRM (sometimes referred to as the "converging associates") paradigm produces great amounts of false memory to critical words and is furthermore such a useful tool because the word lists can be altered to address varying experimental questions (e.g., emotional DRM, as will be discussed in the following section). Fuzzy trace theory (FTT, Brainerd & Reyna, 1998) accounts for DRM false memories through two types of memory traces stored during list presentation. Verbatim traces capture specific details and may contain perceptual information, whereas gist traces capture broader, semantic information that may facilitate connections among items with similar semantic meanings. During the test phase, gist traces that contain meaning information for both the list words and critical words cause false memories. If participants were exposed to the sleep list and remember that the gist of the list was sleep, they might accept the word "sleep" on a recognition test because it fits with the gist that they remember. Activation monitoring theory (AMT; Roediger et al., 2001) was proposed as an alternative but quite similar theory and accounts for DRM-induced false memory due to activation of the unpresented critical words via presentation of the list words. During the test phase, source confusion causes participants to falsely recognize the activated critical words as presented words. Unlike FTT, according to AMT these associated activations would be temporary, creating false memories that don't last long. In fact, false memories have been shown to last longer than AMT would predict, up to one week (e.g., Toglia, Neuschatz, & Goodwin, 1999). Furthermore, in a critical test of the two theories, Dewhurst, Pursglove, and Lewis (2007) noted that FTT but not AMT predicted that strengthening list themes without strengthening word associations, by presenting DRM lists in story contexts, would elevate false memory, and elevate it especially in participants with lower initial levels of false memory. Their data confirmed both predictions, providing support for a FTT explanation of DRM effects.

DRM studies originally and most commonly used words as stimuli; however, researchers (e.g., Israel and Schacter, 1997) have also used DRM word lists accompanied by pictures and found lower false memory for verbally presented words accompanied by pictures than for words accompanied by visual presentation of the word. The authors attributed this effect to pictures strengthening verbatim representations via distinctive perceptual information; thus, finding false memories using pictures might provide even more conservative evidence of false memory.

Although it has been done (e.g., Huang & Janczura, 2013; Drowos, Berryhill, Andre, et al., 2010), researchers have not employed pictures nearly as frequently as words in the DRM paradigm. However, Koutstaal (1997) developed a similar paradigm (sometimes referred to as the "categorized associates" paradigm) originally intended for use with picture stimuli. Rather than being semantic associates whose meaning converge upon a single critical word, the pictures presented on a list in this paradigm are all members of a single category (e.g., flowers, kittens; see Appendix A for examples) such that other pictures depicting members of that category serve as the unpresented critical lures. Thus, pictures in a given list have the same semantic meaning but different perceptual details. Similar to the DRM task, this paradigm produces robust false memory effects. To date, Koutstaal's categorized pictures procedure has not been implemented with emotional stimuli, despite that it lends itself to manipulation of the stimuli in such a way, similar to the DRM paradigm.

Experimental evidence. The following review of the work on false memory and emotion primarily deals with studies that used the DRM and categorized lists paradigms. Similar to the preceding review of true memory literature, this section is organized around how emotions may be conceptualized.

Continuous emotions. Similar to what we have seen for true memory, emotion appears to increase false memory compared to nonemotional stimuli, via both valence and arousal. For example, Brueckner and Moritz (2009), as well as Gallo, Foster, and Johnson (2009) demonstrated a false memory EEM for both positive and negative valence compared to neutral valence, using words and pictures, respectively. In a factorial manipulation of valence and arousal in the DRM paradigm, Brainerd, Holliday, and Reyna (2010) found that false memory was greater for negative than positive lists and greater for arousing than nonarousing lists. Similar to true memory, negative valence and arousal appear to increase false memory, along with positive valence as well, as compared to neutral, nonarousing content.

Turning now to mood, results are much more dissimilar to true memory results. It will be remembered that mood does not have a clear, if any, effect on accurate memory, but mood does appear to influence false memory in some way. Positive and negative moods appear to have opposite effects on false memory, depending on whether they occur naturally (e.g., in patients with depression or PTSD) or are induced experimentally. False memory seems to be greater for participants in induced positive moods as compared to negative moods (e.g., Storbeck, 2013) but it seems to be greater for participants in negative natural moods compared to controls in positive moods (e.g., Jelinek, Hottenrott, & Randjbar, 2009). It should be noted, however, that an experimental manipulation of mood provides a more reliable measure of mood effects, as self-reported moods are more subject to bias. Therefore, the false memory enhancement for induced positive induced moods should take some precedence over the finding of greater false memory for negative natural moods. In sum, the research on a continuous conceptualization of emotional content and mood is much less conclusive, yet does provide further support for the general finding of increased false memory due to emotion.

Discrete emotions. Very few researchers have investigated false memory for discrete emotional content, however, one group that did conduct such an investigation provided evidence in line with what we have seen so far. Schefter, Werheid, and Almkvist (2013) found greater false recognition of pictures of angry faces compared to neutral faces. The angry faces were highly arousing, however, whereas the neutral faces were not, demonstrating again a valence and arousal confound while providing support for some kind of emotional false memory enhancement.

Similarly, there are few studies that addressed false memory under discrete mood conditions. One such study, however, demonstrated an effect of sad moods in enhancing confidence compared to positive moods (Van Damme & Seynaeve, 2013). The authors induced six different moods and found increased confidence in false memories for those participants in negative moods compared to positive moods. This result runs counter to Storbeck and Clore's (2005) affect-as-information theory, which suggests that negative emotion reduces false memory by strengthening verbatim representations of targets, although this theory does not make predictions about individual emotions. Further analyses by Van Damme and Seynaeve revealed that this difference was driven by a difference between sad moods and all other moods. It will be remembered that we saw similar types of findings in the true memory mood literature: research suggests that in addition to general valence differences, there may be different effects on memory due to different discrete negative emotions.

Trends in false memory and emotion. As the above research indicates, the idea of an emotional memory enhancement is not limited to true memory. For false memory, the effect may be even broader, applying to both positive and negative valence as compared to neutral valence and to high arousal as well. A theoretical explanation for this effect lies in the idea of emotion as a conceptual gist that may strengthen relationships among items, thereby increasing the tendency to have memories of unpresented but related items. Participants may be more likely to falsely accept unpresented negative critical words in the DRM paradigm than neutral ones because of the ability of negative valence to make salient the semantic relations that cause critical word acceptance. In fact, Burke, Heuer, & Reisberg (1992) have proposed that emotional content enhances memory for general gist information while reducing memory for peripheral details. The reviewed experimental evidence supports this view because gist information would be conducive to false memories whereas the detailed verbatim information would allow participants to correctly reject false memories.

Gaps and Controversies in the Literature

The most obvious issue that still lacks a clear solution is the valence and arousal confound. Although there has been a handful of studies that factorially manipulated valence and arousal, they do not provide a clear story when taken together (i.e., the results have not always been consistent among experiments). It is possible that these inconsistencies have been due to methodological variations among factors such as retention interval, presentation order, number of studied items, etc. A unique component of the present study is the manipulation of several of these factors (to be discussed in the following section) in order to pinpoint how they affect false memory for emotional stimuli. By comparing levels of such factors within a single experiment, clearer distinctions are possible.

Another gap in the emotional false memory literature is the lack of a thorough understanding of the processes that cause the many effects demonstrated. Although such process-based analyses have been conducted in word recognition studies (e.g., Brainerd, et al., 2008), they have been rare, and few researchers have done so with picture recognition, which, as mentioned, may provide a more conservative measure of false memory, and, of course, is likely due to different memorial processes.

The Present Experiment

Past research has indicated that emotional valence may indeed cause false memories, even when arousal is held constant, but the present study sought to provide further evidence on this matter by broadening the task to picture recognition. If that claim is supported by the present study, several follow up questions arise. Is there a difference in false memory rates for positive and negative emotions? If so, is this difference due to differences in memory processes that contribute to false memory when the studied material is positive versus negative, and what are those processes? In order to answer these questions, I used a designed developed to differentiate these processes. Furthermore, in order to address the discrete emotion questions suggested by prior work—that is, that false memory for negative emotion could result from sadness specifically rather than general negativity—I additionally analyzed retrieval processes based on three positive and three negative individual emotions.

Design. I utilized a full factorial design with instructional condition, valence, and list length as within-subjects factors, presentation order as the between subjects factor, and true and false memory as dependent variables. These factors will be described in more detail in a later section. In order to induce robust false memory effects, I implemented Koutstaal's (1997) paradigm using emotional pictures belonging to several categories. I manipulated the presentation of pictures in several ways to enhance false memory and further pinpoint factors influencing false memory, as well as integrated the paradigm with a conjoint recognition design (Brainerd, Stein, & Reyna, 1998) in order to identify underlying memory processes, particularly those contributing to false memory. The conjoint recognition methodology allows one to measure and differentiate the memory phenomenologies of familiarity, phantom recollection, recollection rejection, and response bias (see Brainerd, Reyna, Wright, & Mojardin, 2003). Familiarity contributes to false recognition via semantic similarity of related distractor items to target items stored in gist memory traces. Phantom recollection also causes false recognition through gist traces that are so strong that related distractors are actually thought to have been presented as targets (i.e., there is illusory vivid recollection of their "presentation"). Recollection rejection, on the other hand, is a process that reduces false recognition via verbatim traces of targets that support the correct rejection of related distractors that do not match those verbatim traces. Finally, response bias is measured for each of the conjoint recognition instructional conditions (explained in the following section).

To briefly explain the experimental design, participants completed two major phases: (a) the study phase in which they viewed the picture stimuli, which were members of positive, negative, and neutral categories and (b) the conjoint recognition test phase. During the test phase participants viewed presented targets, unpresented related distractors, and unpresented unrelated distractors, which prove measures of true recognition, false recognition, and response bias, respectively. Each picture was accompanied by either a verbatim, gist, or verbatim-plus-gist question. The yes-no responses to these questions were analyzed using the conjoint recognition model to estimate the memory phenomenologies of phantom recollection, familiarity, recollection rejection, and response bias.

Hypotheses and theoretical explanations. The main prediction of the present experiment was that emotional pictures would cause more false recognition than neutral pictures if it is the case that emotion facilitates the formation of a semantic gist. Additionally, negative emotion may create an even stronger false memory effect than positive emotion, which may be less salient as a gist. A similar pattern of results would occur for true memory as well if verbatim and gist traces strengthened by emotion support true memory, and taken together these effects on true and false memory would support FTT's account of emotional false memory. Although experimental evidence often supports a dissociation of true and false memory, in cases such as the present experiment in which gist traces are strongly fostered, true and false memory may behave similarly. There are several examples in the false memory literature of manipulations, often semantic ones, that affect true and false memory similarly (Brainerd et al., 2008). They are often called more-is-less manipulations (Toglia, Neuschatz, & Goodwin, 1999).

Furthermore, FTT would predict process-based effects as well: if emotional valence encourages retrieval of gist traces that support false memory, familiarity should be higher for emotional pictures as compared to neutral pictures. Similarly, if verbatim traces are not strong for emotional pictures, recollection rejection should be lower for those pictures.

Turning now to the other experimental manipulations, I predicted that both list length (the number of category members presented during the study phase) and presentation order (whether the category members were presented in sequence or interspersed with each other) would affect false memory. More specifically, longer lists and blocked presentation were predicted to induce more false recognition than shorter lists and random presentation, respectively, because both manipulations would further strengthen the semantic gist of the category, encouraging greater familiarity and consequently greater false acceptance of related distractors.

Method

Participants

76 undergraduate students (52 women and 24 men; mean age = 19.62 years) participated in exchange for course credit. Participants were randomly assigned to one of the two presentation order

conditions, with 39 participants in the blocked condition and 37 participants in the random condition.

Materials

Pilot test. Pilot testing was conducted in order to ascertain valence and arousal levels of potential stimulus pictures as well as their ability to induce sufficient false memory. Potential pictures were taken from the IAPS (Lang, Bradley, & Cuthbert, 1999), the GAPED (Dan-Glauser & Scherer, 2011), and stock photo websites, to create a large pool of pictures across categories meant to vary in terms of valence and arousal. In order to determine valence levels for each picture category, mean valence scores for each picture category were computed based on individual ratings for each picture. We used the valence and arousal norms that Lang, et al. and Dan-Glauser & Scherer respectively reported for pictures taken from the IAPS and GAPED. For pictures taken from the stock photo website, we obtained valence and arousal ratings from 25 pilot testers using Lang's (1985) Self-Assessment Manikin (SAM) rating method. During the SAM procedure, participants viewed the images for 2 seconds and rated the degree to which each one made them feel happy versus unhappy and calm versus excited, representing valence and arousal respectively. Each scale ranged from 1-9 with higher values representing more positive and more arousing feelings. Categories with valence means above six were considered positive, those with valence means from 3-5.99 were neutral, and those with valence means below 3 were negative (see Table 1). Low arousal was designated by scores below six and high arousal was scores of 6 and above. All categories were determined to have low arousal and no category arousal means were significantly different from each other based on IAPS, GAPED and pilot testing ratings, indicating that the stimuli effectively controlled for arousal.

A second rating phase was conducted to determine the discrete emotion most associated with each positive and negative picture category. For each picture category, the ANEW (Bradley & Lang, 1999) was used to determine the three basic emotional words with the highest association to the category names. Pilot participants then completed a rating task in which they viewed each picture and chose from the highly associated emotional words the one that they thought was most relevant to the picture. Responses were aggregated and the emotional words with the highest ratings for each picture category were determined. This procedure resulted in six emotional words, three of which were positive (calm, interest, and joy) and three of which were negative (disgust, fear, and sadness), with two categories being associated with each word.

Stimulus materials. 129 color pictures, taken from the International Affective Pictures System (IAPS; Lang, Bradley, & Cuthbert, 1999), the Geneva Affective Picture Database (GAPED; Dan-Glauser & Scherer, 2011), and a stock photo website (freeimages.com), provided the target and distractor materials. The pictures were members of 18 object, person, and scene categories (e.g., couches, babies, car accidents) and were assigned to one of two list length conditions such that short lists consisted of 3 studied targets and 9 nonstudied related distractors and long lists consisted of 8 studied targets and 4 nonstudied related distractors; all categories were thus comprised of 12 pictures. There were also 18 unrelated pictures that were not members of any of the categories, 9 of which were used as unrelated targets and 9 of which were unrelated distractors included for use in bias correction. The distractors were evenly distributed among valences such that there were 3 unrelated distractors of each valence. A total of 18 categories were formed, 6 of whose valence was positive, 6 were negative, and 6 were neutral, with list length balanced such that 3 categories of each valence were small categories and 3 were large categories.

Within each picture category, 3 pictures were used as starting points to create the remaining 9 pictures in the category. That is, each of the original pictures was visually manipulated to create the remaining pictures by two processes: changing the hue of the picture and creating a mirror image. Thus, from each original picture, 3 additional versions of it were created by changing the hue, mirroring it, and doing both. Therefore, within each category there were 12 images comprised as follows: picture 1a with three other versions 1b-1d, picture 2a with versions 2b-2d, and picture 3a with versions 3b-3d, with pictures 1, 2, and 3 being distinct from one another and the corresponding lettered versions being similar to their original counterparts. As an example, the “baby” category contained pictures of three different babies and four versions of each baby, to make up 12 total baby pictures. From this pool of 216 (18 categories x 12 pictures per category), 158 categorized pictures were tested as well as 18 unrelated distractor pictures (see Appendix for complete list of tested pictures).

Procedure

The experiment involved three phases over two testing sessions: (a) list presentation, (b) immediate test, and (c) one-week test. Phases (a) and (b) were completed during the first session and phase (c) was completed during the second session, which occurred one week after the first.

List presentation. Upon arrival at the laboratory, participants were randomly assigned to one of the two presentation order conditions. Those in the blocked condition viewed all pictures from each category in sequence, whereas those in the random condition viewed pictures from all categories in a random order with no more than two pictures from the same category appearing in sequence. To begin the first session, all participants read instructions about the study task. They were instructed to look at the upcoming series of pictures, which were presented on a computer screen for a duration of 1.5 seconds each. Picture presentation began and ended with 3 buffer pictures that did not belong to any of the picture categories. After viewing all 111 of the target pictures, the participants then worked on math problems for 3 minutes. After three minutes had passed, participants proceeded to take the first memory test.

Immediate test. Participants read the instructions, again presented on the computer screen, and then proceeded with the self-paced conjoint recognition task. Conjoint recognition is a paradigm that separates underlying retrieval processes in true and false memory from one another, and it has been used in dozens of prior false memory experiments (for a review, see Brainerd, Gomes, & Moran, in press). The instructions explained that they would view a series of pictures, each of which would be a picture they may or may not have seen and each of which would be accompanied by one of three statements that they were to respond to by filling in A or B (indicating yes or no) on a Scantron sheet. The three statements (the three conjoint recognition test instructions) were explained in depth: if the statement was "I saw this picture during the study phase" (the V instruction) they were to respond "yes" if that picture was presented and "no" otherwise. If the statement was "this picture is new but similar to a picture from the study phase" (the G instruction) they were to respond "yes" if the picture was similar to one from the study phase, but not identical, and "no" otherwise. Finally, if the statement was "I saw either this picture or a similar picture during the study phase," (the V+G instruction) they were to respond "yes" if the picture was either one that was presented or similar to one that was presented, even if they could not remember which was true, and "no" if it was neither one that was presented nor similar to one that was presented. Participants were instructed that this portion of the test would be self-paced (they were to click the mouse to progress from picture to picture) and that they should answer all items without skipping any, even if they were unsure. Participants were shown three example pictures along with instructions and the correct responses and were given the opportunity to ask questions before proceeding.

After reading the instructions, participants completed the 63-item self-paced recognition test. Half of the pictures were tested, with the second half being delayed until the one-week test. The immediate test was comprised of 30 targets, 28 related distractors, and 5 unrelated distractors, with the targets and distractors being drawn as equally as possible from each of the categories and from small and large categories. Furthermore, the V, G, and V+G instructions were distributed among categories, targets, and related distractors such that there were approximately 20 pictures associated with each instruction, half of which were targets and half were related distractors, as well as 9 of the 18 unrelated distractors.

One-week test. After one week, participants returned to the laboratory to complete the second recognition test. Again, they read instructions identical to those presented prior to the first test and then proceeded with the self-paced conjoint recognition task. On this test, all 63 targets and all 63 distractor pictures were tested, such that half of the pictures (those tested during the first test) were tested for a second time and half were tested for the first time. Those pictures that were being tested for the second time were paired with the same probes with which they had been paired on the immediate test. The composition of the one-week test was as follows, and thus included all 126 items: 42 pictures were associated with each instruction, half of which were targets and half of which were related distractors, and half of which had been presented on the immediate test, as well as all 18 of the unrelated distractors Upon completion of the conjoint recognition task, participants answered demographic questions and received a debriefing.

Results

Data Preparation

Measures of true and false memory were computed using proportions of “yes” responses to each of the three test probes for targets and related distractors. The target acceptance rate was computed as the mean proportion of “yes” responses to targets and the related distractor acceptance rate was the mean proportion of “yes” responses to related distractors.

These acceptance proportions—for the V, G, and V+G conditions—were bias-corrected using the two-high threshold (Snodgrass & Corwin, 1988) method in two ways. Using the “same-valence” bias correction, “yes” responses to unrelated distractors of a particular valence were subtracted from the acceptance proportion for that valence. That is, the target acceptance rate for positive pictures was computed as [(# of yes responses to positive targets)/(# of positive targets)] - [(# of yes responses to positive unrelated distractors)/(# of positive unrelated distractors)]; the same method was used for negative and neutral targets and for positive, negative, and neutral related distractors. Target and related distractor acceptance rates for individual emotions were adjusted in the same way such that positive unrelated distractor acceptance rates were subtracted from joy, calm and interest pictures and negative unrelated distractor acceptance rates were subtracted from fear, sadness, and disgust pictures. In the second, “neutral bias correction” method, acceptance rates for neutral unrelated distractors were subtracted from each emotional condition regardless of valence. The following ANOVAs, however, did not lead to different results based on which method was used; those data are consequently reported for the “same-valence bias correction” only.

ANOVA Results

Descriptive statistics. The mean acceptance proportions for targets, related distractors, and unrelated distractors are reported in Table 2, organized by instructional condition and valence. Visual inspection of these data suggest several preliminary results: (a) target acceptance in the V condition was greater for negative than positive and neutral pictures, (b) related distractor acceptance in the V condition was highest for negative pictures and quite low for neutral pictures. These results, if statistically reliable, would indicate that negative valence increases false as well as true memory, whereas true memory is quite weak for nonemotional pictures. As for the unrelated distractors, preliminary *t* tests revealed that there were no differences based on valence when collapsed across instructional condition; the acceptance proportions were .15, .17, and .20 for negative, neutral, and positive unrelated distractors respectively.

Table 3 displays mean acceptance proportions organized by instructional condition and individual emotions. Visual inspection of this table suggests again that (a) target acceptance in the V condition was greater for negative emotions than positive emotions and (b) related distractor acceptance in the V and G conditions was not consistent among emotions of the same valence, which was not apparent from Table 2. Related distractor acceptance in the G condition was lower for fear than sadness and disgust, and related distractor acceptance in the V condition was lowest for calm and highest for interest. These data, if reliable, would suggest that both verbatim and gist memory play a role in memory differences among specific emotions of the same valence.

True Memory. A 3 (instructional condition: V, G, V+G) x 3 (valence: positive, negative, neutral) x 2 (list length: short, long) x 2 (presentation order: blocked, random) mixed model ANOVA was computed with presentation order as the between subjects factor and target acceptance rate as the dependent variable. The target acceptance rate was bias corrected in two ways, as mentioned, and data for both methods are presented in the tables, but all means and test statistics reported in-text refer to the same-valence bias correction. The main effect of instructional condition was significant, $F(2,140) = 92.50$, $p < .001$. Planned comparisons revealed that the target acceptance rate was significantly higher in the VG condition ($M = .82$) than in the V condition ($M = .56$), $p < .001$, which was higher than the G condition ($M = .32$), $p < .001$, indicating greater target acceptance in the verbatim instructional condition than in the gist condition. There was also a significant main effect of valence, $F(2,140) = 6.69$, $p < .01$. Planned comparisons revealed that the acceptance rate was higher for negative target pictures ($M = .63$) than neutral targets ($M = .50$), $p < .01$; the hit rate for positive pictures ($M = .59$) was also higher than the target acceptance rate for neutral pictures, $p < .05$ but did not differ significantly from negative pictures.

These main effects, however, were qualified by an instructional condition by valence interaction,

$F(1,140) = 17.77$, $p < .001$. As can be seen in Figure 2, positive and negative target acceptance was greater under verbatim than gist instructions but neutral target acceptance was equal under verbatim and gist instructions; target acceptance was highest under V+G instructions for positive and neutral pictures but for negative pictures fell between V and G target acceptance rates.

Contrary to my prediction, presentation order did not have a significant effect on true memory, $F(1,69) = 1.90$, *n.s.,* but there was a main effect of list length, $F(1,140) = 33.58$, $p < .001$, qualified by interactions with both valence and instructional condition, as well as a three-way interaction. The main effect of list length occurred because target acceptance was greater for longer lists ($M = .61$) than for shorter lists ($M = .63$), $F(1,140) = 9.67$, $p < .001$, see Figure 3. The list length-valence interaction, shown in Figure 4, indicates that for shorter lists, target acceptance was higher for negative pictures than positive pictures and higher for positive pictures than neutral pictures, whereas for longer lists target acceptance was not significantly different for positive and negative pictures but was higher for emotional pictures than neutral pictures. The list length-instructional condition interaction was such that target acceptance was higher in the V+G condition than the V condition and higher in the V condition than the G condition for both list lengths but these differences were greater for short lists than long lists, see Figure 5. Finally, the three way list length by condition by valence interaction is shown in Figure 6 and indicates a different condition by valence interaction for short and long lists, $F(4,276) = 9.40$, $p < .001$. For short lists, there was greater target acceptance in the V condition than the G condition for emotional pictures but not for neutral pictures; for long lists there was greater acceptance in the V condition than the G condition for negative pictures only but not for positive and neutral pictures.

Discrete emotion analysis revealed a main effect of emotion on target acceptance, $F(5,350) = 3.53$, $p < .01$, as depicted in Figure 7. Post-hoc tests revealed the following differences: the hit rate was higher for pictures associated with calm than those associated with joy, interest, fear, and sadness, and the hit rate was higher for those associated with disgust than fear. However, again there was a significant interaction between emotion and condition, $F(10,700) = 11.76$, $p < .001$. As can be seen in Figure 8, the general pattern of acceptance rates across instructional conditions is similar for each emotion; however, for interest and disgust the difference in target acceptance did not differ significantly between the V and G conditions.

False Memory. A parallel 3 (instructional condition: V, G, V+G) x 3 (valence: positive, negative, neutral) x 2 (list length: short, long) x 2 (presentation order: blocked, random) mixed measures ANOVA was computed with presentation order as the between subjects factor and related distractor acceptance rate as the dependent variable. Again, the related distractor acceptance rate was bias corrected in two ways, as mentioned, and data for both methods are presented in the tables, but all means and test statistics reported in-text refer to the same-valence bias correction. Again, the main effect of instructional condition was significant, $F(2,140) = 96.88$ $p < .001$. Planned comparisons revealed that the related distractor acceptance rate was significantly higher in the VG condition ($M = .79$) than in the G condition ($M = .38$), $p < .001$, which was higher than the V condition ($M = .25$), $p < .02$, indicating greater distractor acceptance in the gist instructional condition than in the verbatim condition, in contrast with the opposite result for target acceptance. There was also a significant main effect of valence, $F(2,140) = 5.45$, $p < .01$. Planned comparisons revealed that the related distractor acceptance rate was higher for negative distractor pictures ($M = .54$) than neutral distractors ($M = .41$), $p < .01$; the hit rate for positive pictures ($M = .46$) did not differ significantly from either of the other two valence levels, which mirrors the valence effect on true memory.

Similar to true memory, these main effects were qualified by an instructional condition by valence interaction, $F(1,140) = 13.14$, $p < .001$. As can be seen in Figure 9, positive and neutral related distractor acceptance was greater under gist than verbatim instructions but negative related distractor acceptance was equal under V and G instructions, with related distractor acceptance being highest under V+G instructions for all valences.

For false memory we also see a pattern of effects for presentation order and list length that mimics the effects on true memory: there was no significant effect of presentation order on false memory, $F(1,69) = .22$, *n.s.,* but there was a significant main effect of list length, $F(1,69) = 7.61$, $p < .01$, with interactions with valence, instructional condition, and a three-way interaction. The main effect of list length on related distractor acceptance rate was similar to the true memory effect: related distractor acceptance was higher for long lists (M = .49) than short lists (M = .46). The list length by condition interaction revealed that for shorter lists related distractor acceptance was higher in the G condition than the V condition but for longer lists this difference was not significant, $F(2,138) = 33.73$, $p < .001$, see Figure 10. The list length by valence interaction, see Figure 11, indicated greater related distractor acceptance for negative pictures as compared to positive and neutral pictures in longer lists, but greater related distractor acceptance of emotional pictures as compared to neutral pictures in shorter lists. The three-way list length by condition by valence interaction for false memory, $F(4,276) = 38.65$, $p < .001$, see Figure 12, was as follows: for shorter lists G related distractor acceptance was greater than V related distractor acceptance for positive and neutral pictures but not negative pictures, and for longer lists V related distractor acceptance was greater than G related distractor acceptance for positive pictures, the reverse was true for neutral pictures, and there was no difference for negative pictures.

Finally, discrete emotion analyses revealed a main effect of emotion on false memory that differed from the main effect on true memory, $F(5,350) = 4.01$, $p < .01$ see Figure 13. Post-hoc tests revealed the following group differences: related distractor acceptance rates were higher for sadness-related pictures than joy-, fear-, and disgust-related pictures and related distractor acceptance rates were higher for interest-related pictures than fear-related pictures. It will be noted that these differences are unlike the differences seen in the true memory results, indicating that discrete emotions affect true and false memory differently. Again, the discrete emotion effect was qualified by a condition by emotion interaction, $F(10,700) = 11.87$, $p < .001$, see Figure 14, such that for joy, calm, disgust, and sadness-related pictures related distractor acceptance was higher in the G condition than the V condition, but for interest-related pictures it was higher in the V condition than the G condition and for fear-related pictures the difference was not significant.

To sum up the ANOVA results, positive and negative emotion increased true memory for targets and negative emotion increased false memory for related distractors. Presentation order did not affect either true or false memory, but longer lists increased both kinds of memory, which is partially consistent with the idea that longer lengths cause a shift from verbatim to gist memory, which would increase false memory while reducing true memory. Calm and disgust increased true memory, whereas interest and sadness increased false memory.

Model Results. The results discussed thus far leave many questions unanswered regarding the process-level effects of emotion. We can infer that false memory is enhanced in certain experimental conditions, but we do not know *why* it is enhanced under those conditions. A model-based approach can help us answer, for example, whether false memory is due to reduced recollection rejection or enhanced phantom recollection.

The models used to assess process-level questions are three variations of the conjoint recognition model developed by Brainerd, Stein, and Reyna (1998), used to estimate the influence of different processes on true and false memory. For a complete summary of the parameters measured by the model please refer to Table 2, and for the associated equations please see Appendix A. We used three different mathematic version of the model developed by Brainerd et al. (in press): multinomial, signal detection, and mixed multinomial/signal detection. Hypotheses regarding parameter differences between conditions were tested using likelihood ratio analyses. Additionally, we used constrained and unconstrained versions of each model, reflecting the number of parameters that were free to vary. The unconstrained models—that is, those whose parameters were not free to vary—estimate parameters for related and unrelated distractors, whereas the constrained models allowed for estimate of target parameters as well.

One might wonder if the results provided by such a model may differ based on the degree to which these processes are treated as continuous versus discrete, a point that has been widely discussed in the cognitive modeling literature (e.g., Pazzaglia, Dube, & Rotello, 2013). In order to address such questions, we present results from all three models that vary continuous versus discrete treatment of memory processes. We begin with the multinomial model, then proceed to the signal detection model, which is at the extreme end of continuous treatment, and conclude with the mixed multinomial-signal detection model that is a middle ground between the two. It will be noted, however, that, as shown in Appendices E-G, the three models were highly correlated in terms of their estimates of corresponding related distractor parameters of interest.

Fit. The adequacy of the models to account for the data was evaluated using a G^2 statistic with one degree of freedom, necessitating rejection of the null hypothesis of fit at a critical value of 3.84 based on a $\chi^2(1)$ distribution. As can be seen in Tables (4-14), the G^2 values for all of the conditions of the experiment were below the critical value of rejection for all of the models. Therefore, the conjoint recognition models provide statistically adequate accounts for the data.

Parameter analyses: Constrained multinomial model. Parameter estimates of the constrained multinomial model are presented in Table 4 for the different emotional conditions by valence as well as discrete emotions; all of these values are presented for both bias correction methods. Parameter significance tests are reported only for the same-valence bias correction because significance tests revealed no significant parameter differences between the two bias correction methods. Table 5 shows parameter significance tests based on emotional condition as well as omnibus tests of model differences based on emotional condition. Turning first to target memory, erroneous recollection rejection was greatest for neutral pictures, followed by positive pictures, and lowest for negative pictures, whereas target recollection was greater for negative pictures than neutral pictures. Taken with the ANOVA results, these results indicate that the true memory advantage for negative compared to neutral pictures was due to enhanced target recollection for negative pictures. For false memory, phantom recollection and recollection rejection were reduced for emotional pictures compared to neutral pictures. These results suggest that the ANOVA result of increased false memory for negative compared to neutral pictures could have been due to reduced recollection rejection for negative pictures. Familiarity for both targets and related distractors was reduced for neutral pictures compared to emotional pictures. Finally, the response bias parameters also differed by valence despite that the mean acceptance proportions for unrelated distractors, as previously mentioned, did not differ by valence: b_v was greater for positive and neutral pictures than negative pictures, b_g was greater for positive than neutral pictures, and b_{vg} was greater for positive and negative pictures than neutral pictures. Overall, this pattern of results suggests greater response bias for emotional items, although the nuances of this effect appear to vary by type of response bias.

Another way to think about these parameter-wise effects is more broadly, in terms of how they affect verbatim and gist trace retrieval. These data indicate that verbatim memory for negative pictures was reduced as shown by the erroneous recollection parameter as well as reduced recollection rejection, but gist memory for negative pictures was also reduced as shown by the phantom recollection parameter. In other words, negative emotion seemed to increase the weaker form of gist (i.e., familiarity) without boosting the stronger form (i.e., phantom recollection), but coupled with the reduction in verbatim memory caused a net result of enhanced false memory. Therefore, the true memory enhancement for negative pictures appeared to be due to better verbatim trace retrieval, whereas increased false memory for negative pictures was due to a more complicated combination of parameter effects.

Making even finer-grained comparisons between discrete emotions revealed additional parameter-wise differences, as shown in Table 5. Four discrete emotional comparisons were made in order to address the question of within-valence emotional differences. The decision to compare interest with joy and calm (and not compare joy with calm with each other) and to compare sadness with fear and disgust (and not compare fear and disgust with each other) was based on significant differences between interest and the other two positive emotions and between sadness and the other two negative emotions. Positive emotion differences seemed to be primarily related to interest: interest increased erroneous recollection rejection compared to joy and calm as well as increased target recollection compared to calm. Interest reduced phantom recollection compared to joy and calm and reduced related distractor recollection rejection compared to joy. Negative emotion differences appeared to be driven by sadness: sadness reduced target recollection compared to fear and disgust, and increased target familiarity compared to fear and related distractor familiarity compared to fear and disgust. These results seem to account for the ANOVA results at least partially: perhaps the increased false memory for sad pictures was due to increased related distractor familiarity.

Unconstrained multinomial model. Parameter estimates of the unconstrained multinomial model appear in Table 6. Significance tests are reported for the unconstrained model only, as correlational analyses revealed that the related distractor parameters of both models were highly correlated, see Appendix C. Table 7 contains parameter-wise differences between emotional conditions for the multinomial model. Familiarity was higher for emotional pictures than neutral pictures and phantom recollection and recollection rejection were highest for neutral pictures, followed by positive pictures, and lowest for negative pictures. As for the bias parameters, b_v was greater for positive than negative pictures and greater for negative than neutral pictures and b_{vg} was greater for positive and negative than neutral pictures.

The significant emotion-wise differences were as follows and are presented in Table 8. Recollection rejection and phantom recollection were reduced for interest as compared to joy and calm. Familiarity was higher for sadness than fear or disgust, phantom recollection was greater for fear than sadness but greater for sadness than disgust and recollection rejection was greater for sadness than disgust. In sum, the parameter differences among emotional conditions and discrete emotions in the multinomial model mimic those in the full constrained model, not surprisingly.

Signal detection model. Parameter estimates of the unconstrained signal detection model appear in Table 9 and for the constrained model in Table 11. Significance tests are only reported for the model in which equal variances are assumed because correlational analyses revealed highly significant ($p < .001$) correlations among the parameters of both equal and unequal variance models, see Appendix B, and they are only reported in-text for the unconstrained model with same-valence bias correction. Table 10 contains parameter-wise differences between emotional conditions for the signal detection model. Familiarity was highest for negative pictures, followed by positive pictures, and was lowest for neutral pictures. The phantom recollection and recollection rejection parameters were highest for neutral pictures, followed by positive pictures, then negative pictures. As for the decision criterion parameters, C_v was greater (reflecting a more strict decision criterion) for negative than positive pictures and C_{vg} was greater for neutral than negative and positive pictures, which corresponds with the response bias differences seen in the preceding model.

As for discrete emotions, phantom recollection and recollection rejection were reduced for interest compared to calm and joy and phantom recollection was reduced for disgust compared to sadness. Familiarity was enhanced for sadness compared to fear.

Mixed multinomial-signal detection model. Parameter estimates of the unconstrained mixed multinomial-signal detection model appear in Table 12 and those of the constrained model appear in Table 14. Again, significance tests are only reported for the model in which equal variances are assumed, see Appendix C, and for the unconstrained model with same-valence bias correction. Table 13 contains parameter-wise differences between emotional conditions for the signal detection model. Phantom recollection and recollection rejection were highest for neutral pictures, followed by positive pictures, and were lowest for negative pictures. Familiarity was higher for emotional pictures compared to neutral pictures.

Phantom recollection was reduced for interest compared to calm and joy and was increased for sadness compared to disgust. Familiarity was reduced for fear compared to sadness and disgust; recollection rejection did not differ among emotions in this model. Again, the parameter estimate differences for the mixed model are consistent with the differences seen in multinomial model with the sole exception that the mixed model did not reveal any differences between emotional conditions or discrete emotions in the R_T parameter.

Summary. Generally, the ANOVA results and the several models together provide a largely consistent account of the data. Positive and negative emotions enhance true memory, whereas negative emotion enhances false memory due to reduced recollection rejection and increased familiarity, but the degree to which these processes act upon negative emotion is not necessarily consistent when emotions are viewed as discrete.

Discussion

The aim of this experiment was to investigate the connection between emotional valence and false memory using a model-based approach that provides process-level measurements that expand upon traditional ANOVA analyses. I manipulated the valence of pictures while holding arousal constant in order to eliminate a common confounding variable and to determine the general effects of three levels of valence as well as the effects of discrete emotions on true and false memory. In particular, I was able to measure the underlying processes of recollection rejection, phantom recollection, familiarity, and response bias in addition to basic hit and false alarm rates. The results provided support for the prior finding that negative emotion increases both true and false memory rates and furthermore suggested that there are within-valence differences in emotional effects on memory (e.g., not all negative emotions increased false memory to the same degree). The model-based results revealed that phantom recollection and recollection rejection were reduced for emotional pictures whereas familiarity was enhanced for emotional pictures, clarifying the process basis for the ANOVA results. These results suggest that negative emotion not only reduces the ability to use verbatim memory to prevent false recognition but also boosts semantic relationships that induce a sense of familiarity, although it does not strengthen gist traces to the extent that phantom recollection is experienced. In other words, although negative emotion causes three different process effects that may seem inconsistent with each other, their net effect explains the broader finding that negative emotion increases false memory. It would seem that the reduction in phantom recollection would reduce false memory, but the decrease in recollection rejection coupled with the increase in familiarity override it, so to speak. In terms of true memory, the story is much simpler: both positive and negative emotions were advantageous due to reduced erroneous recollection rejection and increased target recollection for negative pictures.

Discrete emotion analyses further qualified these results by suggesting that false memory was greater for sadness than for fear and disgust and that this difference was due to elevated related distractor familiarity for sadness. The positive emotions provide a slightly more complicated story in that interest appeared to increase false recognition compared to the other positive emotions by reducing phantom recollection yet also reducing recollection rejection. Nonetheless, these data suggest that in order to fully understand emotional effects on memory, one must consider how processes differ for individual emotions rather than merely focus on general target and related distractor acceptance rates for broad levels of valence.

Theoretical Implications

The present results regarding target and related distractor acceptance rates are in line with past conjoint recognition research that revealed elevated true and false memory for negative words as compared to neutral words. Brainerd et al., (2008) attributed this difference to elevated semantic familiarity of negative related distractors as compared to neutral related distractors, whereas positive related distractors reduced semantic familiarity. Furthermore, that difference was due to reduced recollection rejection for negative words and enhanced recollection rejection for positive words, as compared to neutral words. In terms of verbatim and gist retrieval, these results suggest reduced verbatim memory for negative words and enhanced verbatim memory for positive words. The present results fit well with those of Brainerd et al. on the negative valence side but not on the positive side: I similarly found elevated familiarity and reduced recollection rejection for negative pictures (that is, enhanced gist but not verbatim memory), but did not find opposing effects for positive pictures; in fact, these parameters did not differ for positive and negative valence. Although, as mentioned, a positive-neutral difference was not reflected in the related distractor acceptance rates of the present experiment, the model-based results seem to suggest that the processes are similar for positive and negative valence when pictures are used even though past research has suggested opposing effects of valence when words were used. This result appears to be a novel finding of the present experiment that could provoke further investigation where the picture-based emotional false memory literature is lacking.

Another difference between the present study and Brainerd et al. (2008) was that Brainerd et al. did not find a reduction in the phantom recollection parameter for negative pictures as I did, which could be due to an important distinction that should be made between the present study and other false memory studies to which it has been compared. Because of the nature of the design in that emotional items were grouped into semantic categories, rather than enhancing gist for negative valence as a whole this design strengthened the gist of specific categories through their valence. Because the false alarm rates to unrelated distractors in the present study did not reveal any overall valence-based gist (which would have been apparent through different unrelated distractor false acceptance rates by valence), gist enhancement was not broadly negative, but rather specific to the categories used. Therefore, although emotion can function as a semantic gist, in this case it is more of a means to strengthen a more specific category gist.

An alternative explanation to my broader finding of false memory enhancement for negative pictures could be related to how emotion affects psychological distance. Previous research (e.g., Fukukura, Ferguson, and Fujita, 2013) demonstrated that increasing psychological distance enables better organization of details and enhanced gist processing. If, when viewing pictures, people are more inclined to psychologically distance themselves from negative pictures while finding psychological closeness to positive pictures, this distance effect could provide another explanations as to why negative pictures enhance gist. In fact, Williams and Bargh (2008) demonstrated that taking a more distant view (in this case the psychological distance was spatial) toward negative information may be adaptive, as it can reduce associated emotional distress.

Moving on to discrete emotions, the ANOVAs provided some interesting and somewhat unique results. Looking at true memory first, there were within-valence differences for both positive and negative emotions: calm-related pictures induced more hits than joy- and interest-related pictures, and disgust-related pictures induced more hits than fear-related pictures. The disgust-fear difference seems to be easier to address, as it is in line with past research that has suggested that recollection and familiarity as measured in the Remember-Know paradigm were both greater for disgust than for fear (Croucher et al., 2011), which could explain elevated hits for disgusting pictures in the present experiment despite the lack of parameter-wise differences between the two emotions. Croucher et al. conducted a follow-up experiment addressing several specific attributes of the images they used and determined that the memory advantage for disgusting images was due to neither valence nor arousal. Instead, it was related to a variable known as “impact” which reflects induction of an instant, personal reaction and may result in greater visual attention to such images. Disgusting images had greater levels of impact than fearful images and thus impact may explain elevated recollection and familiarity for disgusting images and consequently could account for the memory advantage seen in the present experiment. It is important to note that this memory advantage for disgust is not merely due to distinctiveness or increased attention.

As demonstrated by Chapman et al. (2012), when such factors, as well as arousal, were controlled for, memory for disgusting images was still greater than memory for fearful images; instead the memory advantage was again attributed to heightened salience for disgust. More generally, this idea suggests that not all negative emotions are created equal and that their effects on true memory are not necessarily the same, even when equated on arousal levels. The negative emotion differences in false memory may have to do with the above explanations. If disgust is quite "impactful" or salient, then perhaps that aided in reducing false memory for disgust, whereas sadness increased a more general sense of familiarity that caused greater false memory compared to disgust.

The positive emotion differences are less clear and do not seem to be corroborated by past research, particularly because it appears that negative emotions have played more of a central role in memory research in the past. However, if one considers interest, calm, and joy at face value, it is not particularly surprising that interest increased target recollection and reduced phantom recollection compared to the other two. "Interest" almost seems like less of an emotion but more of a measure of distinctiveness or uniqueness, which are attributes that might strengthen verbatim memory traces but not gist traces.

It is somewhat surprising that I did not find the expected effect of presentation order on false memory. Based on past DRM research (e.g., McDermott, 1996; Toglia, Neuschatz, & Goodwin, 1999; Dewhurst, Bould, Knott, & Thorley, 2009) it was predicted that blocked presentation would induce greater false memory than random list presentation due to strengthened semantic relationships among list items. However, I found no false memory (or true memory, for that matter) difference between the two presentation orders. Perhaps this was due to the fact that rather than being DRM lists, mine were categorized associates which were able to produce equally high false memory in the random condition because category definitions were clear even when items were not presented in sequence. One can see how it might be difficult to connect the words "bed," "dream," and "awake" (from the sleep list) if they are interspersed with "candy," "sour," and "chocolate," (from the sweet list) whereas it might be easier to see a list containing babies, spiders, and couches mixed together and be able to identify those three categories. Furthermore, an obvious potential reason for the difference in results is that research has focused on the blocked/random distinction with words but not for pictures. Like the idea of false memory ceiling effect due to categorization, pictures may have had the same effect in causing an overall increase in false memory regardless of presentation order, whereas words require stronger connections to boost false memory.

The list length manipulation, on the other hand, did result in the expected true and false memory effects in that longer lists increased both target and related distractor acceptance, in line with past DRM findings that has demonstrated a long-list advantage for false memory but in contrast with findings demonstrating a short-list advantage for true memory (e.g., Robinson & Roediger, 1997; Arndt & Gould, 2006). The fuzzy trace theory explanation for the false memory result is that increasing the number of presented associates strengthens the gist of the list, or under activation-monitoring, that it increases the strength of the critical word activation, and in the case of true memory the same result would be evident because of the gist-boosting effects of emotion. However, in the present study the length manipulation did not seem to simply increase gist as it has in previous work, as false alarms to the gist probe were more frequent in short lists than long lists; in short lists there were more false alarms to the gist probe than the verbatim probe but in long lists there was no difference. Rather, this pattern suggests that instead of a shift from verbatim to gist with longer lists, the opposite was true. The valence by list length interaction may help elucidate the apparent lack of a gist advantage for long lists because related distractor acceptance on long lists were more due to negative than positive or neutral pictures, whereas related distractor acceptance on short lists were due to positive and negative pictures more so than neutral pictures. Because negative false alarms occurred equally for V and G probes, no gist advantage was apparent.

Limitations and Future Research

The present study certainly leaves unanswered the question of how arousal would moderate the observed effects, which is a limitation in that it has already been well-established that arousal plays a huge role in affecting memory. An obvious direction for future research would be to determine the role of arousal in this paradigm and how it interacts with valence. Although it was necessary, as a starting point, to clarify what effects are strictly due to valence, the intention was not to overlook the role of arousal because it is clear that there is one.

A second limitation of the present study relates to discrete emotions. The picture categories were originally selected in order to fall into the three valence levels while maintaining constant arousal, but where not selected with discrete emotions in mind. It was convenient that an equivalent number of picture categories ended up being associated with each emotion and that three distinct emotions fell out of the rating task for both positive and negative pictures. However, if I were to reverse the order of the development stage and select discrete emotions first, then choose fitting picture categories, I may not have chosen the six emotions used in this study. Rather, it might be wise to do so based on previous research and create picture categories based on, for example, Ekman's six basic emotions, anger, disgust, fear, sadness, joy, and surprise. It might be worthwhile to follow such a procedure in future studies to ensure that not only is the greatest range of emotions included but that they truly are distinct from each other. As the present study does not fully clarify the within-valence differences among emotion found for true and false memory, yet suggests that they exist, there remains much to be explored in future studies.

Conclusions

At the broadest level, this study provided further evidence contrary to the theory that arousal is a necessary component of the emotional enhancement of memory. Arousal is not necessary for valence to affect memory, and moreover valence effects can be fine-grained at the level of distinct emotions even when arousal is held constant. In that connection, the present study provides support for a distinct view of emotions and the idea that a full understanding of how valence affects memory must acknowledge that not all negative emotions are identical at a process level.

In terms of applications, the present study further corroborates claims that negative emotion can have negative consequences when memory accuracy is desirable, as in the notable case of eyewitness reporting. Negative emotion reduces recollection rejection while increases familiarity, which could explain the aforementioned finding that eyewitnesses tend to feel quite confident in their judgments despite the fact that their accuracy is low. Knowing that these processes are at play and prompting further investigation into how eyewitness reporting accuracy can be improved could have great benefit to not only our theoretical understanding but also, eventually, to the legal system.

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Table 1

Valence and arousal means for each picture category

Category	*Mean Valence (SD)*	*Mean Arousal (SD)*
	Negative	
Accidents	1.74 (1.14)	6.35 (1.7)
Funeral	1.50 (.79)	3.28 (1.88)
Garbage	2.27 (.99)	4.19 (1.64)
Human Concerns	1.53 (.91)	4.48 (2.14)
Medical	3.09 (1.53)	5.31 (1.54)
Spiders	2.40 (1.59)	6.15 (1.56)
	Neutral	
Abstract	5.59 (1.65)	5.18 (1.81)
Couches	5.78 (1.77)	2.50 (1.25)
Men	5.12 (1.54)	3.87 (1.56)
Mushrooms	4.31 (2.10)	3.94 (1.66)
Mugs	5.06 (1.30)	3.39 (2.06)
Trees	5.78 (1.86)	3.28 (2.16)
	Positive	
Babies	7.41 (1.41)	5.55 (2.23)
Baseball	6.89 (1.51)	4.55 (1.98)
Clouds	7.00 (1.41)	1.61 (.78)
Holding Hands	7.00 (1.53)	4.26 (1.96)
Kittens	5.85 (2.22)	4.26 (2.12)
Mountains	6.56 (1.20)	4.61 (2.09)

Table 2

Parameters of the conjoint recognition model

Parameter	Definition
$R_C(TG)$	Erroneous recollection rejection (target produces retrieval of verbatim trace for another target and incorrect rejection of target)
$R_T(TG)$	Identity judgment (target produces retrieval of verbatim trace and correct acceptance of target)
$R_C(RD)$	Phantom recollection (RD produces retrieval of gist trace of similar target and false acceptance of RD)
$R_T(RD)$	Recollection rejection (RD produces retrieval of verbatim trace of similar target and rejection of RD)
F(TG)	Similarity judgment (target produces retrieval of gist trace and accept target)
F(RD)	Similarity judgment (RD produces retrieval of gist trace of similar target and accept distractor)
B_v	URD produces false alarm in V condition
B_g	URD produces false alarm in G condition
B_{vg}	URD produces false alarm in VG condition

Table 3

Mean acceptance proportions for targets, related distractors, and unrelated distractors by instructional condition and valence.

	V	G	V+G
Targets			
Overall	.56	.32	.86
Positive	.52	.35	.88
Negative	.85	.29	.76
Neutral	.36	.32	.82
Related Distractors			
Overall	.26	.37	.82
Positive	.21	.43	.79
Negative	.45	.47	.69
Neutral	.07	.31	.88
Unrelated Distractors			
Overall	.19	.25	.05
Positive	.25	.26	.08
Negative	.04	.26	.15
Neutral	.29	.22	.01

Table 4

Mean acceptance proportions for targets and related distractors by instructional condition and individual emotion.

	V	G	V+G
Targets			
Joy	.52	.31	.85
Calm	.63	.49	.89
Interest	.41	.32	.90
Fear	.87	.25	.75
Sadness	.82	.22	.79
Disgust	.86	.40	.75
Related Distractors			
Joy	.42	.44	.88
Calm	.21	.45	.87
Interest	.68	.48	.61
Fear	.46	.18	.79
Sadness	.58	.53	.82
Disgust	.39	.63	.55

Table 5

Parameter estimates of unconstrained multinomial model for each emotional condition.

	R_T(RD)	R_C(RD)	F(RD)	B_v	B_g	B_{vg}	G^2
Overall	.44	.5	.52	.19	.25	.05	.13
Same-Valence Bias Correction							
Positive	.43	.35	.61	.25	.26	.08	.27
Negative	.33	.19	.66	.04	.26	.15	.42
Neutral	.54	.76	0	.28	.21	.01	.69
Joy	.54	.65	.74	.25	.26	.08	.35
Interest	.28	.05	.51	.25	.26	.08	.56
Calm	.46	.52	.81	.25	.26	.08	.23
Fear	.44	.87	.17	.04	.26	.15	.54
Sadness	.36	.30	.91	.04	.26	.15	.11
Disgust	.28	0	.57	.04	.31	.14	.49
Neutral Bias Correction							
Positive	.45	.36	.62	.29	.22	.01	.27
Negative	.40	.23	.66	.29	.22	.01	.46
Neutral	.54	.76	0	.28	.21	.01	.69
Joy	.54	.65	.75	.29	.22	.01	.37
Interest	.31	.06	.52	.29	.22	.01	.39
Calm	.47	.52	.82	.29	.22	.01	.20
Fear	.47	.90	0	.29	.22	.01	.52
Sadness	.38	.31	.92	.29	.22	.01	.10
Disgust	.39	0	.56	.29	.26	.01	.56

Table 6

χ2 values for differences between parameters of unconstrained multinomial model based on emotional condition (same-valence bias correction).

	B_v	B_g	B_{vg}	F(RD)	R_C(RD)	R_T(RD)	Omnibus Test χ2 Value
Positive vs. Negative	14.90*	0	2.57	1.04	4.13*	6.38*	29.02**
Positive vs. Neutral	2.88	3.31	6.70*	25.30*	28.00*	11.3*	75.49**
Negative vs. Neutral	20.80*	3.31	15.8*	40.50*	57.70*	38.90*	177.01**
Joy vs. Interest	—	—	—	1.18	18.50*	14.80*	34.38**
Calm vs. Interest	—	—	—	3.76	13.70*	5.26*	22.72**
Fear vs. Sadness	—	—	—	13.30*	17.30*	1.90	32.50**
Sadness vs. Disgust	—	—	—	46.30*	30.70*	12.20*	59.20**

* Exceeds critical value for significance at an alpha level of .05.
**Exceeds critical value of 12.59 for χ^2 test with 6 degrees of freedom.
^ Marginally significant.

Table 7

Parameter estimates of the constrained multinomial model for each emotional condition.

	R_T (TG)	R_C (TG)	F (TG)	R_T (RD)	R_C (RD)	F (RD)	B_v	B_g	B_{vg}	G^2
Overall	0.21	0.68	0.62	0.14	0.73	0.41	0.19	0.25	0.05	.65
				Same-Valence Bias Correction						
Positive	.17	.86	.64	.23	.65	.46	.25	.26	.08	.94
Negative	.36	.08	.81	.16	.49	.57	.04	.26	.15	1.01
Neutral	.07	.67	.46	.21	.83	.24	.29	.22	.01	1.48
Joy	.23	.76	.61	.24	.90	.41	.25	.26	.08	1.04
Interest	.10	.95	.49	.24	.13	.49	.25	.26	.08	1.35
Calm	.17	.81	.82	.18	.88	.48	.25	.26	.08	1.16
Fear	.40	.00	.81	0	.89	.44	.05	.23	.15	1.26
Sadness	.44	.19	.83	.12	.87	.67	.04	.26	.15	.64
Disgust	.22	.20	.81	.28	.00	.57	.04	.31	.14	.80
				Neutral Bias Correction						
Positive	.14	.87	.63	.27	.66	.47	.29	.22	.01	1.04
Negative	.33	.41	.76	.27	.54	.54	.29	.22	.01	1.22
Neutral	.07	.67	.46	.21	.83	.24	.29	.22	.01	1.48
Joy	.20	.79	.61	.27	.91	.42	.29	.22	.01	1.13
Interest	.07	.96	.48	.27	.14	.50	.29	.22	.01	1.12
Calm	.15	.83	.81	.21	.89	.48	.29	.22	.01	1.12
Fear	.37	.33	.76	.02	.92	.31	.29	.22	.01	1.35
Sadness	.41	.49	.78	.20	.88	.65	.29	.22	.01	.56
Disgust	.18	.49	.76	.39	0	.56	.29	.26	.01	.93

Table 8

χ2 values for differences between parameters of the constrained multinomial model based on emotional condition (same-valence bias correction).

	B_v	B_g	B_{vg}	R_C (TG)	R_T (TG)	R_C (RD)	R_T (RD)	F (TG)	F (RD)	Omnibus Test χ^2 Value
Positive vs. Negative	23.98*	.87	1.38	23.18*	.51	2.71	3.60	.80	6.93*	63.96**
Positive vs. Neutral	3.02	5.94*	21.48*	4.02*	2.90	32.01*	15.39*	30.81*	18.93*	134.50**
Negative vs. Neutral	23.98*	.87	1.38	32.58*	3.86*	57.68*	38.87*	32.37*	40.50*	232.09**
Joy vs. Interest	—	—	—	11.81*	.29	38.95*	15.79*	.95	1.89	69.68**
Calm vs. Interest	—	—	—	25.64*	6.28*	35.78*	2.50	1.45	1.20	72.85**
Fear vs. Sadness	—	—	—	.14	14.75*	2.98	2.04	5.23*	3.83^	28.97**
Sadness vs. Disgust	—	—	—	.38	38.91*	1.02	.15	4.86*	47.74*	93.06**

* Exceeds critical value for significance at an alpha level of .05.
**Exceeds critical value of 16.92 for χ^2 test with 9 degrees of freedom.
^ Marginally significant.

Table 9

Parameter estimates of the unconstrained signal detection model with equal variances assumed for each emotional condition.

	μTR (RD)	μCR (RD)	μF (RD)	C_v	C_g	C_{vg}	σ_{UD}	σ_{RD}	G^2
Overall	1.03	.92	.86	.87	.67	1.68	1	1	0
Same-Valence Bias Correction									
Positive	.98	.69	.86	.67	.63	1.41	1	1	0
Negative	.15	.39	1.50	1.76	.63	1.03	1	1	0
Neutral	1.64	1.32	.52	.55	.76	2.22	1	1	0
Joy	1.41	1.05	.78	.67	.63	1.41	1	1	0
Interest	.66	.35	.90	.67	.63	1.41	1	1	0
Calm	1.21	.99	.89	.67	.63	1.41	1	1	0
Fear	.45	1.04	1.16	1.76	.63	1.03	1	1	0
Sadness	.43	.73	1.71	1.76	.63	1.03	1	1	0
Disgust	-.01	-.21	1.76	1.76	.63	1.03	1	1	0
Neutral Bias Correction									
Positive	1.45	1.03	.86	.55	.76	2.22	1	1	0
Negative	1.35	.92	.97	.55	.76	2.22	1	1	0
Neutral	1.64	1.32	.52	.55	.76	2.22	1	1	0
Joy	1.80	1.39	.79	.55	.76	2.22	1	1	0
Interest	1.12	.69	.90	.55	.76	2.22	1	1	0
Calm	1.68	1.33	.90	.55	.76	2.22	1	1	0
Fear	1.65	1.57	.62	.55	.76	2.22	1	1	0
Sadness	1.63	1.26	1.17	.55	.76	2.22	1	1	0
Disgust	1.19	.33	1.22	.55	.76	2.22	1	1	0

Table 10

χ2 values for differences between parameters of unconstrained signal detection model with equal variances assumed based on emotional condition (same-valence bias correction).

	C_v	C_g	C_{vg}	μF (RD)	μCR (RD)	μTR (RD)	Omnibus Test χ^2 Value
Positive vs. Negative	14.90*	0	2.57	11.20*	2.82	17.90*	49.39**
Positive vs. Neutral	0.30	.32	4.13*	4.07*	7.01*	7.93*	23.76**
Negative vs. Neutral	19.20*	.32	13.60*	27.20*	19.50*	47.30*	127.12**
Joy vs. Interest	—	—	—	0.35	9.01*	9.12*	18.48**
Calm vs. Interest	—	—	—	0	7.74*	5.81*	13.55**
Fear vs. Sadness	—	—	—	5.13*	2.18	.01	7.31
Sadness vs. Disgust	—	—	—	.04	20.60*	3.29	23.92**

* Exceeds critical value for significance at an alpha level of .05.
**Exceeds critical value of 12.59 for χ^2 test with 6 degrees of freedom.
^ Marginally significant.

Table 11

Parameter estimates of the constrained signal detection model with equal variances assumed for each emotional condition.

	μTR (TG)	μCR (TG)	μF (TG)	μTR (RD)	μCR (RD)	μF (RD)	C_v	C_g	C_{vg}
Overall	.34	1.88	1.05	.13	2.19	.71	.69	.54	1.65
				Same-Valence Bias Correction					
Positive	.25	2.24	1.04	.29	1.73	.73	.54	.51	1.38
Negative	.89	.18	1.58	0	1.03	1.22	1.25	.57	1.01
Neutral	.05	2.56	.76	.30	3.03	.39	.44	.61	2.18
Joy	.33	1.93	.97	.30	2.59	.65	.54	.51	1.38
Interest	.15	2.96	.80	.31	.91	.77	.54	.51	1.38
Calm	.33	2.00	1.43	.22	2.46	.76	.54	.51	1.38
Fear	.75	.34	1.49	0	2.10	.90	.99	.71	1.01
Sadness	1.00	.31	1.55	0	1.84	1.42	1.22	.58	1.01
Disgust	.78	.13	1.71	.25	0	1.46	1.41	.47	1.05
				Neutral Bias Correction					
Positive	.15	3.13	1.04	.39	2.42	.73	.44	.61	2.18
Negative	.53	2.06	1.17	.05	3.62	.49	.44	.61	2.18
Neutral	.05	2.56	.76	.30	3.03	.39	.44	.61	2.18
Joy	.23	2.82	.97	.39	3.28	.66	.44	.61	2.18
Interest	.05	3.85	.80	.41	1.60	.77	.44	.61	2.18
Calm	.23	2.89	1.43	.32	3.15	.77	.44	.61	2.18
Fear	.53	2.06	1.17	.05	3.62	.49	.44	.61	2.18
Sadness	.60	2.25	1.17	.35	3.04	1.04	.44	.61	2.18
Disgust	.23	2.22	1.30	.85	.87	1.09	.44	.61	2.18

Table 12

Parameter estimates of the unconstrained mixed multinomial-signal detection model with equal variances assumed for each emotional condition.

	R_T	μCR	μF	C_v	C_g	C_{vg}	σ_{UD}	σ_{RD}
Overall	0.51	1.20	1.10	0.87	0.67	1.68	1	1
			Matching-Valence Bias Correction					
Positive	.50	.84	1.21	.67	.63	1.41	1	1
Negative	.14	.40	1.54	1.76	.63	1.03	1	1
Neutral	.58	2.66	0	.60	.76	2.00	1	1
Joy	.56	1.40	1.35	.67	.63	1.41	1	1
Interest	.39	.34	1.06	.67	.63	1.41	1	1
Calm	.49	1.21	1.54	.67	.63	1.41	1	1
Fear	.34	1.32	1.12	1.76	.63	1.03	1	1
Sadness	.28	.78	1.94	1.76	.63	1.03	1	1
Disgust	.02	0	1.63	1.80	.51	1.10	1	1
			Neutral Bias Correction					
Positive	.54	1.21	1.58	.55	.76	2.22	1	1
Negative	.50	1.01	1.71	.55	.76	2.22	1	1
Neutral	.58	2.66	0	.60	.76	2.00	1	1
Joy	.57	1.76	1.79	.55	.76	2.22	1	1
Interest	.49	.66	1.28	.55	.76	2.22	1	1
Calm	.50	1.56	1.99	.55	.76	2.22	1	1
Fear	.50	3.47	0	.56	.76	2.22	1	1
Sadness	.40	1.35	2.47	.55	.76	2.22	1	1
Disgust	.53	.12	1.73	.55	.76	2.22	1	1

Table 13

χ2 values for differences between parameters of the unconstrained mixed multinomial-signal detection model based on emotional condition (same-valence bias correction).

	C_v	C_g	C_{vg}	μF (RD)	μCR (RD)	R_T (RD)	Omnibus Test χ^2 Value
Positive vs. Negative	14.90*	0	2.57	2.98	4.49*	17.20*	42.14**
Positive vs. Neutral	9.93*	10.10*	11.70*	14.50*	25.20*	15.70*	87.13**
Negative vs. Neutral	26.30*	10.10*	17.90*	18.50*	45.00*	56.30*	174.10
Joy vs. Interest	—	—	—	0.66	12.80*		
Calm vs. Interest	—	—	—	2.47	10.00*		
Fear vs. Sadness	—	—	—	10.90*	3.20		
Sadness vs. Disgust	—	—	—	4.63*	21.40*		

* Exceeds critical value for significance at an alpha level of .05.
**Exceeds critical value of 12.59 for χ^2 test with 6 degrees of freedom.
^ Marginally significant.

Table 14

Parameter estimates of the constrained mixed multinomial-signal detection model with equal variances assumed for each emotional condition.

	R_T (TG)	μ_{CR} (TG)	μF (TG)	R_T (RD)	μ_{CR} (RD)	μ_F (RD)	C_v	C_g	C_{vg}
Overall	.59	0	3.40	.12	3.04	.70	.66	.53	2.26
Matching-Valence Bias Correction									
Positive	.56	0	3.60	.23	2.24	.77	.53	.50	1.66
Negative	.62	0	3.00	.07	1.84	1.04	.96	.47	1.51
Neutral	.54	0	3.33	.22	4.02	.34	.44	.60	2.79
Joy	.55	0	3.18	.23	3.27	.68	.53	.50	1.64
Interest	.55	0	4.03	.24	1.10	.83	.54	.51	1.60
Calm	.58	0	3.86	.17	3.06	.80	.54	.51	1.61
Fear	.60	0	2.70	0	2.76	.82	.91	.66	1.29
Sadness	.67	0	3.34	0	2.49	1.37	1.15	.55	1.26
Disgust	.58	0	3.00	.35	0	1.51	1.14	.48	1.36
Neutral Bias Correction									
Positive	.56	0	4.42	.28	3.00	.80	.44	.61	2.53
Negative	.63	0	3.71	.29	2.90	.94	.44	.60	2.73
Neutral	.54	0	3.33	.22	4.02	.34	.44	.60	2.79
Joy	.56	0	4.01	.29	4.08	.70	.44	.61	2.53
Interest	.55	0	4.93	.29	1.87	.86	.44	.61	2.51
Calm	.58	0	4.68	.23	3.88	.83	.44	.61	2.52
Fear	.62	0	3.52	.04	4.37	.48	.44	.60	2.59
Sadness	.67	0	3.81	.22	3.82	1.19	.44	.61	2.57
Disgust	.59	0	3.65	.51	.72	1.49	.44	.60	2.62

Figure 1. Effect of valence and instructional condition on target acceptance rate. Error bars represent standard error values.

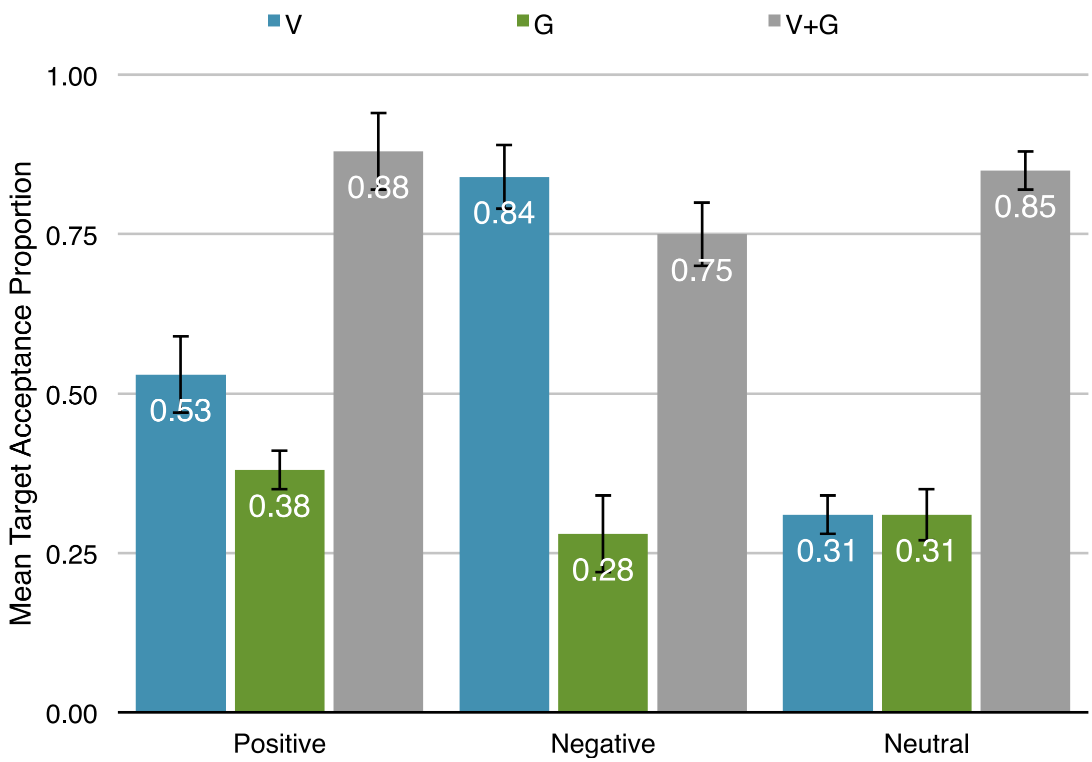


Figure 2. Effect of list length and valence on target acceptance rate.

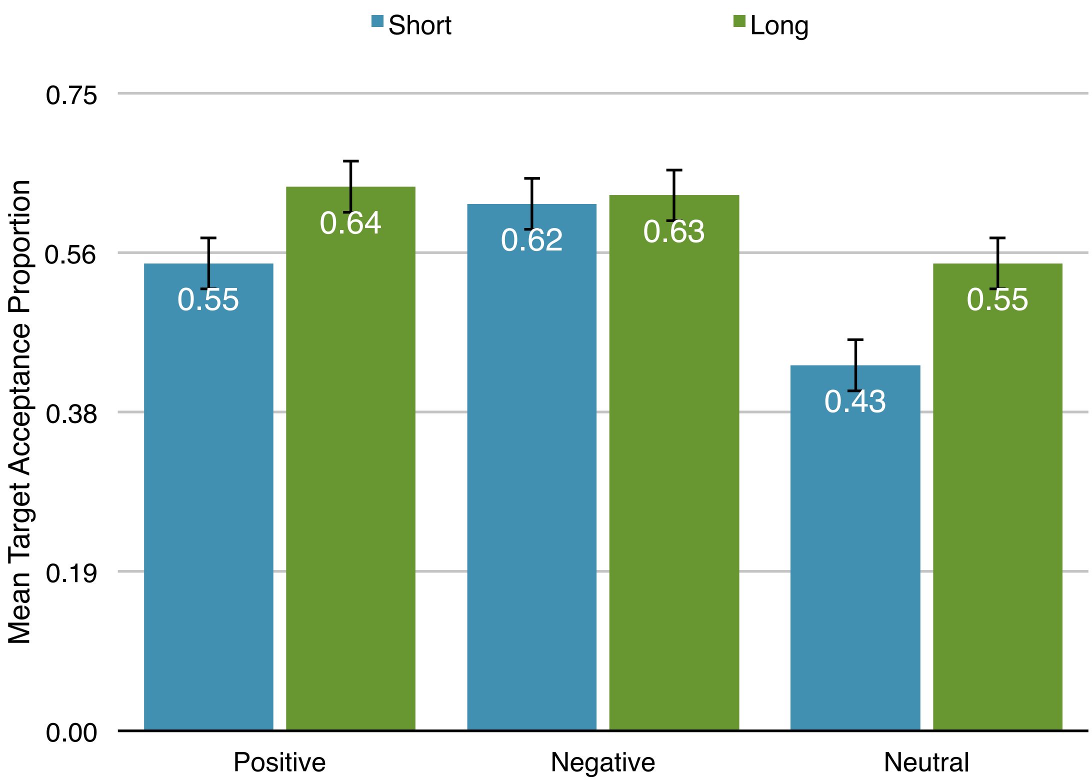


Figure 3. Effect of instructional condition and list length on target acceptance rate.

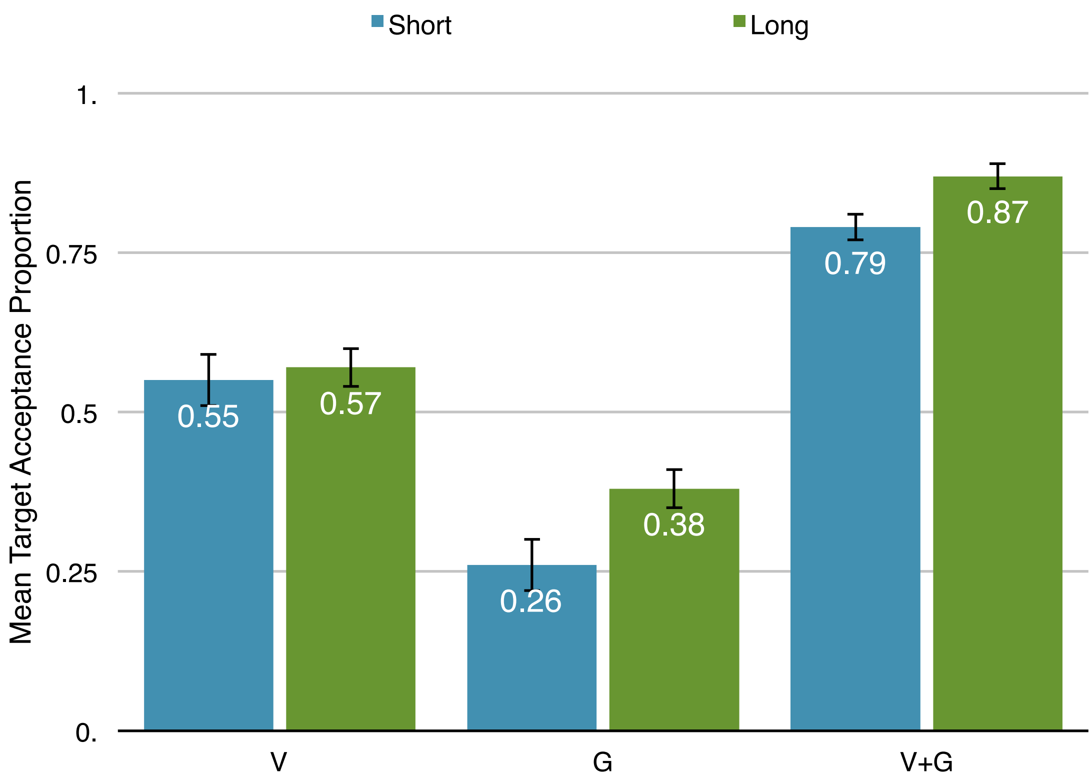
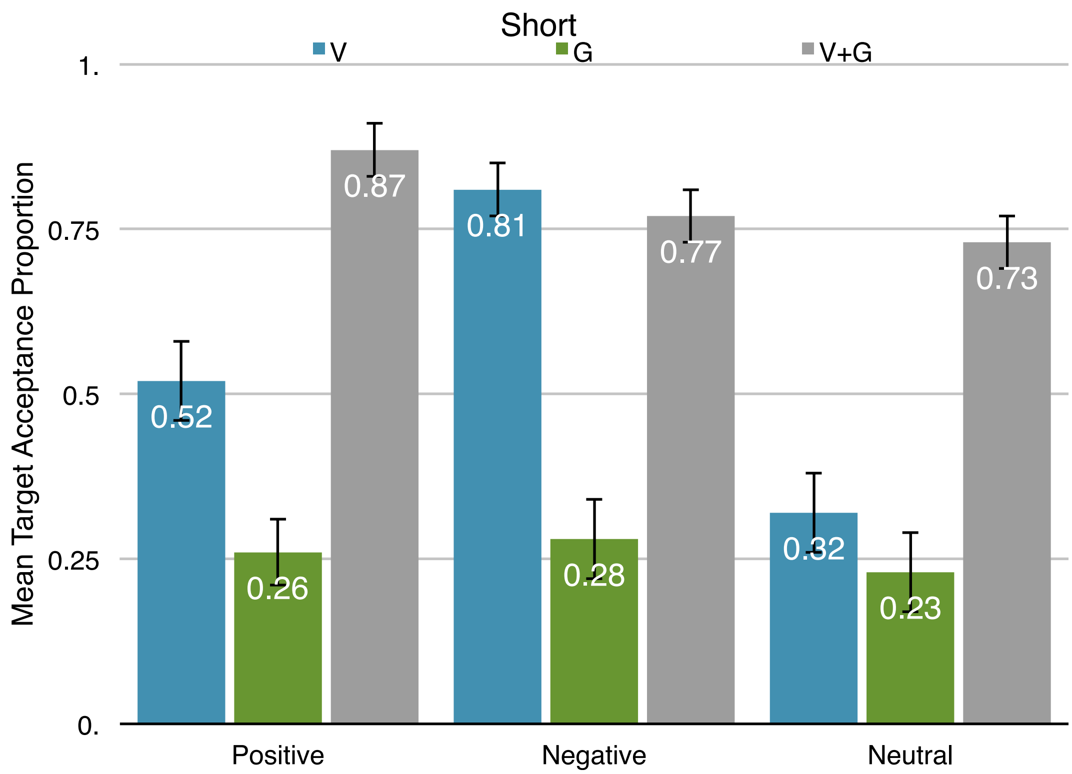


Figure 4. Effect of list length, valence, and instructional condition on target acceptance rate.



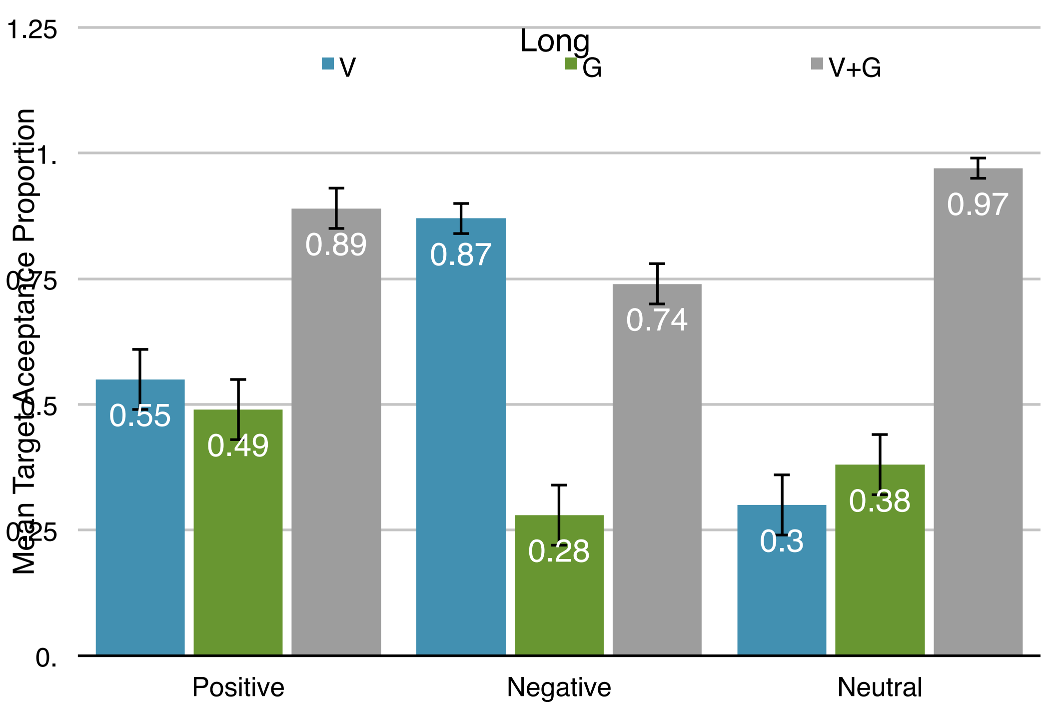


Figure 5. Effect of individual emotion on target acceptance rate.

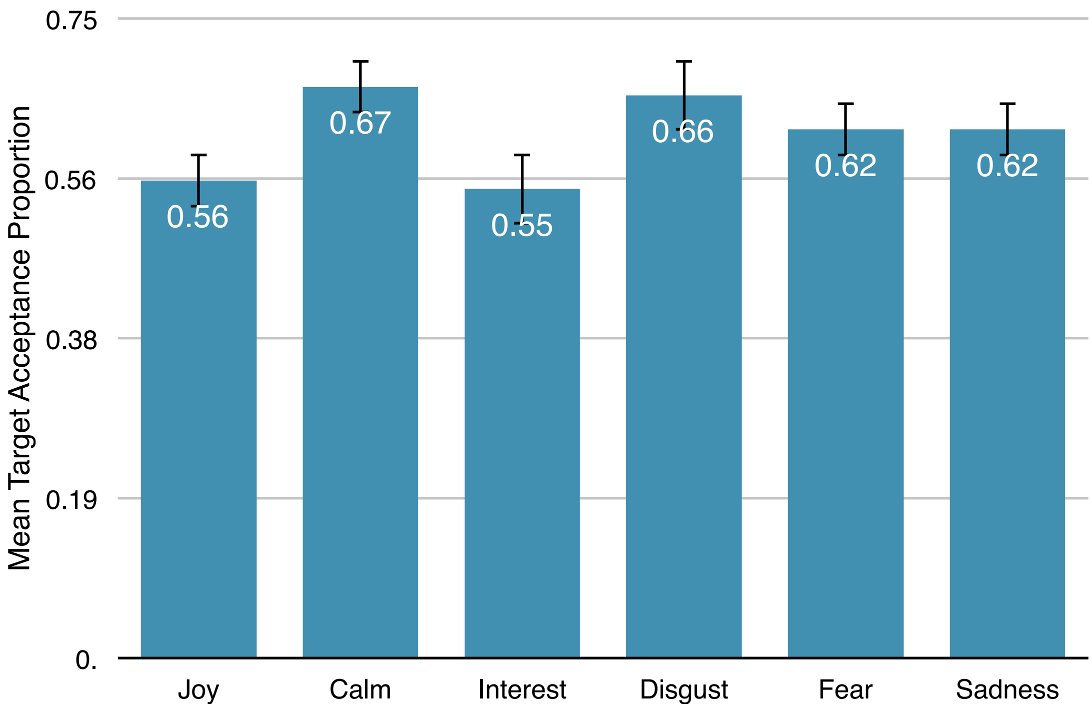


Figure 6. Effect of individual emotion and instructional condition on target acceptance rate.

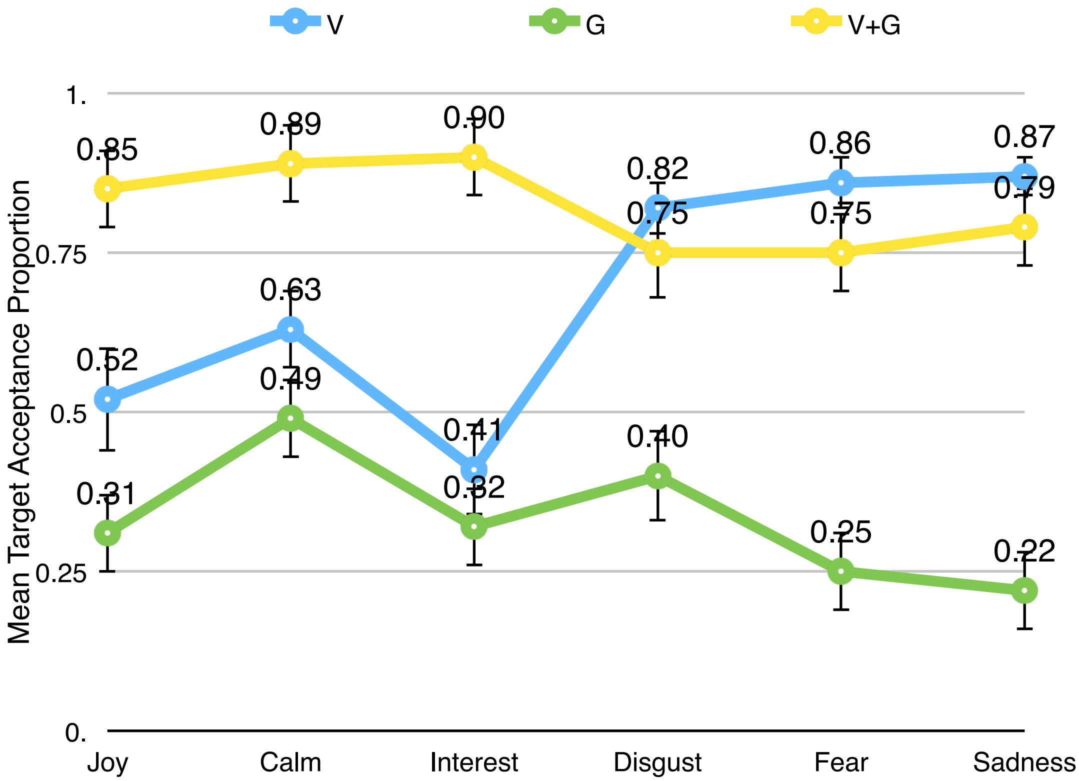


Figure 7. Effect of valence and instructional condition on related distractor acceptance rate.

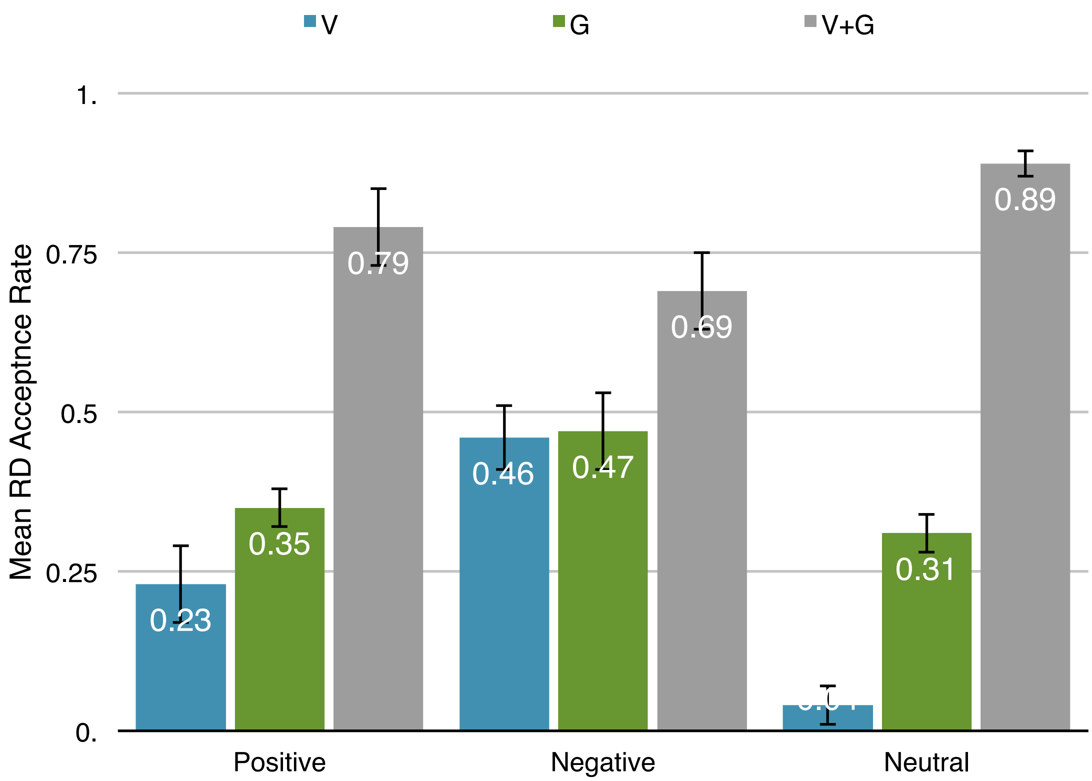


Figure 8. Effect of list length and valence on related distractor acceptance rate

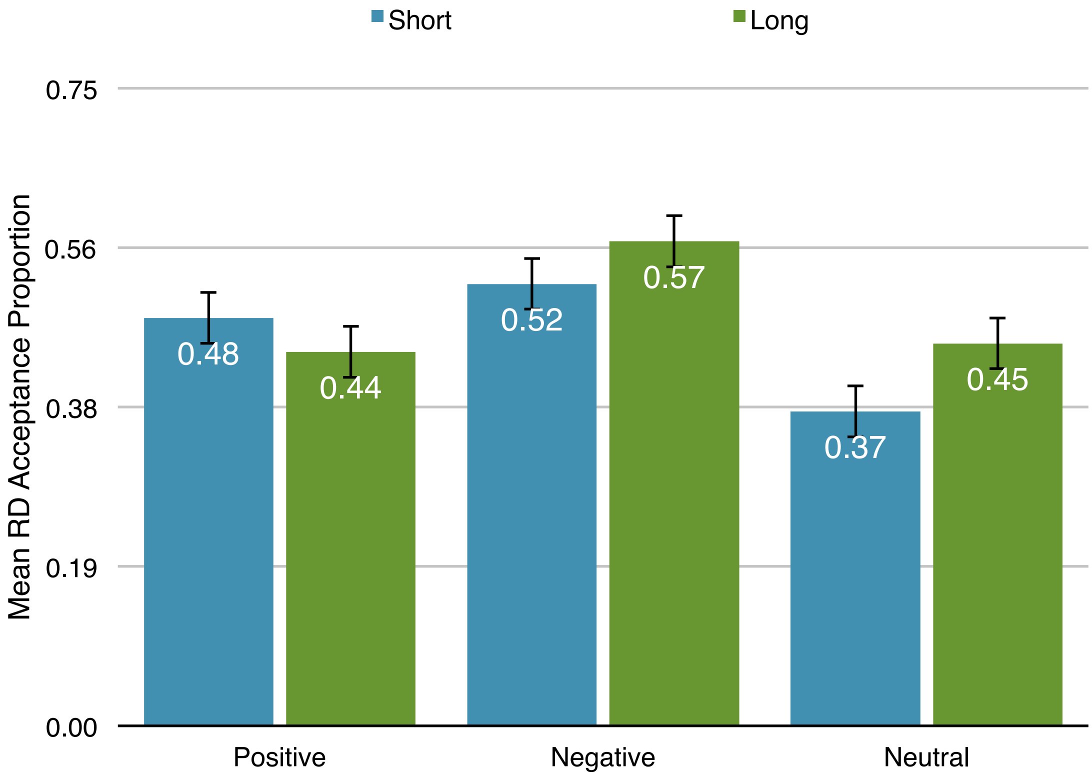


Figure 9. Effect of instructional condition and list length on related distractor acceptance rate.

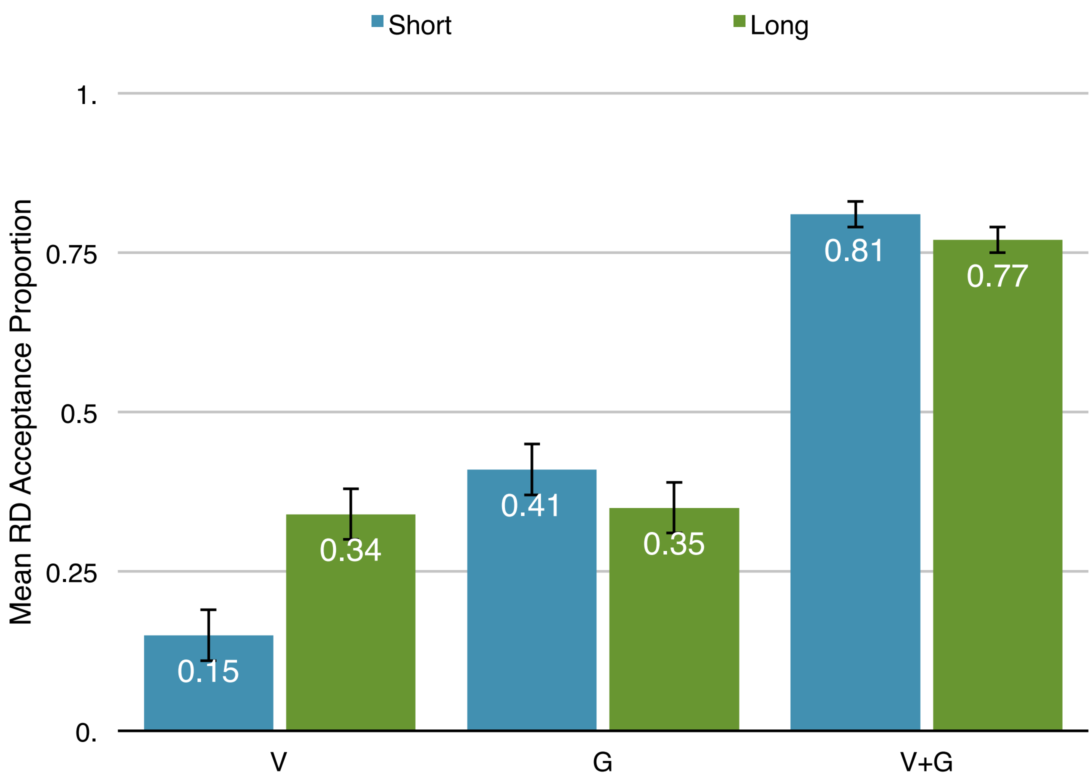


Figure 10. Effect of list length, valence, and instructional condition on related distractor acceptance rate

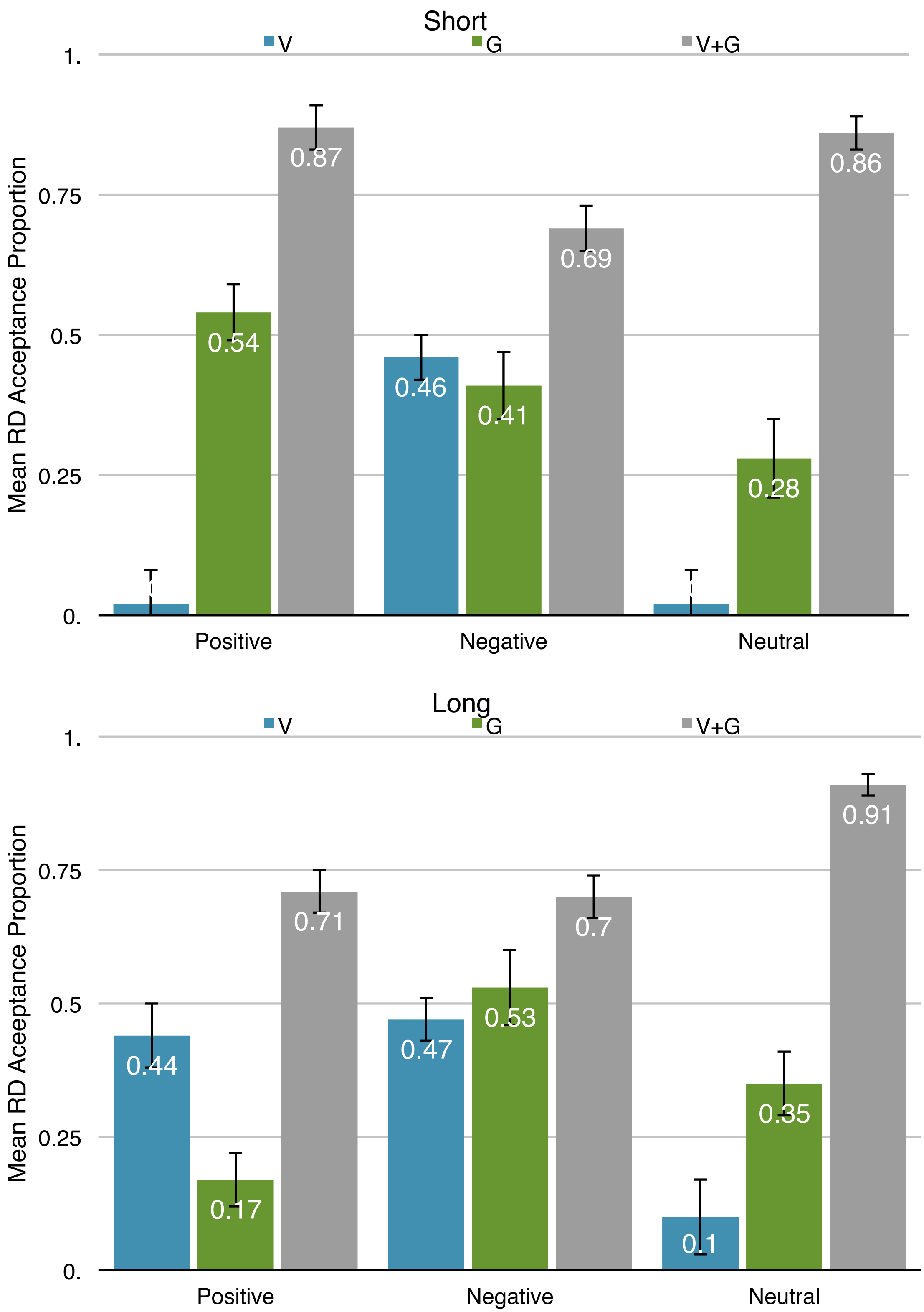


Figure 11. Effect of individual emotion on related distractor acceptance rate.

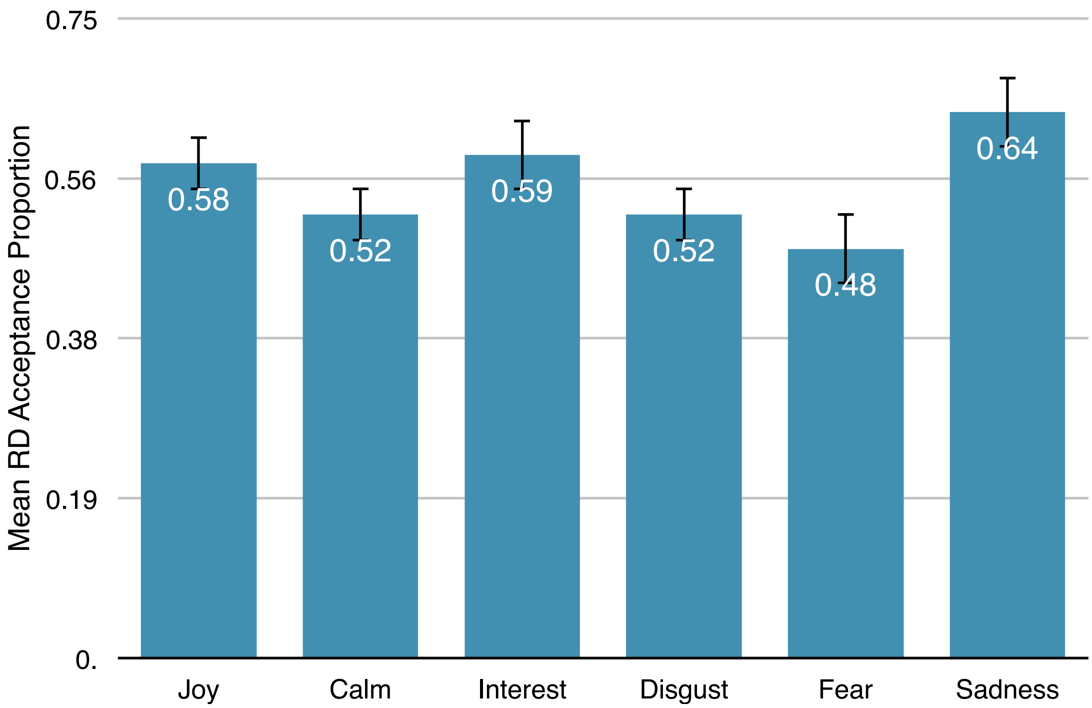
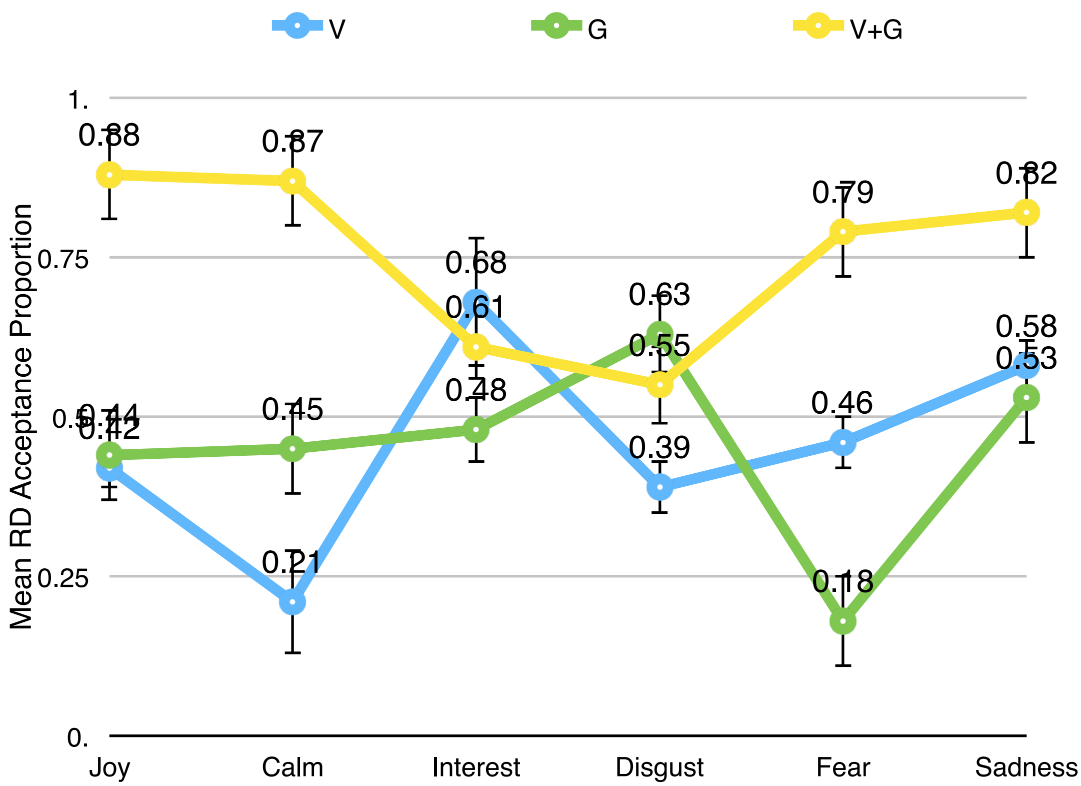


Figure 12. Effect of individual emotion and instructional condition on related distractor acceptance rate.



Appendix A

Expressions for Acceptance of Related and Unrelated Distractor Probes in the Multinomial, Signal Detection, and Mixed Models in the Three Conjoint Recognition Conditions (Brainerd, Gomes, & Moran, in press)

Distractor acceptance probability by condition	Expression
	Multinomial Model
pV(RD)	$(1 - R_T)R_C + (1 - R_T)(1 - R_C)FR + (1 - R_T)(1 - R_C)(1 - F)b_V$
pG(RD)	$R_T + (1 - R_T)(1 - R_C)F + (1 - R_T)(1 - R_C)(1 - F)b_G$
pVG(RD)	$R_T + (1 - R_T)R_C + (1 - R_T)(1 - R_C)F + (1 - R_T)(1 - R_C)(1 - F)b_{VG}$
pV(TG)	$R_T + (1 - R_T)R_C + (1 - R_T)(1 - R_C)F + (1 - R_T)(1 - R_C)(1 - F)b_V$
pG(TG)	$(1 - R_T)R_C + (1 - R_T)(1 - R_C)F + (1 - R_T)(1 - R_C)(1 - F)b_G$
pVG(TG)	$R_T + (1 - RTR_T)R_C + (1 - R_T)(1 - R_C)F + (1 - R_T)(1 - R_C)(1 - F)b_{VG}$
pV(UD)	b_V
pG(UD)	b_G
pVG(UD)	b_{VG}
	Signal Detection Model
pV(RD)	$\Phi\left(\frac{\mu_{CR\|RD}-\mu_{TR\|RD}+\mu_{F\|RD}-C_V}{\sqrt[2]{\sigma_{TR\|RD}{}^2+\sigma_{CR\|RD}{}^2+\sigma_{F\|RD}{}^2}}\right)$
pG(RD)	$\Phi\left(\frac{\mu_{TR\|RD}-\mu_{CR\|RD}+\mu_{F\|RD}-C_G}{\sqrt[2]{\sigma_{TR\|RD}{}^2+\sigma_{CR\|RD}{}^2+\sigma_{F\|RD}{}^2}}\right)$
pVG(RD)	$\Phi\left(\frac{\mu_{TR\|RD}+\mu_{CR\|RD}+\mu_{F\|RD}-C_{VG}}{\sqrt[2]{\sigma_{TR\|RD}{}^2+\sigma_{CR\|RD}{}^2+\sigma_{F\|RD}{}^2}}\right)$

pV(UD)	$\Phi\left(-\frac{c_V}{\sqrt[2]{\sigma_{TR\|UD}{}^2+\sigma_{CR\|UD}{}^2+\sigma_{F\|UD}{}^2}}\right)$
pG(UD)	$\Phi\left(-\frac{c_G}{\sqrt[2]{\sigma_{TR\|UD}{}^2+\sigma_{CR\|UD}{}^2+\sigma_{F\|UD}{}^2}}\right)$
pVG(UD)	$\Phi\left(-\frac{c_{VG}}{\sqrt[2]{\sigma_{TR\|UD}{}^2+\sigma_{CR\|UD}{}^2+\sigma_{F\|UD}{}^2}}\right)$
Mixed Model	
pV(RD)	$(1-R_T)\Phi\left(\frac{\mu_{CR\|RD}+\mu_{F\|RD}-c_V}{\sqrt[2]{\sigma_{CR\|RD}{}^2+\sigma_{F\|RD}{}^2}}\right)$
pG(RD)	$R_T+(1-R_T)\Phi\left(\frac{\mu_{F\|RD}-\mu_{CR\|RD}-c_G}{\sqrt[2]{\sigma_{CR\|RD}{}^2+\sigma_{F\|RD}{}^2}}\right)$
pVG(RD)	$R_T+(1-R_T)\Phi\left(\frac{\mu_{CR\|RD}+\mu_{F\|RD}-c_{VG}}{\sqrt[2]{\sigma_{CR\|RD}{}^2+\sigma_{F\|RD}{}^2}}\right)$
pV(UD)	$\Phi\left(-\frac{c_V}{\sqrt[2]{\sigma_{CR\|UD}{}^2+\sigma_{F\|UD}{}^2}}\right)$

pG(UD)	$\Phi\left(-\frac{c_G}{\sqrt[2]{\sigma_{CR\|UD}{}^2+\sigma_{F\|UD}{}^2}}\right)$
pVG(UD)	$\Phi\left(-\frac{c_{VG}}{\sqrt[2]{\sigma_{CR\|UD}{}^2+\sigma_{F\|UD}{}^2}}\right)$

Note. V = accept only targets, G = accept only related distractors, VG = accept both targets and related distractors, RD = related distractor, UD = unrelated distractor, and $\Phi(\cdot)$ is the Gaussian cumulative distribution function.

Appendix B

Correlations among related distractor parameters of the equal and unequal variance SDT models.

	μTR	μCR	μ_F	C_v	C_g	C_{vg}
Overall	.95	.95	.98	.99	.99	.93
Positive	.82	.90	.88	.92	.89	.95
Negative	.92	.90	.87	.92	.95	.95
Neutral	.81	.86	.96	.99	.90	.83
Joy	.58	.26*	.26*	.28*	.33**	.46
Calm	.74	.70	.70	.85	.89	.96
Interest	.83	.89	.77	.53	.67	.98
Fear	.68	.78	.79	.93	.81	.84
Disgust	.75	.87	.82	.93	.89	.94
Sadness	.72	.64	.76	.89	.87	.94

Note. p values are less than .001 unless otherwise indicated

* .Significant at an alpha level of .02

** Significant at an alpha level of .01

Appendix C

Correlations among related distractor parameters of the equal and unequal variance mixed models.

	Rt	μCR	μF	C_v	C_g	C_{vg}
Overall	.99	.98	.98	.99	.99	.98
Positive	.99	.98	.99	.99	.99	.99
Negative	.99	.98	.99	.99	.99	.98
Neutral	.99	.99	.97	.99	.99	.97
Joy	.99	.90	.93	.99	.99	.99
Calm	.95	.86	.84	.98	.83	.95
Interest	.98	.98	.99	.99	.98	.99
Fear	.97	.98	.99	.99	.95	.99
Disgust	.98	.96	.96	.99	.97	.99
Sadness	.88	.91	.96	.95	.78	.99

Note. All p values are less than .001.

Appendix D

Correlations among related distractor parameters of the constrained and unconstrained multinomial models.

	F	Rt	Rc
Overall	.52	.62	.85
Positive	.69	.81	.71
Negative	.77	.68	.78
Neutral	.47	.63	.87
Joy	.82	.97	.48
Calm	.58	.98	.27*
Interest	.84	.83	.60
Fear	.85	.94	.53
Disgust	.97	.99	.19**
Sadness	.70	.82	.52

Note. All p values are significant at an alpha level of .001 unless otherwise indicated.

* Significant at an alpha level of .02

** Nonsignificant

Appendix E

Correlations between related distractor parameters of the multinomial and signal detection models.

	Rc-μCR	F-μF	Rt-Rt
Overall	.86	.81	.95
Positive	.74	.79	.95
Negative	.72	.76	.94
Neutral	.86	.79	.95
Joy	.14**	.76	.92
Calm	.26*	.48	.95
Interest	.56	.69	.93
Fear	.42	.67	.89
Disgust	.08**	.80	.90
Sadness	.17**	.79	.82

Note. All p values are significant at an alpha level of .001 unless otherwise indicated.

* Significant at an alpha level of .01

** Nonsigniicant

Appendix F

Correlations between parameters of the signal detection and mixed models.

	μCR-μCR	μF-μF	μTR-Rt
Overall	.53	.29*	.59
Positive	.56	.35*	.36*
Negative	.64	.28**	.58
Neutral	.55	.32*	.47
Joy	.43	.68	.24**
Calm	.71	.58	.81
Interest	.62	.55	.79
Fear	.62	.79	.51
Disgust	.65	.69	.73
Sadness	.38	.58	.74

Note. All p values are significant at an alpha level of .001 unless otherwise indicated.

* Significant at an alpha level of .01

** Significant at an alpha level of .05

Appendix G

Correlations between parameters of the mixed and multinomial models.

	μCR-Rc	μF-F	μTR-Rt
Overall	.41	.24	.55
Positive	.44	.28	.47
Negative	.73	.49	.59
Neutral	.62	-.06**	.50
Joy	.68	.55	.36*
Calm	.50	.47	.84
Interest	.63	.59	.79
Fear	.77	.52	.51
Disgust	.33*	.56	.73
Sadness	.61	.55	.62

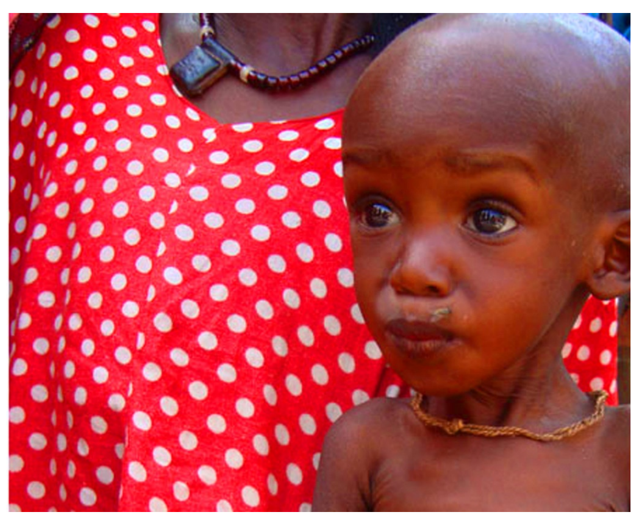
Note: all p values are significant at an alpha level of .001 unless otherwise indicated.

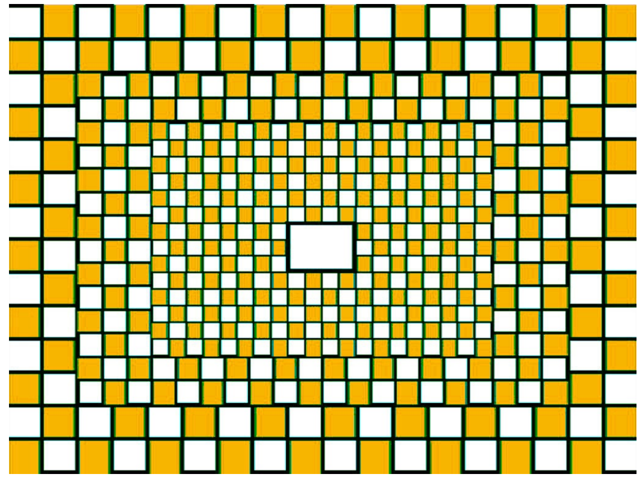
** Significant at an alpha level of .05*

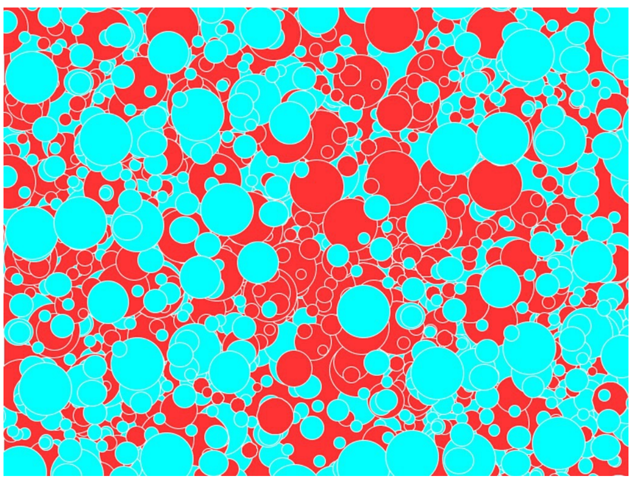
*** Nonsignificant*

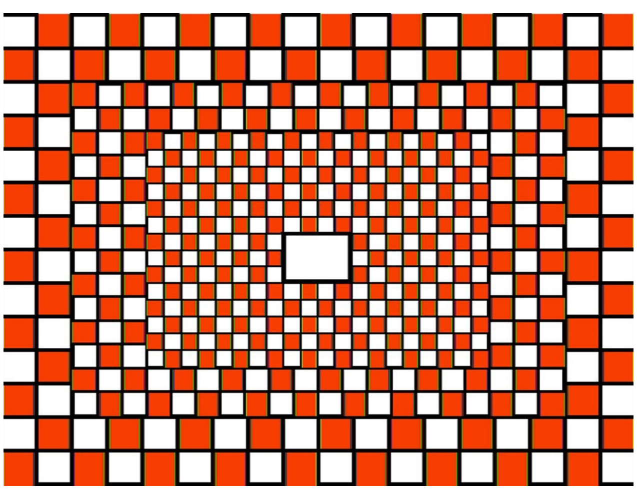
Appendix H

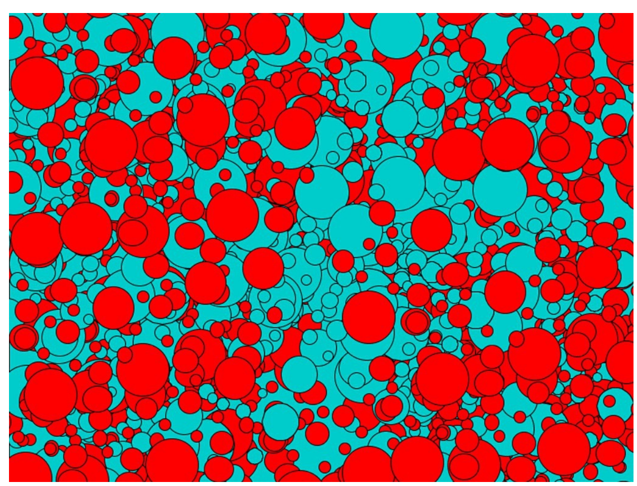
Sample stimuli.









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OUTS 1
INNING
B 2







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