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Emotionally Negative Pictures Enhance Gist Memory

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Abstract

In prior work on how true and false memory are influenced by emotion, valence and arousal have often been conflated. Thus, it is difficult to say which specific effects are due to valence and which are due to arousal. In the present research, we 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 revealed that negative valence (a) reduced erroneous suppression of true memories and (b) increased the familiarity of the semantic content of both true and false memories. Overall, negative valence impaired the verbatim side of episodic memory but enhanced the gist side, and these effects persisted even after a week-long delay.

Keywords

emotional valence; fuzzy-trace theory; conjoint recognition

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 we ate for lunch. For decades, researchers have studied memory for emotional content, and a particularly interesting line of work deals with the impact of emotion on false memory. As emotion affects memory for true events, so it may affect false memories for events that did not happen. The importance of understanding the connection between emotion and false memory becomes clear when one considers, for example, situations such as legal cases in which the to-be-remembered events are emotionally charged and memory is the only available record of events. Basing convictions on one or a few eyewitness reports is risky if they are apt to be distorted by emotion. However, conflicting data have been reported on that: Emotional content has sometimes increased false memory and sometimes decreased it. These differences could be due to the conflation of valence and arousal and the tendency to interpret results as valence effects even when arousal is not controlled. Consequently, in the present study, we investigated the effects of valence on false memory with arousal controlled.

Background

Researchers have found evidence of an emotional enhancement of memory for emotional content as compared to neutral content for stimuli that range from words to pictures to

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videos (e.g., Budson, Todman, Chong, Adams, Kensinger, Krangel, & Wright, 2006; Charles, Mather, & Carstensen, 2003; Maras, Gaigg, & Bowler, 2012). Further, in some of these studies emotion increased false memory compared to nonemotional stimuli. For example, Brueckner and Moritz (2009), as well as Gallo, Foster, and Johnson (2009), reported increased false memory for both positive and negative valence compared to neutral valence, using words and pictures, respectively. However, valence and arousal are often conflated in these studies. To illustrate, Budson et al. used versions of the Deese/Roediger/McDermott (DRM; Deese, 1959; Roediger & McDermott, 1995) word lists that were highly arousing as well as negative, relative to neutral, non-arousing DRM lists. Similarly, El Sharkawy, Groth, Vetter, Beraldi, and Fast (2008) used negative DRM lists without controlling arousal, finding that negative lists increased both true and false memory compared to neutral lists. A common result is enhanced memory for negative (and sometimes positive) arousing content compared to neutral, non-arousing content, which makes it difficult to determine whether the enhancement is a result of valence, arousal, or both. In order to measure actual valence effects, it is necessary to compare emotional stimuli to neutral stimuli with equivalent arousal levels.

Research on emotion-memory effects has been focused more on negative than positive valence and, indeed, positive valence has often been intentionally omitted. For example, Kensinger and colleagues (e.g., Kensinger & Corkin, 2004; Kensinger & Schacter, 2007) have explored negative emotion extensively by comparing negative, arousing stimuli to neutral stimuli, demonstrating greater true memory for negative, arousing items compared to neutral items. This difference has been attributed to arousal and is consistent with other research demonstrating enhanced memory for arousing content (e.g., Block, Greenberg, & Goodman, 2009). The focus on negative valence is motivated by the fact that in many high-stakes memory situations, such as legal cases and risky decision making, moods and to-be remembered information are negative and arousing. However, the lack of data on positive valence and the lack of control of arousal means that it is unclear whether memory enhancement is specific to negative content and whether it is due to arousal rather than valence.

The focus on negative valence applies to false memory studies as well. Neither Budson et al. nor El Sharkawy et al. included positive lists. Neither did two other similar studies by Pesta, Murphy, and Sanders (2001) and Gaigg and Bowler (2009), in which case false memory for negative, arousing lists was compared to false memory for neutral lists. Brainerd, Stein, Silveira, Rohenkohl, and Reyna (2008), however, controlled arousal while manipulating valence, and found that positive and negative valence affected memory differently. Using emotional DRM lists, they found that true and false memory were highest for negative words and lowest for positive words, suggesting that arousal was not the sole cause of emotion effects in prior false memory studies. In some similar research, Dehon, Laroi, and Van der Linden (2010) used positive, negative, and neutral word lists with equal arousal levels and found higher levels of false memory for positive and negative lists compared to neutral lists, although true memory was not affected by valence. Thus, there is evidence of pure valence effects on false memory for words.

Other researchers have manipulated valence and arousal factorially in false memory experiments. Van Damme and Smets (2014) reported dissociations between valence and arousal and between positive and negative valance. For instance, negative valence reduced true memory for peripheral details of pictures in the misinformation paradigm, but arousal increased true memory for central details. In addition, false memories of peripheral details were more common for negative information relative to positive information, regardless of arousal level. Similarly, Brainerd, Holliday, Reyna, Yang, and Toglia (2010) reported that the effects of valence but not arousal differed for true and false memory. Negative valence increased false memory and decreased true memory, relative to positive valence, but arousal increased both. These data suggest that when arousal is controlled or valence and arousal are manipulated factorially, pure valence effects on both true and false memory are obtained and that these effects may be different for positive versus negative valence.

In the work reviewed thus far, the dominant methodology was the DRM illusion, in which subjects study words that all relate to an unpresented critical word (e.g., the "sleep" list contains the words *bed, rest, awake*, etc., but not *sleep*) and then complete a recognition or recall test. The usual finding is high levels of false memory for critical words. Fuzzy-trace theory (FTT, Brainerd & Reyna, 1998) explains these false memories via two types of memory traces that are stored in parallel during list presentation. Verbatim traces capture the surface form of words, whereas gist traces capture broader, semantic content that includes connections among items with similar meanings. During the test phase, retrieval of gist traces supports false memories, but retrieval of verbatim traces suppresses them.

Activation monitoring theory (AMT; Roediger, Watson, McDermott, & Gallo, 2001) accounts for DRM false memory via automatic associative activation of unpresented critical words during list presentation. During the test phase, source confusion causes subjects to falsely recognize or recall the activated critical words. Another theory that is based on word associations, associative-activation theory (AAT; Howe, 2005; Howe, Wimmer, Gagnon, & Plumpton, 2009), proposes that activation of list words spreads to nearby concepts, which in turn activate other concepts, resulting in activation of critical words. A key difference between the gist versus word-association mechanisms for DRM false memory is that associative activations are known to be short-lived, typically lasting for a few seconds (Tse & Neely, 2005), whereas gist memories are known to be stable over weeks, months, and longer (Brainerd & Reyna, 2005). In DRM experiments, associative activation has typically been measured by incorporating implicit priming tasks, such as lexical decision, in the DRM paradigm. Such tasks reveal that associative priming effects in that paradigm are relatively short-lived (Tse & Neely, 2005, 2007), although longer lasting associative activation has been detected with other procedures, such as incubation in problem solving tasks (Sio & Ormerod, 2015). Thus, the gist mechanism expects that false memories for critical words will be long-lasting, spanning weeks, whereas the word-association mechanism predicts that they will be short-lived (Roediger et al., 2001). The former result has been consistently observed (e.g., Seamon, Luo, Kopecky, Price, Rothschild, Fung, & Schwartz, 2002; Toglia, Neuschatz, & Goodwin, 1999).

In another comparison of the two theoretical accounts, Dewhurst, Pursglove, and Lewis (2007) noted that the gist mechanism but not the word-association mechanism predicts that strengthening list themes without strengthening word associations, by presenting DRM lists in story contexts, should elevate false memory and elevate it especially in subjects with weaker meaning connection abilities. Their data confirmed both predictions. Some may interpret Dewhurst et al.'s findings as not ruling out the word-association mechanism on that ground that story contexts may somehow have unintentionally increased associative activation as well as strengthening list themes. Although that is possible, note that the gist mechanism clearly predicts Dewhurst's results, whereas the word-association mechanism does not.

Returning to emotion and false memory, FTT has been applied to false memory for emotional words (Brainerd et al., 2008) and so have associative theories (Talmi & Moscovitch, 2004). However, questions about emotion and false memory extend to many types of to-be-remembered events other than word lists. It is not obvious how associative accounts could be applied outside the word list domain because the mechanism that generates false memories is concerned with pre-existing properties *of words*. FTT is readily applied in other domains, however, because its mechanism is not confined to properties of words; indeed, its mechanism was originally developed to explain false memory for more complex events, such as narratives and real-life experiences (Brainerd & Reyna, 2005).

This is an important consideration because it is clearly important to study emotion-false memory effects with materials other than DRM lists, and to at least determine whether the effects that are obtained with DRM lists hold up with other materials and paradigms. In the present research, we implemented a quite different procedure that involves false memory for realistic pictures, which was originally developed by Koutstaal and Schacter (1997). Pictures are presented that are all members of the same category (e.g., cows), and unpresented pictures from that category then serve as the critical distractors that measure false memory. This paradigm generates levels of false memory that are similar to the DRM paradigm, but false memories are rooted in categorical relations among real-world objects and events (as depicted in pictures) rather than word associations. We introduced an emotional valence manipulation in this paradigm in order to determine how false memories for such objects and events are affected by their valence.

Another important feature of the present research, relative to most prior work in this area, is that we measure valence effects at the level of specific retrieval processes as well as at the level of raw memory performance. Here, we implemented a procedure that Brainerd et al. (2008) used in their experiments, which is called conjoint recognition (Brainerd, Reyna, & Mojardin, 1999). In that procedure, the contributions of verbatim and gist retrieval to true and false memory are factored with the parameters of a mathematical model, which allows one to determine which type of retrieval is affected by valence. We briefly summarize conjoint recognition methodology before reporting our research.

Conjoint Recognition

In FTT, true memories are supported by both verbatim and gist traces, but the two types of traces have opposite effects on false memory. Many manipulations have been studied that should affect verbatim and gist retrieval differently (for a review, see Brainerd & Reyna, 2005), and such predictions can be measured with conjoint recognition methodology. The specific retrieval processes that are measured are noted and defined in Table 1. Conjoint recognition methodology has two key features. First, on memory tests, three different types of test questions are administered for all test items: Verbatim (V; I saw this item); gist (G; I did not see this item but I saw one with the same meaning); and verbatim + gist (VG; I either saw this item or one with the same meaning).[1] Second, a multinomial model (see Appendix) is defined over this 3 × 3 data space that measures three distinct retrieval processes for false memory (see Brainerd, Reyna, Wright, & Mojardin, 2003): (a) recollection rejection, which supports correct rejection of related distractors by retrieving verbatim traces of their corresponding targets, (b) phantom recollection, which supports false acceptance of related distractors by retrieving gist traces that are so strong that they stimulate illusory vivid reinstatement of their "presentation" and (c) familiarity, which also supports false acceptance of related distractors by retrieving weaker gist traces. The model also measures three retrieval processes for true memory: (a) erroneous recollection rejection, which supports false rejection of targets via retrieval of verbatim traces of other related targets, (b) identity judgment, which supports correct acceptance of targets by retrieving their verbatim traces, and (c) familiarity, which supports correct acceptance of targets by retrieving their gist traces.

In the research that we report, conjoint recognition methodology was combined with Koutstaal and Schacter's (1997) false memory paradigm. We administered emotional pictures belonging to several categories and then estimated the processes in Table 1 in order to pinpoint the effects of emotional content on specific retrieval processes. To generate those data, the valence of the pictures (positive, negative, neutral) was factorially manipulated with arousal controlled.

Within this core design, we also investigated the effects of the number of exemplars that were presented per category, blocked versus random presentation of exemplars, amount of prior memory testing, and retention interval, on false memory. These four manipulations were included because they have been previously demonstrated to be effective at dissociating verbatim and gist processing. The number of exemplars is a gist repetition manipulation that strengthens memory for categorical relations but does not strengthen verbatim memory for individual exemplars because each exemplar is only presented once (Powell, Roberts, Ceci, & Hembrooke, 1999). Similarly, presenting all of the members of a category in a block, rather than interspersing exemplars from different categories, strengthens memory for categorical relations but does not strengthen verbatim memory for individual exemplars because each exemplar is only presented once (Payne, Elie, Blackwell, & Neuschatz, 1996). Finally, we investigated the effects of amount of prior testing and retention interval using two separate recognition tests in order to determine whether false memory can be elevated merely by testing the same item twice, and how false memories are affected over a week-long delay. These are matters of high relevance to forensic

[1]There are two versions of this first feature: In the multiple choice version (Stahl & Klauer, 2008), each test item is accompanied by a multiple-choice question that contains all three options, one of which subjects must pick; in the yes/no version, each test item is paired with one of the three test questions and subjects must pick yes or no (Brainerd et al., 2003). We implemented the second version because it provides more independent response probabilities and thus delivers identifiable parameters for all of the retrieval processes in Table 1, which the multiple-choice procedure does not do.

interviewing. Moreover, it is obviously important to understand how the effects of valence are modified by repeated testing and by forgetting.

Method

Subjects

Sixty-eight undergraduates (46 women and 22 men; mean age = 19.59 years) participated in exchange for course credit. Subjects were randomly assigned to one of two presentation order conditions (blocked or random).

Materials

Pilot test—Pilot testing was conducted in order to determine the valence and arousal levels of stimulus pictures, as well as their ability to induce false memory. Candidate pictures were taken from the International Affective Pictures System (IAPS; Lang, Bradley, & Cuthbert, 2008), the Geneva Affective Picture Database (GAPED; Dan-Glauser & Scherer, 2011), and stock photo websites, creating a large pool of pictures with categories that varied in valence and arousal. Mean valence scores for categories were computed based on the ratings of individual pictures. We used the valence and arousal norms that Lang, et al. and Dan-Glauser and Scherer reported for the IAPS and GAPED. For pictures from the photo website, we obtained valence and arousal ratings from 25 subjects using Bradley and Lang’s (1994) Self-Assessment Manikin (SAM) rating method. Subjects viewed the images for 2 seconds and rated the degree to which each made them feel happy versus unhappy and calm versus excited. Each scale ranged from 1-9 with higher values representing more positive and more arousing feelings. Picture categories were selected to fall into three valence groups based on previously used valence categories for pictures using the SAM scale (e.g., Kensinger & Schacter, 2008; Mickley & Kensinger, 2009): positive (mean valence = 6.79), negative (mean valence = 2.09), and neutral (mean valence = 5.27). See Table 2 for valence and arousal means for each picture category. All three valence categories had mean arousal scores of less than 6.5 and did not differ significantly in mean arousal.

The target and related distractor materials were 216 color pictures, which were members of 18 object, person, and scene categories (e.g., couches, babies, car accidents). There were 6 positive, 6 negative, and 6 neutral categories, each containing 12 items. 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.

Within each picture category, 3 pictures were used as starting points to generate the remaining 9 pictures in the category by manipulating the picture’s hue, its mirror image, or both (see Table 3). These manipulations were chosen in order to create high levels of visual similarity as well as to maintain consistency in the way pictures of different valences were altered. Within each category there were 12 images comprised as follows: picture 1a with three other versions, 1b-1d; picture 2a with three other versions, 2b-2d; and picture 3a with three other versions, 3b-3d. Pictures 1, 2, and 3 were distinct from one another, whereas the other versions of each picture were all similar to it and to each other. As an example, the "baby" category contained pictures of three different babies. There were four versions of those babies, for a total of 12 baby pictures.

Each category was assigned to one of two number of exemplar conditions such that 3-exemplar categories had 3 targets and 9 nonstudied related distractors, and 8-exemplar categories had 8 targets and 4 nonstudied related distractors. The number of exemplars manipulation was counterbalanced so that three of the 6 positive categories were 3-exemplar categories and 3 of the positive categories were 8-exemplar categories, etc. The 3-exemplar lists consisted of pictures one, 2, and 3 from a given category—that is, 3 distinct exemplars —whereas the 8-exemplar lists consisted of each of the 3 distinct pictures plus 1 or 2 of the other versions of each of those, randomly chosen (see Table 4 for a sample list). In other words, the number of exemplars manipulation was not purely numerical, but the two conditions also differed in terms of the strength of the gist of the list. The 3-exemplar lists would create a weaker gist, for babies in general, for example, whereas the 8-exemplars lists would create a stronger gist, and stronger gist for some babies in particular, by having more pictures in total and by repeating some of them either two or three times, counterbalanced across lists. From this pool of 216 (18 categories × 12 pictures per category), 108 categorized pictures were tested, as well as 18 unrelated pictures.

Procedure

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

Picture presentation—Upon arrival at the laboratory, subjects were randomly assigned to one of the two presentation order conditions. Those in the blocked condition viewed all pictures from each category in sequence, with category order being randomized. Those in the random condition viewed pictures in a fully randomized order with no more than two pictures from the same category appearing in sequence. All subjects read instructions about the study task (to just look at the pictures), and then picture presentation began with 3 buffer pictures that did not belong to any of the categories, followed by the target pictures, and ended with 3 buffer pictures that did not belong to any of the categories (see Table 4). Each picture was presented for 1 second. Next, the subjects worked on math problems for 3 minutes.

Immediate test—Subjects read the test instructions for conjoint recognition (see Brainerd et al., 1999), again presented on the computer screen, and then proceeded with a self-paced conjoint recognition test. The instructions explained that subjects would view a series of test pictures, each of which might or might not have been presented earlier, and that each picture would be accompanied by one of three types of test questions, to which they should respond yes or no. The three conjoint recognition questions were explained in depth: if the question was "I saw this picture during the study phase" (V), subjects were to respond "yes" if the picture was presented and "no" otherwise. If the question was "this picture is new but similar to a picture from the study phase" (G), subjects were to respond "yes" if the picture was similar to one from the study phase, but not identical, and "no" otherwise. Finally, if the question was "I saw either this picture or a similar picture during the study phase," (VG) they were to respond "yes" to any picture that was not an unrelated distractor. Subjects were instructed that the test would be self-paced, to click the mouse to progress from picture to picture, and to answer all items without skipping any, even if they were unsure of the answer. Subjects were shown example pictures for each type of test question, along with the correct responses, and were given the opportunity to ask questions before proceeding.

After reading the instructions, subjects completed the 63-item self-paced immediate recognition test. Half of the pictures were tested, with testing of the second half being delayed until the second session. This method of testing only half of the items and retesting them later along with untested items was chosen because it allows two effects to be measured (see Brainerd, Reyna, & Estrada, 2006): forgetting and prior testing. Forgetting can be measured by comparing responses to items on the immediate test with responses to untested items on the delayed test, whereas the effects of prior testing can be measured by comparing responses to tested and untested items on the delayed 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 3- and 8-exemplar lists. Further, the V, G, and VG test questions were distributed among categories, targets, and related distractors such that there were approximately 20 pictures per test question type, half of which were targets and half of which were related distractors, in addition to the 5 unrelated distractors (see Table 5).

One-week test—After one week, subjects returned to the laboratory to complete the delayed recognition test. They read the same instructions as before and responded to a self-paced conjoint recognition test. On this test, all of the target, related distractor, and unrelated distractor pictures were tested, with half being tested for the first time and half being retested (see Table 6). Pictures that were tested for the second time were paired with the same test questions as on the immediate test. Upon completion of the conjoint recognition test, the subjects answered demographic questions and received a debriefing.

Results

Qualitative Patterns

Descriptive statistics—The mean acceptance proportions for targets, related distractors, and unrelated distractors are reported in Table 7. For the unrelated distractors on the delayed test (when all of the unrelated distractors were tested), acceptance rates were higher for positive and neutral items compared to negative items in the V condition, $t(67) = 3.55$ and $t(67) = 4.49$, both p-values < .05, but across test question there were no reliable valence differences, p-values > .05.

True memory analyses of variance (ANOVAs)—To conduct ANOVAs, the acceptance proportions for targets and related distractors for the V, G, and VG test questions were bias-corrected using the two-high threshold method (Snodgrass & Corwin, 1988). Two mixed model ANOVAs were computed with presentation order as the between subjects factor and bias corrected target acceptance rates on the immediate and delayed tests as the dependent variables. The ANOVA for the immediate test was 3 (test question: V, G, VG) × 3 (valence: positive, negative, neutral) × 2 (number of exemplars: 3, 8) × 2 (presentation order: blocked, random), and the ANOVA for the delayed test was 3 (test question: V, G, VG) × 3 (valence: positive, negative, neutral) × 2 (number of exemplars: 3, 8) × 2 (presentation order: blocked, random) × 2 (prior testing: tested, not tested). Finally, a third ANOVA was conducted in order to examine the effects of forgetting over the one-week retention interval with 3 (test question: V, G, VG) × 3 (valence: positive, negative, neutral) × 2 (number of exemplars: 3, 8) × 2 (presentation order: blocked, random) × 2 (retention interval: immediate, 1 week). The items in the one-week condition were only those that had not been tested on the immediate test so that the comparison could be made between immediate and delayed testing without an effect of repeated testing.

Immediate test: The main effect of test question on target acceptance was significant, $F(2,128) = 153.09$, $p < .001$. Planned comparisons revealed that the target acceptance rate was higher in the VG condition than in the V condition, which was higher than the G condition (see Table 7). (Remember that it is correct to accept targets in the VG and V conditions but not in the G condition.) There was also a main effect of valence on the target acceptance rate, $F(2,128) = 3.18$, $p < .05$. Planned comparisons revealed that the acceptance rate was higher for negative and positive pictures than neutral ones (see Table 7). Neither presentation order, $F(1,64) = .46$, *n.s.,* nor number of exemplars, $F(1,64) = .03$, *n.s.,* affected target acceptance.

There was a test question × valence × number of exemplars interaction, $F(4,256) = 20.33$, $p < .001$. As is shown in Figure 1, the number of exemplars did not affect target acceptance in the G or VG conditions, but increasing the number of exemplars reduced target acceptance in the V condition for positive and neutral items while increasing target acceptance in the V condition for negative items. In other words, presenting more pictures within a category increased verbatim memory for negative items but reduced it for positive and neutral items.

Delayed test: The main effect of test question on target acceptance on the delayed test was significant, $F(2,128) = 86.74$, $p < .001$. Planned comparisons revealed that the target acceptance rate was higher in the VG condition than in the V condition, which was higher than the G condition, as on the immediate test. There was also a main effect of valence on the target acceptance rate, $F(2,128) = 3.34$, $p < .05$. Planned comparisons revealed that the acceptance rate was higher for negative and positive pictures than neutral ones, as on the immediate test. Neither presentation order, $F(1,64) = .08$, *n.s.,* nor number of exemplars, $F(1,64) = 1.15$, *n.s.,* affected target acceptance. There was also a significant effect of prior testing on the delayed test, $F(1,64) = 30.96$, $p < .001$, with target acceptance being higher for items that had been previously tested ($M = .65$) than those that had not been previously tested ($M = .45$).

There was a test question × valence × number of exemplars × prior testing interaction, $F(4,256) = 19.41$, $p < .001$ (see Table 8 and Figure 2). Prior testing increased the target acceptance rate in the V condition for all valences except for positive 3-exemplar items. Prior testing also increased target acceptance in the G condition for positive 8-exemplar items and negative 3-exemplar items only, and did not affect neutral items in that condition at all. More generally, prior testing seemed to increase both verbatim retrieval and gist retrieval, but the latter effect was only for emotional items.

Retention interval: The effect of retention interval was significant, $F(1,64) = 5.72$, $p < .05$, with higher target acceptance for untested items on the immediate test ($M = .64$) than untested items on the delayed test ($M = .43$). The test question × valence × number of exemplars × retention interval interaction was significant, $F(4,256) = 10.35$, $p < .001$ (see Table 9 and Figure 2). Target acceptance in the V condition was lower on the delayed test for positive and neutral items and negative 8-exemplar items. Target acceptance in the G condition, however, was higher on the delayed test for positive 3-exemplar items, negative 8-exemplar items, and neutral items. In brief, forgetting reduced verbatim memory, particularly for emotional items, while increasing gist memory for neutral items and some emotional items. This pattern of decreasing verbatim retrieval coupled with gist stability or increases is consistent with prior research on forgetting and false memory (e.g., Howe, Candel, Otgaar, Malone, & Wimmer, 2010; Lampinen, Copeland, & Neuschatz, 2001).

To sum up the true memory ANOVAs, target acceptance was higher for emotional than neutral pictures on both the immediate and the delayed tests. Prior testing increased both verbatim and gist memory, whereas forgetting reduced verbatim memory for emotional items while increasing gist memory.

False memory ANOVAs—Another pair of ANOVAs was computed with presentation order as the between subjects factor and bias corrected related distractor acceptance rates on the immediate and delayed tests as the dependent variables. The ANOVA for the immediate test was 3 (test question: V, G, VG) × 3 (valence: positive, negative, neutral) × 2 (number of exemplars: 3, 8) × 2 (presentation order: blocked, random), and the ANOVA for the delayed test was 3 (test question: V, G, VG) × 3 (valence: positive, negative, neutral) × 2 (number of exemplars: 3, 8) × 2 (presentation order: blocked, random) × 2 (prior testing: tested, not tested). Finally, a third ANOVA was conducted in order to examine the effects of forgetting over the one-week retention interval, which was 3 (test question: V, G, VG) × 3 (valence: positive, negative, neutral) × 2 (number of exemplars: 3, 8) × 2 (presentation order: blocked, random) × 2 (retention interval: immediate, 1 week).

Immediate test: The main effect of test question on related distractor acceptance was reliable, $F(2,128) = 60.06$, $p < .001$. Planned comparisons revealed that the related distractor acceptance rate was higher in the VG condition than the V and G conditions (see Table 7). (Remember that it is correct to accept related distractors in the VG and G conditions but not in the V condition. This lack of difference between the V and G conditions reveals that this was a strong false memory illusion.) There was also a main effect of valence on the related distractor acceptance rate, $F(2,128) = 16.01$, $p < .001$. Planned comparisons revealed that the acceptance rate was higher for negative than positive pictures and higher for positive pictures than neutral ones (see Table 7). This is slightly different from the pattern for targets, where the acceptance rates for negative and positive items did not differ. Presentation order did not affect related distractor acceptance, $F(1,64) = .17$, *n.s.,* but the number of exemplars did, $F(1,64) = 60.20$, $p < .001$. The effect of number of exemplars was that the related distractor acceptance rate was higher for 8-exemplar lists (M = .66) than 3-exemplar lists (M = .54). Recall that this effect was not present for targets.

There was a test question × valence × number of exemplars interaction, $F(4,256) = 31.32$, $p < .001$. As shown in Figure 3, increasing the number of presented exemplars increased positive and negative related distractor acceptance in the V condition and reduced positive related distractor acceptance in the G condition. This effect is parallel to the effect on targets, wherein increasing the number of exemplars increased acceptance of negative pictures in the G condition and reduced acceptance of positive pictures in the V condition. For related distractors, as well, the number of exemplars increased verbatim memory for emotional items but reduced gist memory for positive items.

Delayed test: The main effect of test question on related distractor acceptance on the delayed test was significant, $F(2,128) = 41.44$, $p < .001$. Planned comparisons revealed that the related distractor acceptance rate was higher in the VG condition than in the G condition, which was higher than the V condition. There was also a main effect of valence on the related distractor acceptance rate, $F(2,128) = 11.37$, $p < .05$. Planned comparisons revealed that the acceptance rate was higher for negative and neutral pictures than positive ones. Recall here that target acceptance rates were higher for positive and negative pictures compared to neutral pictures on the delayed test.

Presentation order did not affect the related distractor acceptance rate, $F(1,64) = .56$, *n.s.,* but the number of exemplars did, $F(1,64) = 36.28$, $p < .001$, with related distractor acceptance being higher for 8-exemplar lists (M = .53) than 3-exemplar lists (M = .46), as on the immediate test. There was also a significant effect of prior testing on the delayed test, $F(1,64) = 22.68$, $p < .001$, with related distractor acceptance being higher for items that had been previously tested (*M = .58)* than those that had not been previously tested (M = .42), similar to the effect on targets.

There was a test question × valence × number of exemplars × prior testing interaction, $F(4,256) = 34.42$, $p < .001$ (see Table 8 and Figure 4). Prior testing increased related distractor acceptance in the G condition for positive 3-exemplar items, negative 8-exemplar items, and neutral items, and increased acceptance in the V condition for negative 3-exemplar items and positive 8-exemplar items. However, it reduced related distractor acceptance in the V condition for negative 8-exemplar items. In other words, prior testing increased gist retrieval for positive related distractors when few exemplars were presented and negative related distractors when many were presented, and increased verbatim retrieval for positive items when many were presented and negative items when few were presented.

Retention interval: The effect of retention interval was not significant, $F(1,64) = 1.45$, *n.s.*, but the test question × valence × number of exemplars × retention interval interaction was , $F(4,256) = 41.56$, $p < .001$ (see Table 9 and Figure 4). Related distractor acceptance was reduced over the delay in the V condition for positive items and negative 8-exemplar items, but did not affect neutral items. The retention interval decreased related distractor acceptance of neutral items in the G condition but did not significantly affect it for negative items. Thus, over time verbatim memory declined, particularly for emotional items, and gist memory declined for neutral items while not affecting negative items.

To sum up the false memory results, emotional pictures caused more false memories (false alarms to V test questions) on the immediate test but only negative pictures caused more false memories on the delayed test. Increasing the number of exemplars increased false memories on both tests, likely driven by stronger gist memories. Prior testing increased related distractor acceptance overall, which was presumably also due to stronger gist memories.

Summary of qualitative patterns for valence—Emotional content appeared to increase both verbatim and gist memory for pictures, with the gist effect being more pronounced for negative content and the verbatim effect being more pronounced for positive content. Prior testing increased memory for both targets and related distractors by increasing both verbatim and gist memory, whereas the retention interval reduced verbatim memory, particularly for emotional items. These effects were modified slightly by the number of presented exemplars, with more exemplars tending to increase gist memory but not verbatim memory.

Modeling Results

Next, we consider *why* these emotional content effects occurred, at the level of specific retrieval processes. To pinpoint the particular retrieval processes that were involved, we applied the conjoint recognition model to the data. First, we consider whether the model fit the data, and then we move on to parametric analyses that identify the process loci of emotional content effects.

Fit—The model's fit was evaluated in the usual way (see Brainerd et al., 2014) by computing likelihood ratio tests. Those tests generate G^2 statistics that are asymptotically distributed as X^2 with one degree of freedom for each condition. Thus, the critical value for rejection of the null hypothesis that the model fits the data of any condition is 3.84. As can be seen in Table 10, the G^2 values for all of the conditions of the present experiment were below this critical value. Therefore, the conjoint recognition model provided a statistically acceptable account of all of the data.

Parameter analyses—Estimates of the model's parameters are presented in Table 10, and Table 11 contains the results of parameter significance tests among valence and testing conditions as well as omnibus tests for between-condition differences in parameter values. (The standard statistical procedure with models of this sort is, first, to compute omnibus tests that establish that at least some of the parameters differ reliably among conditions and then to parameterwise tests that identify the specific parameters that differ among conditions; see Brainerd, Howe, & Desrochers, 1982.) Remember that each of the model's parameters measures a specific verbatim or gist retrieval process.

Immediate test: Turning first to true memory, negative valence affected both verbatim and gist memory for targets. The familiarity parameter, which measures the retrieval of gist traces by target cues, was higher for negative pictures compared to neutral pictures. Another parameter that measures verbatim retrieval of *other targets* by target cues, erroneous recollection rejection, was reduced for negative pictures. Thus, the overall picture of the effects of emotional content on retrieval processes for target cues was that (a) negative valence decreased incorrect verbatim retrieval (erroneous recollection rejection), and (b) it also increased gist retrieval (familiarity).

For false memory, the overall effects of emotional content were to increase gist retrieval and decrease verbatim retrieval, which can be seen in values of the familiarity and recollection rejection parameters for related distractors. Recollection rejection, which suppresses false memory by retrieving verbatim traces of targets, was lower for positive pictures on the immediate test. Familiarity, which supports false memory by retrieving weaker gist traces, was higher for negative pictures compared to neutral pictures.

Delayed test: First, for true memory, emotional pictures again increased familiarity compared to neutral pictures and negative pictures reduced erroneous recollection rejection compared to neutral pictures, demonstrating that the immediate effects on verbatim and gist retrieval were still present one week later.

For false memory, the results paralleled those of the immediate test with the additional effect of emotional content reducing the stronger form of gist retrieval, as measured by the phantom recollection parameter. More specifically, positive and negative pictures reduced recollection rejection, increased familiarity, and reduced phantom recollection compared to neutral pictures. Emotional pictures reduced verbatim memory and the stronger form of gist memory while increasing the weaker form of gist memory.

Prior testing also affected both the true and false memory parameters. It enhanced verbatim memory for targets while enhancing gist memory for related distractors and reducing verbatim memory for targets when related distractors were retrieval cues, thereby producing net increases in both true and false memory. For true memory, the familiarity and identity parameters were larger for items on the delayed test that had been previously tested. For false memory, the phantom recollection parameter was larger while the recollection rejection parameter was smaller for previously tested items.

Finally, forgetting, the comparison between the immediate test and items on the delayed test that had not been previously tested, also affected true and false memory parameters. The identity, erroneous recollection, phantom recollection, and related distractor familiarity parameters were all higher on the immediate test compared to the delayed test, suggesting that the forgetting taking place over the week-long delay reduced both verbatim and gist retrieval but especially verbatim retrieval.

These data indicate that the true memory advantage for negative pictures was due to enhanced gist memory retrieval and reduced erroneous verbatim retrieval for negatively valenced targets. However, the increased levels of false memory for negative pictures were due to reduced verbatim retrieval coupled with increased gist retrieval by related distractors. In the latter connection, negative valence increased one form of gist retrieval (familiarity) and actually decreased another (phantom recollection), at least on the delayed test, but the first effect was far larger, producing net increases in false memory for negative pictures. With respect to verbatim memory, negative valence also increased false memory by reducing subject's ability to use verbatim traces of targets to reject related distractors.

Comparisons with Brainerd et al. (2008)—It is informative to compare the present parameter results with those of a study in which the conjoint recognition model was applied to positive, negative, and neutral DRM lists (Brainerd et al., 2008). Brainerd et al. found higher levels of false memory for negative than positive or neutral lists because negative lists increased the familiarity parameter and decreased the recollection rejection parameter; that is, negative lists increased gist retrieval and decreased verbatim retrieval. Negative valence affected true memory by increasing the familiarity parameter and decreasing the identity parameter; that is, by increasing gist retrieval and decreasing verbatim retrieval for targets. In the present study, using a very different procedure, we found similar valence effects at the level of retrieval processes: Negative pictures increased gist retrieval for both targets and related distractors, and they decreased verbatim retrieval for related distractors. Unlike Brainerd et al., however, negative valence did not decrease the identity parameter. Thus, the effects in the present study were completely parallel to Brainerd et al.'s for DRM at the level of gist retrieval but not entirely parallel are the level of verbatim retrieval.

Discussion

The aim of this experiment was to investigate the connections between emotional valence, false memory, and true memory in a novel paradigm using a model-based approach that measures valence effects at the level of specific retrieval processes. We manipulated the valence of pictures while controlling their arousal levels in order to avoid the trend in prior studies of conflating valence and arousal. By applying the conjoint recognition model to the data, we were able to measure underlying verbatim and gist retrieval processes. At a general level, a positive outcome of our experiment is that the results were consistent with prior findings that were generated by quite different materials (DRM word lists) in the sense that negative emotional content increased false memory. Thus, this distortive effect of negative valence seems to have considerable generality because it holds across very different memory materials and procedures.

Our results are less consistent with DRM prior findings showing that negative emotion can reduce true memory (e.g., Howe, 2007) or that it enhances true memory only if it is also arousing (e.g., Kensinger & Corkin, 2003). In the present experiment, true memory was enhanced by negative pictures when arousal was controlled at moderate levels. This experiment thus provides evidence that emotional valence can enhance true as well as false memory and that high levels of arousal are not required for either effect to occur. Unlike negative emotional effects on false memory, which appear to be consistent across paradigms, the effect of negative valence on true memory appears to be sensitive to the target materials. Some prior research with pictures is consistent with the negative advantage that we detected for true memory (Choi, Kensinger, & Rajaram, 2013; Gallo et al., 2009), but without evidence showing that negative pictures simultaneously inflate false memory. The present study appears to be the first to show that negative, nonarousing pictures of realistic objects and events have both of these effects.

A primary goal of this research was to identify the specific retrieval processes that control valence-memory effects. Based on estimates of the conjoint recognition model's parameters, it appears that valence affects the retrieval of both verbatim and gist traces, although the verbatim effect depends on the retrieval cue (target versus related distractor). The gist effect was simple: Emotional pictures increased the familiarity parameters, relative to neutral pictures, which increased both true and false memory. The verbatim effect was more complex: Emotional pictures suppressed the recollection rejection parameter for related distractors, thereby increasing false memory, but did not affect the identity parameter, which contributes to increasing true memory; instead they suppressed the erroneous recollection parameter, thereby increasing true memory. Overall, emotionally valenced materials increased true and false memory because they (a) drove gist retrieval up for targets and related distractors and (b) drove verbatim retrieval down for related distractors. As previously noted, this pattern of parameter differences is somewhat unlike that of previous emotional word experiments (Brainerd et al., 2008), which found that negative valence increased gist retrieval for both targets and related distractors and suppressed verbatim retrieval for both. It therefore appears that although the gist effects of valence are robust in the face of procedural variations, its verbatim effects may be sensitive to changes in target materials.

Two other manipulations, presentation order and the number of category exemplars, provided further evidence for effects that change as a function of the nature of the target materials. Concerning presentation order, a good deal of prior DRM research has shown that blocking items that share meaning increases false memory, relative to random presentation, by selectively strengthening gist memory (e.g., Dewhurst et al., 2009; McDermott, 1996; Toglia Neuschatz, & Goodwin, 1999). With realistic pictures, however, neither false nor true memory were affected by this manipulation. This may be due to an important difference in the level of relatedness of our pictorial materials versus DRM word lists. The words on DRM lists are semantically but not *physically* related (e.g., "pillow" and "dream" are both share "sleep" meaning but they neither look nor sound alike). In contrast, our emotional pictures were similar in both meaning and visual appearance (e.g., all pictures of trees looked more similar to each other than to other pictures). In other words, the fact that our target materials were related was more obvious than it is with word lists, making the materials less sensitive to manipulations that encourage subjects to process relations among items.

Turning to the number of exemplars, remember that this manipulation varied the number of exemplars of each category that were presented, which has been found to affect the strength of gist for categorical relations in prior research. We found that presenting more exemplars of a category increased false memory for related distractors but did not affect true memory for targets. The modeling analyses revealed that the familiarity parameter was larger for categories for which larger numbers of exemplars were presented, implicating the gist retrieval in the false memory enhancement for 8-exemplar categories. These findings are inconsistent with prior work on DRM false memory (e.g., Robinson & Roediger, 1997; Swannell & Dewhurst, 2013), which showed that increasing the length of word lists increases false memory and reduces true memory. However, the present data are consistent with research on categorized word lists, which showed that increasing list length increases false memory without affecting true memory (Dennis & Chapman, 2010). This difference suggests that although associatively-related items and categorized items have similar gist effects (increasing false memory), their verbatim effects are different.

Looking at those results in relation to valence, increasing the number of exemplars increased gist memory for negative items, but reduced gist memory and increased verbatim memory for positive items. This pattern highlights the different roles that gist and verbatim memory play for different types of valence, which is apparently more gist-based for negative valence and more verbatim-based for positive valence, a general pattern than has also been noted by others in word list experiments (Brainerd et al., 2008; Gomes, Brainerd, & Stein, 2013). This pattern is also consistent with previous research demonstrating that whereas negative information promotes false memory, positive information may actually protect against it (e.g., Porter, Spencer, & Birt, 2003; Porter, ten Brinke, Riley, & Baker, 2014).

Finally, we were interested in the extent to which these effects persist over time and whether the retrieval processes that control them change over time, as well as how prior testing modulates those effects. The effect of valence on both true and false memory declined slightly over time but remained reliable. It is well established that verbatim memory declines more rapidly than gist memory and that it contributes more to true than to false memory (Brainerd & Reyna, 2005). Thus, when there are comparable declines in a manipulation’s effects on true and false memory, the implication is that it is chiefly a gist effect. This was the pattern in our experiment, and that agrees with the modeling finding that the most consistent valence effect was on the familiarity parameters.

Prior testing increased verbatim and gist retrieval for targets, as well as increased gist memory for related distractors. That is consistent with previous demonstrations that prior testing elevates false memory on delayed tests (Brainerd et al., 2006). Taken together, the decline in verbatim retrieval over time and the increase in gist retrieval for related distractors after prior testing provides a simple explanation for the known tendency of repeated questioning to falsely alter the contents of memory (e.g., Ceci & Bruck, 1995).

At the broadest level, our results provide further evidence challenging the notion that arousal is the key component of emotional content that produces emotional enhancement of memory. It appears that valence is able to affect both true and false memory when arousal is controlled at moderate levels. Another finding of broad significance is the apparent generality of negative valence’s ability to distort episodic memory. We now know that this pattern holds for pictures of realistic objects and events as well as for word lists, and that in both spheres, the effect is tied to the tendency of negative valence to strengthen memory for the gist of experience. Potentially, this pattern has wide applicability in high-stakes situations in the real world where negative emotion figures prominently. Eyewitness memory in legal cases is a classic example. The determinative evidence in criminal proceedings comes overwhelmingly from the memory reports of witnesses, even in capital trials (Brainerd, 2013), and those reports revolve around events that are fraught with negative emotion. When our findings are added to earlier work, it seems that such circumstances increase the risk of memory reports of events that did not happen—as when a witness incorrectly reports that a robbery suspect was carrying a knife or made threatening statements. In contrast to most memory experiments, witnesses' reports of events usually occur after substantial delays. Hence, it is particularly important that the distortive effects of negative valence remained stable over the delay, and indeed, those effects have sometimes been found to increase over a delay (e.g., Howe et al., 2010).

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Appendix

Table A1

Expressions for Acceptance of Related and Unrelated Distractor Test questions in the Model in the Three Conjoint Recognition Conditions

Acceptance probability by condition	Expression
pDV	$(1 - R_D)P_D + (1 – R_D)(1 - P_D)F_D + (1 – R_D)(1 - P_D)(1 - F_D)\ \beta_V$
pDG	$R_D + (1 – R_D)(1 - P_D)F_D + (1 – R_D)(1 - P_D)(1 - F_D)\ \beta_G$
pDVG	$R_D + (1 – R_D)P_D + (1 – R_D)(1 – P_D)F_D + (1 – R_D)(1 - P_D)(1 - F_D)\ \beta_{VG}$
pTV	$R_T + (1 - R_T)E_T + (1 - R_T)(1 - E_T)F_T + (1 - R_T)(1 - E_T)(1 - F_T)\ \beta_V$
pTG	$(1 - R_T)E_T + (1 - R_T)(1 – E_T)F_T + (1 - R_T)(1 – E_T)(1 - F_T)\ \beta_G$
pTVG	$R_T + (1 - R_T)E_T + (1 - R_T)(1 - E_T)F_T + (1 - R_T)(1 - E_T)(1 - F_T)\ \beta_{VG}$
pUDV	β_V
pUDG	β_G
pUDVG	β_{VG}

Note. V = accept only targets, G = accept only related distractors, VG = accept both targets and related distractors, D = related distractor, T = target, and UD = unrelated distractor.

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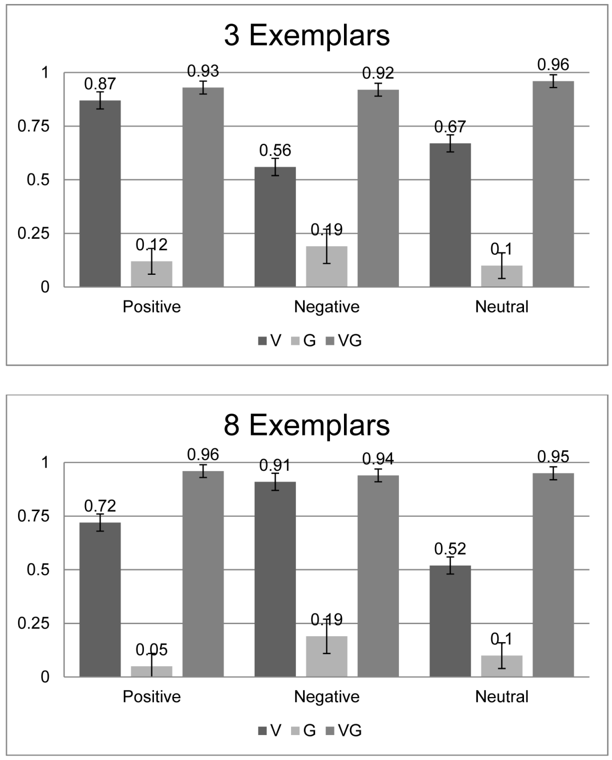

Figure 1.
Effect of test question, valence, and number of exemplars on target acceptance rate on the immediate test.

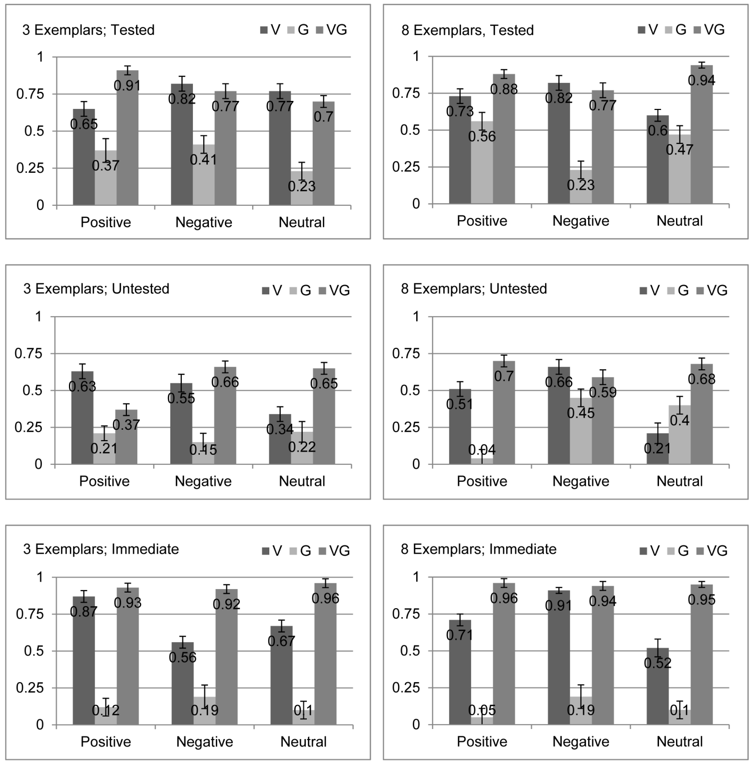

Figure 2.

Effect of test question, valence, number of exemplars, prior testing, and retention interval on target acceptance.

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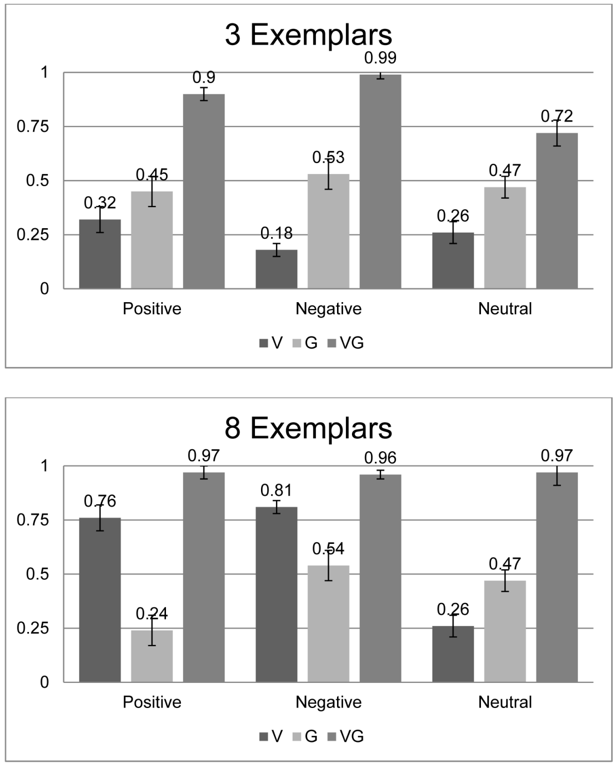


Figure 3.

Effect of test question, valence, and number of exemplars on related distractor acceptance rate on the immediate test.

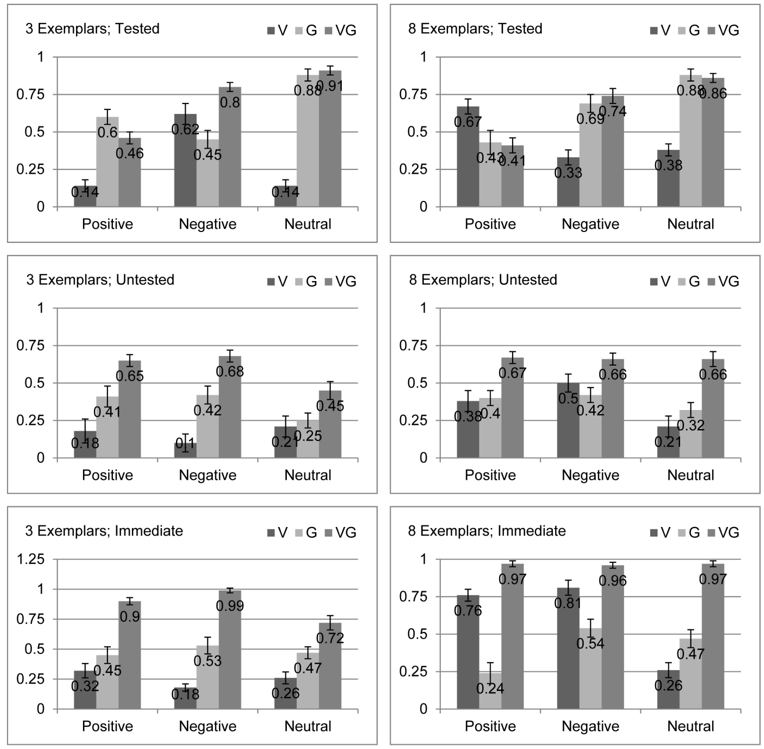


Figure 4.

Effect of test question, valence, number of exemplars, prior testing, and retention interval on related distractor acceptance.

Table 1

Parameters of the Conjoint Recognition Model

Parameter	Definition
False Memory Processes	
P_D	Phantom recollection (RD produces retrieval of gist trace of similar target and false acceptance of RD)
R_D	Recollection rejection (RD produces retrieval of verbatim trace of similar target and correct rejection of RD)
F_D	Similarity judgment (RD produces retrieval of gist trace of similar target and acceptance of RD)
True Memory Processes	
E_T	Erroneous recollection rejection (target produces retrieval of verbatim trace for another target and incorrect rejection of target)
R_T	Identity judgment (target produces retrieval of verbatim trace and correct acceptance of target)
F_T	Similarity judgment (target produces retrieval of gist trace of similar target and acceptance of target)
Response Bias Processes	
B_V	URD produces false alarm in V condition
β_G	URD produces false alarm in G condition
β_{VG}	URD produces false alarm in VG condition

Note. RD = related distractor, TG = target, and URD = unrelated distractor.

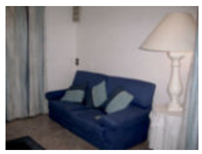
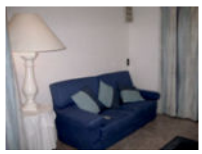
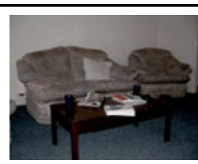
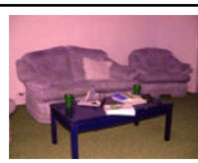
Table 2

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 Figures	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 3

Examples of Experimental Stimuli

	Babies (positive)	Spiders (negative)	Couches (neutral)
1a			
1b			
1c			
1d			
2a			
2b			
2c			
2d			

Note: Adapted from “The Geneva affective picture database (GAPED): A new 730-picture database focusing on valence and normative significance” by E. S. Dan-Glauser and K. R. Scherer, 2011, *Behavioral Research Methods, 43*, 468-477. Copyright 2011 by Springer.

Table 4

Sample study list

Item Number	Name	Valence
1	Buffer1	Neutral
2	Buffer2	Neutral
3	Buffer3	Neutral
4	Babies1c	Positive
5	Babies2b	Positive
6	Babies3a	Positive
7	Funeral3b	Negative
8	Funeral1a	Negative
9	Funeral2c	Negative
10	Funeral1c	Negative
11	Funeral3a	Negative
12	Funeral1d	Negative
13	Funeral2b	Negative
14	Funeral3d	Negative
15	Unrelated1	Neutral
16	Abstract3a	Neutral
17	Abstract2b	Neutral
18	Abstract1c	Neutral
19	Baseball2d	Positive
20	Baseball1b	Positive
21	Baseball3c	Positive
22	Baseball2a	Positive
23	Baseball3b	Positive
24	Baseball1d	Positive
25	Baseball3a	Positive
26	Baseball2c	Positive
27	Unrelated2	Neutral
28	Couch2d	Neutral
29	Couch1a	Neutral
30	Couch2c	Neutral
31	Couch3b	Neutral
32	Couch1c	Neutral
33	Couch2a	Neutral
34	Couch3c	Neutral
35	Couch1b	Neutral
36	Accidents3c	Negative
37	Accidents2b	Negative
38	Accidents1d	Negative
39	Unrelated3	Positive

Item Number	Name	Valence
40	Men2a	Neutral
41	Men1c	Neutral
42	Men3d	Neutral
43	Couples3b	Positive
44	Couples1c	Positive
45	Couples2a	Positive
46	Couples3d	Positive
47	Couples2b	Positive
48	Couples1a	Positive
49	Couples2c	Positive
50	Couples3a	Positive
51	Unrelated4	Positive
52	Garbage2b	Negative
53	Garbage1a	Negative
54	Garbage3c	Negative
55	Mountain1a	Positive
56	Mountain3b	Positive
57	Mountain2c	Positive
58	Mountain1d	Positive
59	Mountain3a	Positive
60	Mountain2d	Positive
61	Mountain1c	Positive
62	Mountain3d	Positive
63	Unrelated5	Negative
64	Child1d	Negative
65	Child2c	Negative
66	Child3a	Negative
67	Child1b	Negative
68	Child3d	Negative
69	Child2b	Negative
70	Child1a	Negative
71	Child3c	Negative
72	Clouds1d	Positive
73	Clouds2b	Positive
74	Clouds3c	Positive
75	Unrelated6	Positive
76	Medical3a	Negative
77	Medical2d	Negative
78	Medical1c	Negative
79	Mug1b	Neutral
80	Mug3d	Neutral

Item Number	Name	Valence
81	Mug2c	Neutral
82	Mug3b	Neutral
83	Mug1a	Neutral
84	Mug2d	Neutral
85	Mug1c	Neutral
86	Mug2b	Neutral
87	Unrelated6	Negative
88	Cat3a	Positive
89	Cat2c	Positive
90	Cat1d	Positive
91	Trees3c	Neutral
92	Trees2d	Neutral
93	Trees3a	Neutral
94	Trees1b	Neutral
95	Trees2c	Neutral
96	Trees1d	Neutral
97	Trees3b	Neutral
98	Trees2a	Neutral
99	Unrelated8	Negative
100	Mushroom2a	Neutral
101	Mushroom1c	Neutral
102	Mushroom3b	Neutral
103	Unrelated9	Neutral
104	Spider3c	Negative
105	Spider2a	Negative
106	Spider1c	Negative
107	Spider3b	Negative
108	Spider1d	Negative
109	Spider2c	Negative
110	Spider3a	Negative
111	Spider2b	Negative
112	Buffer4	Neutral
113	Buffer5	Neutral
114	Buffer6	Neutral

Table 5

Sample immediate test list

Item Number	Name	Valence	Question Type	Item Type
1	Garbage1a	Negative	V	T
2	Clouds2c	Positive	V	RD
3	Unrelated9	Neutral	VG	URT
4	Accidents3c	Negative	VG	T
5	Tree1b	Neutral	VG	T
6	Mushroom2d	Neutral	G	RD
7	Spider3b	Negative	V	T
8	Babies3a	Positive	G	T
9	Cat2a	Positive	VG	RD
10	Unrelated6	Positive	G	URT
11	Mountains2c	Positive	V	T
12	Couples1b	Positive	V	RD
13	Baseball1b	Positive	VG	T
14	Unrelated5	Negative	V	URT
15	Men1c	Neutral	G	T
16	Abstract2b	Neutral	V	T
17	Couch1c	Neutral	VG	T
18	Accidents1d	Negative	V	T
19	Mug3a	Neutral	G	RD
20	Unrelated2	Neutral	G	URT
21	Couples3c	Positive	VG	RD
22	Funeral2a	Negative	G	RD
23	Baseball3a	Positive	V	T
24	Child2b	Negative	V	T
25	Child1c	Negative	VG	RD
26	Couch2b	Neutral	G	RD
27	Funeral1d	Negative	VG	T
28	Cat1d	Positive	G	T
29	Tree3d	Neutral	G	RD
30	Medical3a	Negative	G	T
31	Unrelated	Positive	V	URD
32	Abstract1d	Neutral	VG	RD
33	Men2a	Neutral	V	T
34	Clouds1a	Positive	VG	RD
35	Mountains1b	Positive	VG	RD
36	Mug2b	Neutral	VG	T
37	Garbage3c	Negative	VG	T
38	Mushroom3b	Neutral	V	T
39	Couples2a	Positive	V	T

Item Number	Name	Valence	Question Type	Item Type
40	Babies2a	Positive	G	RD
41	Unrelated	Neutral	V	URD
42	Spider2c	Negative	VG	T
43	Clouds3c	Positive	V	T
44	Couch3c	Neutral	V	T
45	Funeral3c	Negative	VG	RD
46	Tree2b	Neutral	VG	RD
47	Babies1d	Positive	VG	RD
48	Garbage2d	Negative	V	RD
49	Unrelated	Negative	G	URD
50	Medical2a	Negative	V	RD
51	Accidents2a	Negative	V	RD
52	Mountains3c	Positive	G	RD
53	Unrelated	Negative	VG	URD
54	Child3b	Negative	V	RD
55	Mug1a	Neutral	G	T
56	Baseball2b	Positive	V	RD
57	Abstract3c	Neutral	G	RD
58	Cat3a	Positive	VG	T
59	Mushroom1a	Neutral	V	RD
60	Men3b	Neutral	G	RD
61	Medical1c	Negative	V	T
62	Spider1a	Negative	G	RD
63	Unrelated	Positive	G	URD

Table 6

Sample delayed test list

Item Number	Name	Valence	Question Type	Item Type	Tested?
1	Baby2b	Positive	VG	T	No
2	Mushroom2a	Neutral	G	T	No
3	Garbage1d	Negative	G	RD	No
4	Men1c	Neutral	G	T	Yes
5	Accidents1d	Negative	V	T	Yes
6	Spider3b	Negative	V	T	Yes
7	Cat1d	Positive	G	T	Yes
8	Unrelated1	Neutral	V	URD	Yes
9	Baby3d	Positive	V	RD	No
10	Baseball1b	Positive	VG	T	Yes
11	Mug3a	Neutral	G	RD	Yes
12	Clouds3c	Positive	V	T	Yes
13	Abstract2a	Neutral	V	RD	No
14	Child2b	Negative	V	T	Yes
15	Tree1b	Neutral	VG	T	Yes
16	Mountain1c	Positive	VG	T	No
17	Spider3d	Negative	V	RD	No
18	Couch1c	Neutral	VG	T	Yes
19	Funeral1a	Negative	V	T	No
20	Unrelated2	Positive	V	URD	Yes
21	Abstract1c	Neutral	VG	T	No
22	Accidents2b	Negative	G	T	No
23	Baseball1a	Positive	G	RD	No
24	Mug2b	Neutral	VG	T	Yes
25	Couch3d	Neutral	VG	RD	No
26	Cat1b	Positive	V	RD	No
27	Couples2a	Positive	V	T	Yes
28	Baseball3a	Positive	V	T	Yes
29	Couples1a	Positive	VG	T	No
30	Mushroom2d	Neutral	G	RD	Yes
31	Unrelated3	Neutral	G	URD	No
32	Funeral1d	Negative	VG	T	Yes
33	Abstract3c	Neutral	G	RD	Yes
34	Couch1a	Neutral	G	T	No
35	Accidents3c	Negative	VG	T	Yes
36	Tree2c	Neutral	G	T	No
37	Garbage1a	Negative	V	T	Yes
38	Men1a	Neutral	V	RD	No
39	Baby2a	Positive	G	RD	Yes

Item Number	Name	Valence	Question Type	Item Type	Tested?
40	Tree3c	Neutral	V	T	No
41	Unrelated4	Positive	VG	URT	No
42	Mushroom3b	Neutral	V	T	Yes
43	Couples3a	Positive	G	T	No
44	Accidents3a	Negative	G	RD	No
45	Child3a	Negative	G	T	No
46	Baseball2a	Positive	G	T	No
47	Unrelated5	Negative	VG	URT	No
48	Clouds3a	Positive	G	RD	No
49	Mountain1b	Positive	VG	RD	Yes
50	Funeral1c	Negative	G	T	No
51	Child1c	Negative	VG	RD	Yes
52	Mug1a	Neutral	G	T	Yes
53	Cat3a	Positive	VG	T	Yes
54	Couch3c	Neutral	V	T	Yes
55	Unrelated6	Neutral	VG	URD	No
56	Medical3a	Negative	G	T	Yes
57	Garbage3a	Negative	VG	RD	No
58	Mushroom1d	Neutral	VG	RD	No
59	Abstract3a	Neutral	G	T	No
60	Unrelated7	Positive	G	URT	Yes
61	Garbage2d	Negative	V	RD	Yes
62	Couples3c	Positive	G	RD	Yes
63	Men2a	Neutral	V	T	Yes
64	Men3d	Neutral	VG	T	No
65	Baseball2b	Positive	V	RD	Yes
66	Spider1a	Negative	G	RD	Yes
67	Clouds2b	Positive	VG	T	No
68	Funeral3c	Negative	VG	RD	Yes
69	Abstract2b	Neutral	V	T	Yes
70	Mountain2c	Positive	V	T	Yes
71	Baby1c	Positive	V	T	No
72	Mountain2d	Positive	G	T	No
73	Mug3c	Neutral	VG	RD	No
74	Mug1c	Neutral	V	T	No
75	Clouds1d	Positive	G	T	No
76	Child2a	Negative	G	RD	No
77	Baby1d	Positive	VG	RD	Yes
78	Funeral2a	Negative	G	RD	Yes
79	Mushroom1c	Neutral	VG	T	No
80	Clouds2c	Positive	V	RD	Yes

Item Number	Name	Valence	Question Type	Item Type	Tested?
81	Spider2c	Negative	VG	T	Yes
82	Medical1c	Negative	V	T	Yes
83	Couch2b	Neutral	V	RD	No
84	Medical1a	Negative	VG	RD	No
85	Tree3d	Neutral	G	RD	Yes
86	Couples2d	Positive	VG	RD	No
87	Child3b	Negative	V	RD	Yes
88	Unrelated8	Negative	V	URT	Yes
89	Cat3d	Positive	G	RD	No
90	Baby3a	Positive	G	T	Yes
91	Unrelated9	Negative	G	URT	No
92	Mountain3c	Positive	G	RD	Yes
93	Abstract1d	Neutral	VG	RD	Yes
94	Baseball3d	Positive	VG	RD	No
95	Medical3b	Negative	G	RD	No
96	Medical2a	Negative	V	RD	Yes
97	Unrelated10	Neutral	VG	URT	Yes
98	Garbage2b	Negative	G	T	No
99	Clouds1a	Positive	VG	RD	Yes
100	Unrelated11	Neutral	G	URT	Yes
101	Unrelated12	Neutral	V	URT	No
102	Couch2b	Neutral	G	RD	Yes
103	Child1a	Negative	VG	T	No
104	Unrelated13	Positive	V	URT	No
105	Unrelated14	Negative	V	URD	NO
106	Men3b	Neutral	G	RD	Yes
107	Unrelated15	Negative	G	URD	Yes
108	Cat2c	Positive	V	T	No
109	Unrelated16	Positive	VG	URD	No
110	Unrelated17	Negative	VG	URD	Yes
111	Mushroom1a	Neutral	V	RD	Yes
112	Accidents1c	Negative	VG	RD	No
113	Cat2a	Positive	VG	RD	Yes
114	Couples1b	Positive	V	RD	Yes
115	Mountain3a	Positive	V	RD	No
116	Funeral2d	Negative	V	RD	No
117	Men2c	Neutral	VG	RD	No
118	Accidents2a	Negative	V	RD	Yes
119	Mug2a	Neutral	V	RD	No
120	Tree1a	Neutral	V	RD	No
121	Unrelated18	Positive	G	URD	Yes

Item Number	Name	Valence	Question Type	Item Type	Tested?
122	Medical2d	Negative	VG	T	No
123	Spider2a	Negative	G	T	No
124	Garbage3c	Negative	VG	T	Yes
125	Spider1b	Negative	VG	RD	No
126	Tree2b	Neutral	VG	RD	Yes
		Negative: 42	V: 42	RD: 54	Untested: 63
		Positive: 42	G: 42	T: 54	Tested 63
		Neutral: 42	VG: 42	URD: 9	

Table 7

Mean Acceptance Proportions for Target, Related Distractors, and Unrelated Distractors by Valence, Test Question, and Test

	V	G	VG	
Targets				
Immediate				
Positive	.79	.08	.94	.61
Negative	.74	.19	.93	.62
Neutral	.60	.10	.95	.55
	.71	.12	.94	
Delayed				
Positive	.63	.29	.79	.57
Negative	.71	.23	.70	.55
Neutral	.48	.33	.74	.52
	.61	.29	.74	
Related Distractors				
Immediate				
Positive	.54	.35	.93	.61
Negative	.50	.54	.97	.67
Neutral	.26	.47	.84	.53
	.43	.45	.92	
Delayed				
Positive	.34	.46	.55	.45
Negative	.39	.50	.72	.53
Neutral	.24	.58	.72	.51
	.32	.51	.66	
Unrelated Distractors				
Immediate				
Pooled Across Valence	.02	.02	.17	
Delayed				
Positive	.25	.25	.07	.19
Negative	.04	.28	.28	.20
Neutral	.32	.22	.17	.29
	.21	.26	.17	

Table 8

Mean Acceptance Proportions for Delayed Test Targets and Related Distractors by Valence, Test Question, Number of Exemplars, and Prior Testing

	V		G		VG			
	Tested	**Untested**	**Tested**	**Untested**	**Tested**	**Untested**	**Tested**	**Untested**
Targets								
3 Exemplars								
Positive	.65	.63	.37	.21	.91	.67	.64	.50
Negative	.82	.55	.41	.15	.77	.66	.67	.36
Neutral	.77	.34	.23	.22	.70	.65	.57	.41
	.75	.51	.34	.19	.79	.66		
8 Exemplars								
Positive	.73	.51	.56	.04	.88	.70	.72	.42
Negative	.82	.66	.23	.45	.77	.59	.61	.57
Neutral	.60	.21	.47	.40	.94	.68	.67	.43
	.72	.46	.42	.30	.86	.66		
Related Distractors								
3 Exemplars								
Positive	.14	.18	.60	.41	.46	.65	.40	.41
Negative	.62	.10	.45	.42	.80	.68	.62	.40
Neutral	.14	.21	.88	.25	.91	.45	.65	.30
	.30	.17	.65	.36	.72	.59		
8 Exemplars								
Positive	.67	.38	.43	.40	.41	.67	.50	.48
Negative	.33	.50	.69	.42	.74	.66	.59	.53
Neutral	.38	.21	.88	.32	.86	.66	.70	.39
	.46	.36	.67	.38	.67	.66		

Table 9

Mean Acceptance Proportions for Targets and Related Distractors by Valence, Test Question, Number of Exemplars, and Retention Interval

	V		G		VG			
	Immediate	**Delayed-Untested**	**Immediate**	**Delayed-Untested**	**Immediate**	**Delayed-Untested**	**Immediate**	**Delayed-Untested**
				Targets				
				3 Exemplars				
Positive	.87	.63	.12	.21	.93	.67	.64	.50
Negative	.56	.55	.19	.15	.92	.66	.56	.36
Neutral	.67	.34	.10	.22	.96	.65	.58	.41
	.70	.51	.13	.19	.93	.66		
				8 Exemplars				
Positive	.71	.51	.05	.04	.96	.70	.57	.42
Negative	.91	.66	.19	.45	.94	.59	.68	.46
Neutral	.52	.21	.10	.40	.95	.68	.52	.43
	.72	.46	.11	.30	.95	.66		
				Related Distractors				
				3 Exemplars				
Positive	.32	.18	.45	.41	.90	.46	.56	.41
Negative	.18	.10	.53	.42	.99	.80	.57	.40
Neutral	.26	.21	.47	.25	.72	.91	.48	.30
	.26	.17	.49	.36	.87	.72		
				8 Exemplars				
Positive	.76	.38	.24	.40	.97	.67	.65	.48
Negative	.81	.50	.54	.42	.96	.66	.77	.53
Neutral	.26	.21	.47	.32	.97	.66	.57	.39
	.61	.36	.42	.38	.96	.66		

Table 10

Parameter Estimates of the Conjoint Recognition Model by Valence, Test, and Prior Testing

Model Parameters

	E_T	R_T	F_T	P_D	R_D	F_D	β_V	β_G	β_{VG}	G^2
Immediate Test										
Positive	.69	.73	.47	.58	.29	.73	.02	.18	.01	2.24
Negative	.44	.58	.83	.55	.51	.87	.02	.18	.01	1.34
Neutral	.90	.67	0	.41	.57	.45	.02	.18	.01	1.62
	.70	.68	.61	.46	.41	.74	.02	.18	.01	1.33

Delayed Test	E_T T	E_T U	R_T T	R_T U	F_T T	F_T U	P_D T	P_D U	R_D T	R_D U	F_D T	F_D U	β_V T	β_V U	β_G T	β_G U	β_{VG} T	β_{VG} U	G^2	G^2
Positive	.57	.86	.51	.01	.83	.67	.44	0	.36	.24	.79	.57	.02	.04	.26	.22	.51	.04	1.52	1.04
Negative	0	.03	.49	.25	.75	.84	.49	.19	.45	.35	.75	.65	.02	.04	.26	.22	.51	.04	1.97	.78
Neutral	.59	.63	.39	.27	.82	0	.27	0	.19	.60	.46	.79	.02	.04	.26	.22	.51	.04	.88	2.01
	.32	.37	.43	.23	.76	.67	.44	.12	.35	.42	.60	.61	.02	.04	.26	.22	.51	.04	1.32	1.07
Positive	.39		.26		.90		.39		.12		.60		.03		.25		.20		.94	
Negative	0		.30		.83		.26		.36		.66		.03		.25		.20		1.01	
Neutral	.46		.31		.46		.62		.53		.26		.03		.25		.20		1.48	
	.30		.30		.75		.32		.39		.57		.03		.25		.20		.65	

Note. T = tested and U = untested.

Table 11

G^2 Values for Differences Between Parameters of the Conjoint Recognition Model Based on Valence, Test, Prior Testing, and Retention Interval

	E_T	R_T	F_T	P_D	R_D	F_D	β_V	β_G	β_{VG}	Omnibus Test G^2 Value
Immediate										
Positive vs. Negative	1.62	3.10	2.95	.06	17.54*	1.91	--	--	--	26.63**
Positive vs. Neutral	1.86	1.66	1.17	2.15	13.49*	6.15*	--	--	--	51.38**
Negative vs. Neutral	8.80*	2.37	5.53*	1.37	1.39	7.02*	--	--	--	30.49**
Delayed										
Positive vs. Negative	47.86*	.11	4.78*	3.25	3.97*	2.00	--	--	--	65.46**
Positive vs. Neutral	.74	.01	79.42*	35.53*	33.41*	15.18*	--	--	--	130.35**
Negative vs. Neutral	41.54*	.13	72.77*	18.91*	16.19*	21.32*	--	--	--	185.25**
Tested vs. Untested	.44	23.55*	3.36	14.85*	2.96	.13	.78	.48	61.33*	245.42**
Immediate vs. Untested	13.72*	118.31*	.17	28.38*	.01	9.73*	.73	.01	1.36	232.33**

*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.