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Are Affective Events Richly Recollected or Simply Familiar? The Experience and Process of Recognizing Feelings Past

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The author used the *remember/know* paradigm and the dual process recognition model of A. P. Yonelinas, N. E. A. Kroll, I. Dobbins, M. Lazzara, and R. T. Knight (1998) to study the states of awareness accompanying recognition of affective images and the processes of *recollection* and *familiarity* that may underlie them. Results from all experiments showed that (a) negative stimuli tended to be remembered, whereas positive stimuli tended to be known; (b) recollection, but not familiarity, was boosted for negative or highly arousing and, to a lesser extent, positive stimuli; and (c) across experiments, variations in depth of encoding did not influence these patterns. These data suggest that greater recollection for affective events leads them to be more richly experienced in memory, and they are consistent with the idea that the states of remembering and knowing are experientially exclusive, whereas the processes underlying them are functionally independent.

You see a car accident during your morning drive to work; the sandwich at lunch tastes unexpectedly good; a photograph of a plane crash in the newspaper makes you wince. Everyday life is punctuated by events that elicit myriad nuances, crescendos, and plateaus of feeling. What happens when we attempt to make contact with memories of these events? How is later recall or recognition of the car accident, lunch, or newspaper article changed because these experiences elicited affective reactions when they first occurred?

Many different, although related, approaches to addressing this issue have been taken. At times, researchers have posed such questions as: Are emotional memories remembered more accurately than neutral memories (e.g., Brown & Kulik, 1977; Loftus, 1993; Matlin & Stang, 1978)? Does emotion promote memory for central or peripheral details (e.g., Christianson, Loftus, Hoffmann, & Loftus, 1991)? Is it the emotional valence or the degree of arousal that determines how well an emotional episode is recalled (e.g., Matlin & Stang, 1978; Reisberg, Heuer, MacLean, & O'Shaughnessy, 1988)? All of these approaches share a primary concern with the objective accuracy of recall or recognition for the events in question. The data collected with these approaches thus describe the conditions under which memories for affective events and stimuli become distorted and inaccurate (e.g., Loftus, 1993; Schacter, 1996b), the kinds of information and details that most resist distortion (e.g., Christianson & Loftus, 1990; Heuer & Reisberg, 1992), and how valenced stimuli, mood states, or levels of arousal modulate these effects (e.g., Bradley, Greenwald, Petry, & Lang, 1992; Bower & Forgas, in press; Christianson, 1992).

Subjective Experience of Recognizing Emotional Events

But are all recognitions or recalls created equal? Is the sense of "pastness" experienced in simply noting that one drove through an intersection a few days earlier equivalent to the full-bodied, polysensory awareness accompanying recognition of that intersection as the site of the gruesome car accident? Simply indicating whether an item was seen on a recognition test, or reporting a list of items on a recall test, indicates little about such states of awareness. This is unfortunate because what matters often is not the objective fact that we can say an event occurred, but what it feels like and means to us to remember what took place (Ochsner & Schacter, in press; Schacter, 1996a; Tulving, 1985). In recognition of the importance that subjective experience plays in memory (and in various cognitive processes more generally), many researchers have shifted their focus away from asking questions about the absolute accuracy of memories to asking questions about the different states of awareness that accompany recollection of them (Gardiner & Java, 1993; Jacoby, Yonelinas, & Jennings, 1997; Ochsner & Schacter, in press; Tulving, 1985). Unfortunately, most of this research has been conducted with neutral and personally inconsequential stimulus materials, leaving unexplored questions concerning the states of awareness that accompany memory for emotional events.

Although there clearly seems to be an important link between affect and recollective experience, research investigating this link has been primarily clinical and anecdotal rather than empirical. The most salient clinical reports

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involve the traumatic flashbacks experienced by combat veterans and victims of assault (Schacter, 1996b; Witvliet, 1997). Most empirical studies that have investigated states of awareness accompanying memory for emotional events have shared a common approach: Typically, participants are asked to rate on a linear scale the vividness of their memories for personal events. Such studies have found that when individuals are asked to recall significant (Conway & Bekerian, 1988), exceptionally clear (Rubin & Kozin, 1984), or consequential and traumatic (Christianson & Loftus, 1990) personal memories, the experiences recalled are rated as highly vivid and emotional.

In these studies and others, the relationship between subjective emotional intensity and vividness has been ambiguous because it is not clear how participants made their ratings: Memories could have been rated as vivid because participants were confident in their accuracy, participants felt they reexperienced the events in question, the memories were detailed, or some other reason. Moreover, sometimes the instructions asked participants to recall only "exceptionally clear" memories with a flashbulb-like character (Rubin & Kozin, 1984), which may have introduced a demand characteristic for participants to rate any memory recalled as being more vivid. These concerns could be addressed by studies that systematically control and vary stimulus attributes at encoding and then measure the vividness of memory for these stimulus attributes later on.

A potentially more controlled method for approaching this problem assumes that at least two distinct types of awareness may accompany recollection of the past. In what has come to be known as the *remember/know,* or R/K, procedure (Gardiner & Java, 1993; Tulving, 1985), an item is recognized on a memory test, and participants are asked to decide if they remember that item or if they just know that it was seen previously. The *remember* (R) type of experience is characterized by specific memories for the episodic context, thoughts, feelings, and sensory details that "take you back" to the event in question. In contrast, if one has a *know* (K) type of experience, one can identify an event as having taken place but cannot necessarily bring to mind anything else about one's specific prior experience of it.[1] In the example of recognizing the site of a car accident that was offered above, simple recognition with a sense of familiarity would be classified as *knowing,* whereas *remembering* would occur if various kinds of details spring to mind, including the crashed car's appearance, the smell of fire, and one's thoughts and feelings about this grisly scene.

Process of Recognizing Affective Events

Conscious reports and overt responses may be the end product of more than one underlying process (Jacoby et al., 1997; Kelley & Jacoby, 1996; Posner, 1985). I aim to understand not only how subjective experience is influenced by the emotional attributes of studied items but also the processes that contribute to that experience and its variations. Theorists have proposed that recognition memory may be driven either by a consciously mediated *recollection* process that brings back details specific to a given episode, by a global sense of *familiarity* engendered relatively effortlessly by perception of a stimulus, or by some combination of the two (e.g., Hintzman & Curran, 1994; Jacoby & Dallas, 1981; Jacoby et al., 1997; Mandler, 1980). There has been some controversy, however, concerning the inferences that can be drawn about the relationship between these processes and variations in recollective experience as measured by the R/K procedure (see Donaldson, 1996; Jacoby et al., 1997; Rajaram & Roediger, 1997; Richardson-Klavehn, Gardiner, & Java, 1996, for a sampling of different positions).

Initially, it was suggested that the states of awareness captured by the R/K procedure might map naturally onto such two-process models of recognition memory: *R* and *K* responses could reflect directly the operation of recollection and familiarity, respectively (Gardiner & Java, 1993). Some have argued against a direct mapping, however. These critics note that the R/K procedure assumes that the bases for making R and K responses are mutually exclusive, that is when an item is recognized it is either exclusively remembered, or exclusively known, which would imply that the processes of recollection and familiarity underlying them also must be mutually exclusive. If this view were correct, then an item either could be recollected, or familiar, but not both.

In contrast, Jacoby, Yonelinas, and their colleagues have argued that the processes of recollection and familiarity are independent (e.g., Jacoby et al., 1997; Yonelinas et al., 1998), rather than mutually exclusive. According to their independence model, whether a given item is recollected does not constrain whether it is familiar: Some items can be exclusively recollected, some exclusively familiar, and some can be both recollected and familiar. This latter group of items—those both recollected and familiar—is overlooked if one interprets R/K responses under the exclusivity model

[1] An important concern is whether remembering and knowing, thus defined, truly tap into distinct states of conscious awareness or whether they are proxies for other kinds of responses, such as ratings of high and low confidence, or highly certain responses as opposed to guesses. This question has special importance for the study of recognition for affective events because it already has been shown that one's feelings about an event can increase the subjective confidence that memory for it is correct (Loftus, 1993; Schacter, 1996b). Three types of evidence argue against any strong similarity of R/K and confidence judgments or guessing strategies. First, R/K judgments have been shown to differ from confidence ratings in that independent variables such as stimulus type and participant group can have opposite effects on them (see Gardiner & Java, 1993 or review). Second, recent experiments by Gardiner and colleagues (Gardiner et al., 1996) have demonstrated that when participants are given a chance to indicate when they are guessing, K responses and guesses show different relationships with encoding tasks: K responses were unaffected by a level of processing manipulation, whereas guesses decreased as overall recognition rates and depth of processing increased. Third, recent electrophysiological (e.g., Mark & Rugg, 1998) and functional neuroimaging (Henson, Rugg, Shallice, Josephs, & Dolan, 1999) data indicate that R and K responses are generated by different constellations of neural systems.

because the method requires participants to give an R response to every item that is recollected (whether or not it is familiar as well). Perhaps partly in response to such criticisms, proponents of the R/K distinction have begun to place primary emphasis on the use of the R/K procedure as a method for understanding discrete states of awareness, rather than underlying processes (e.g., Gardiner, Richardson-Klavehn, & Ramponi, 1997).

Part of the controversy about the relationship between familiarity and K responses may have to do with confusion about the use of the term familiarity. As used by Jacoby and colleagues, familiarity does not refer to the subjective sense that an object has been experienced previously that is termed "familiarity" in everyday language and is indexed by K responses. According to Jacoby et al.'s (1997) independence model of recognition, familiarity refers to the automatic process that gives rise to this sense of pastness and not the experience itself. Recently, Yonelinas et al. (1998) have proposed a further refinement of the independence model by suggesting that the familiarity process draws on many different kinds of automatic signals that together contribute to the experience of knowing. This model incorporates aspects of signal detection theory to account for differences in response bias that can obscure the influence of experimental variables upon both familiarity and recollection.

On this dual-process signal-detection model, R responses provide a fairly direct estimate of recollection for specific details, but estimating recollection from the proportion of correct R responses to old items (remember "hits") may be inflated due to a bias to respond "remember." Thus recollection can be estimated more accurately if one takes into account remember "false alarms"[2] (see Footnote 2 for the equation and Yonelinas et al., 1998 for details). The contribution of familiarity to recognition can be estimated by assuming that each K response is a discriminative judgment modeled well by signal detection theory. The idea is that both studied and nonstudied items can elicit feelings of familiarity, and judging that one knows an item was seen previously requires sensitivity to detecting differences in the familiarity signals generated by studied as opposed to nonstudied items. To estimate familiarity, a sensitivity statistic designated *Fd'* is calculated. *Fd'* is derived from the tendencies to give a K response correctly to studied items and incorrectly to nonstudied items (see Footnote 2 for details of calculation). With its correction for response bias, this version of the independence model may make more reasonable assumptions about the processes underlying the R/K relationship, and it has been found to make sense of data that other models cannot accommodate (see Yonelinas et al., 1998 for discussion).

The present research was intended (a) to determine whether and when affect leads to rich recollective experience, and (b) to draw inferences about how recollection and familiarity contribute to recognition of an affective event. Use of the R/K procedure allows both goals to be met, and data for all experiments will be presented both in a standard R/K format and in terms of the Yonelinas et al. process estimates (as others also have begun doing, see e.g., Schacter, Verfaellie, & Anes, 1997).

Emotion, Distinctiveness, Recollection, and Remembering

The primary hypothesis is that emotion will increase the distinctiveness with which an event is encoded in memory and will lead that event to be richly recollected more often than a comparable neutral event (cf. Christianson, 1992). Considerable research has indicated that any factor which increases the distinctiveness with which an item has been encoded will make one more likely to recollect it later on (Rajaram, 1993, 1998; Rajaram & Roediger, 1997).[3] The key idea is that distinctive, emotionally evocative stimuli possess unique attributes that differentiate them from other stimuli (cf. Bradley, 1994; Christianson, 1992; Hunt & McDaniel, 1993).

The distinctiveness with which stimuli are encoded can be maximized when there are more attributes available to encode (e.g., pictures as opposed to words: Dewhurst & Conway, 1994; Rajaram, 1993), and when participants intentionally devote their full attention to elaborating those attributes (Conway & Dewhurst, 1995; Dewhurst & Conway, 1994; Gardiner & Parkin, 1990; Rajaram, 1993, Experiment 3). Affective stimuli can be distinctive in both ways: They may elicit physiological and evaluative responses not generated by neutral stimuli so they can have more attributes available to support robust recollection (cf. Bower & Forgas, in press), and the affective charge of a

[2] Recollection is indexed by first subtracting the proportion of remember false alarms (Rs given to new items = R_{new}) from remember hits (Rs to old items = R_{old}) and then dividing by the proportion of times a participant could have responded remember correctly (reflected by $1 - R_{new}$). The resulting ratio reflects how often items were correctly recollected relative the number of opportunities participants had to do so.

The overall contribution of familiarity is calculated in two steps. First, one must compute the probability of correctly responding know to an old item based on familiarity (F_{old}) and the probability of incorrectly responding know to a new item based on familiarity (F_{new}). Second, these two values can then be used to calculate *Fd'* using *d'* tables. F_{old} and F_{new} are based on the fact that a K response can be given only when an item is familiar but cannot be recollected. This means that the probability of responding know to an old (K_{old}) or new (K_{new}) item is equal to the probability that it is familiar and was not given an R response. For old items, the equation is $K_{old} = F_{old}\ (1 - R_{old})$, which Yonelinas et al. (1998) rearranged to solve for F_{old}, yielding the equation $F_{old} = K_{old}/(1 - R_{old})$. F_{new} can be calculated in like fashion, yielding the equation $F_{new} = K_{new}/(1 - R_{new})$.

[3] Although the concept of distinctiveness is somewhat ill defined (see Hunt & McDaniel, 1993 for discussion), for present purposes, the definition of distinctiveness suggested by Rajaram (1998) seems appropriate. She notes that distinctiveness is a property of stimuli that share few rather than many features either with other information in memory or with other items presented in close proximity to those stimuli within a given study context. Distinctive items thus have unique features defined relative either to one's enduring knowledge base or to the backdrop of recent experience (e.g., the items presented in a given study list of stimuli). In the present experiments because affective stimuli occurred with equal frequency and at the same intervals as nonaffective stimuli only stimulus attributes could influence the distinctiveness of encoding.

stimulus tends to capture attention and hold it, which leads to speeded processing and increased rehearsal of affect-relevant information (e.g., Christianson et al., 1991; Loftus, Loftus, & Messo, 1987; Pratto & John, 1991; see Ochsner & Schacter, in press for discussion). Increased attention to, and processing of, emotional stimuli could enhance memory for them by increasing the distinctiveness with which they are encoded.

Although these effects are predicted for positive and for negative stimuli, there are at least three reasons to believe that recollection and the experience of remembering, which depends upon recollection, could be greater for negative than for positive stimuli because the mechanisms that enhance distinctive encoding may operate more effectively for negative stimuli. First, attentional and perceptual biases are commonly found for negative (e.g., threat-related) stimuli but not for positive stimuli (Christianson & Fallman, 1990; Pratto & John, 1991; Williams, Mathews, & MacLeod, 1996). Second, people may have a bias to ruminate about and more extensively elaborate negative information (Skowronski & Carlston, 1989; Thomas & Diener, 1990). And third, it would make sense for an organism to be able to quickly detect and richly recollect negative, survival-relevant information of the kind depicted in the disgusting and fear-related photos used in the current experiments (cf. Ohman, 1988).

Emotion, Fluency, Familiarity, and Knowing

Familiarity is thought to depend on the ease with which an item can be processed (often referred to as fluency) either perceptually or conceptually, and K responses are thought to be based on familiarity (e.g., Gardiner & Java, 1993; Rajaram, 1998). Thus factors which influence the ease with which a stimulus can be perceived at test (such as stimulus repetition, Rajaram 1993; see Rajaram & Roediger, 1997, for review) will make stimuli more likely to be known. Increases in conceptual fluency have not yet been shown to influence K responses using the R/K procedure (cf. Rajaram & Roediger, 1997), although conceptual fluency has been shown to bias judgments of familiarity in other paradigms that require participants to make an attribution about the source of familiarity signals generated by studied and nonstudied items[4] (Whittlesea, 1993).

Various lines of evidence suggest that without prior study, emotional and especially negative stimuli are processed more fluently than neutral stimuli. Speeded perceptual or conceptual access for emotionally arousing stimuli has been shown in studies of word perception (Bargh, Chaiken, Govender, & Pratto, 1992; Kitayama, 1990), color naming in the emotional Stroop (Williams et al., 1996), picture perception (Christianson et al., 1991), and conditioning to affective pictures presented for subthreshold durations (e.g., Ohman, 1988). Many of these studies used only negative stimuli (Christianson et al., 1991; Loftus et al., 1987; Ohman, 1988), and among those that have included both positive and negative stimuli, increased fluency for positive items either has not been found or is less reliable (Christianson & Fallman, 1990; Williams et al., 1996; cf., however, Riemann & McNally, 1995).

Taken together, these data suggest that at study affective and especially negative stimuli will be processed more fluently, but it also means that nonstudied affective stimuli seen at test will be processed more fluently as well. Because *Fd'* depends on discriminating familiarity signals generated by studied and nonstudied items, increases in *Fd'* for affective stimuli would be expected only if encoding significantly boosts fluency for studied items above an already elevated baseline for fluent processing so that familiarity signals for studied stimuli are reliably stronger than such signals for nonstudied stimuli. It is predicted that to the extent that familiarity benefits accrue, they are likely to be small and most robust for negative stimuli.

These hypotheses were addressed as follows: Across three experiments participants studied photos that differed in arousal and valence and the proportions of R and K responses, and the contributions of recollection and familiarity, were compared. An additional question of secondary interest was to what extent the predicted advantage in rich recollective experience for affective stimuli required elaboration of the affective attributes of stimuli during encoding. In addressing this question, the degree to which participants focused on and elaboratively encoded arousal and valence was manipulated across experiments.

Experiment 1

The first experiment was designed to explore the relationship between (a) the subjective experience and process of recognition and (b) variations in both the valence and arousal elicited by stimuli when participants were instructed to attend to and rate these dimensions. It was thought that the results of Experiment 1 could shed new light on an old question concerning the impact of valence on memory. Claims that both positive or negative items are remembered best have been made, although they seldom have been compared within a single study (for reviews see Bradley, 1994; Ochsner & Schacter, in press). A handful of studies have directly compared accuracy of recall for positive and negative personal experiences (Reisberg, Heuer, MacLean, & O'Shaughnessy, 1988; Thomas & Diener, 1990) or emotional slides (Bradley et al., 1992). All found that valence did not differentially influence performance. Bradley et al. (1992) was the only one to test recognition, but performance was near ceiling (95% correct hits) for both positive and negative slides. It is possible that past null effects of valence on overall accuracy mask differences in the processes which contribute to recognition and the

[4] Demonstrations that manipulations of conceptual fluency influence familiarity-based knowing using the R/K paradigm are just beginning to emerge. One problem with using existing data to support such a claim is that some manipulations, such as massed repetition of stimuli at study or the processing of global as opposed to distinctive stimulus features, may make both perceptual and conceptual features of the stimulus more accessible (see Rajaram, 1998 for discussion).

experience of those memories once they come to mind. It was predicted that this experiment would demonstrate effects of valence on subjective experience and recognition processes that went undetected in past research.

To serve as reasonable laboratory analogs of real-world affective events, photographs were selected from the International Affective Picture System (the IAPS, see e.g., Bradley et al., 1992; Lang, Greenwald, Bradley, & Hamm, 1993) that depicted people, objects, buildings, animals, and both indoor and outdoor scenes. These photos differed in terms of their valence and arousal (which was verified both by Lang's ratings and by having participants explicitly rate stimuli along these dimensions) and have been shown to reliably elicit valence and arousal–specific patterns of physiological responses (Lang et al., 1993). In all experiments, participants first studied a large set of these photos and then completed a recognition test that employed the R/K procedure.

One other type of data was collected on variables that could be related to memory performance. After completion of the memory test, participants completed a debriefing questionnaire that assessed how much they had thought about the photographs during the study–test interval. It was hoped that if participants had a bias to rehearse one type of stimuli (e.g., highly arousing or aversive photos; cf. Thomas & Diener, 1990), this tendency would be revealed by their responses on the questionnaire.

Method

Participants. Eight male and 8 female undergraduate students at Harvard University received $15 each for their voluntary participation. All participants were right-handed and between 17 and 21 years of age.

Design and materials. One-hundred sixty-eight photos from the IAPS (Lang et al., 1993) were selected for use as stimuli. In Lang's experiments, representative subsets of these stimuli have been reliably classified in terms of valence and arousal, and these ratings are associated with changes in skeletomuscular activity and skin conductance responses (SCRs), respectively (e.g., Lang et al., 1993).

Using normative ratings of valence and arousal provided by Lang et al. (1993) to match for overall levels of valence and arousal, I designated 24 photographs as filler or buffer photos to be presented at encoding only, and I divided the remaining 144 photos into two groups of 72 photos each. Care was taken to ensure that one third of the stimuli in each group were classified as negative, one third as neutral, and one third as positive; similarly, care was taken to equate numbers of high-, medium-, and low-arousal photos within each group. To minimize differences in the perceptibility of photos, I adjusted each photo in size so that it measured no more than 6.75 in. (17.15 cm), and no less than 6.0 in. (15.24 cm) in height or width. Photos could not be matched exactly for size without distorting their proportions.

The two photo groups were designated as Sets A and B and their use as studied or nonstudied items was counterbalanced across participants. Whenever possible, photos in Sets A and B were matched for content so that the unique visual aspects of a given image could not serve as a unique cue on the memory test. This procedure also helped to maintain equivalent levels of valence and arousal in each stimulus set. Thus, if a photo of a flower was placed in Set A, a photo of a different flower was placed in Set B; if a photo of a burned body was placed in Set A, a similar photo was placed in Set B, and so on. This procedure allowed content matching for approximately 70% of the slides in each set. The remaining slides were matched for general semantic class (e.g., both animals, but not the same animal). Matching by appearance and class was also thought to be desirable to ensure that memory for photos would not be at ceiling, which was a concern given that recognition memory for pictures can be quite robust even after long delays.

Four study lists were constructed with stimuli placed in a pseudorandom order such that no three stimuli of the same valence or arousal occurred in succession. Twelve buffer stimuli were placed at the beginning and end of each list to reduce primacy and recency effects. Study Lists 1 and 2 contained photos from Set A, and Lists 3 and 4 contained photos from Set B. To counterbalance for order effects, Lists 2 and 4 presented stimuli in orders that were the reverse of the orders used in Lists 1 and 3, respectively.

Two test lists were constructed using only stimuli from Sets A and B presented in a pseudorandom order. No buffer items were used. Test List 2 presented study items in an order that was the reverse of the order used in test List 1.

Procedure. All participants participated in one study session lasting approximately 30 min and one test session lasting approximately 45 min. Sessions were spaced 2 weeks apart because pilot testing had determined that a 2-week interval produced levels of recognition memory below ceiling but acceptably above chance (approximately 70–75% correct collapsing across stimulus types). All photos were presented on a 13-in. (33.02-cm) Macintosh color display and at a viewing distance of 60 cm subtended a maximum of 16.27° and a minimum of 14.49° of visual angle vertically and horizontally. A Macintosh Quadra 700 computer running the software program MacLab controlled response collection and presentation of instructions and study and test stimuli.

At the beginning of a study session, participants were instructed that they were going to be asked to rate photos, some of which might have some emotional content, and they would be asked to come back for a second session in 2 weeks. They were not informed that the second session would be a memory test. Participants then sat in front of the computer with their chin on a rest and read the instructions on the computer screen.

The instructions informed participants that their task was to study photographs of objects and scenes and rate each one along each of three dimensions: valence, arousal, and visual complexity. Valence corresponded to the feeling one has when looking at the photograph, from 1 (*very negative*) to 7 (*very positive*), with a moderate rating of 4 indicating a neutral feeling. Arousal corresponded to the intensity of this feeling, or how aroused one is when looking at a photograph, from 1 (*very weak*) to 7 (*very strong*), with a rating of 4 indicating moderate arousal. Participants were told to try to make this rating independently of the rating of valence, that very positive and negative scenes could generate either high or low or moderate arousal, and that neutral scenes could generate different levels of arousal as well. The final rating was visual complexity, ranging from 1 (*not at all complex*) to 7 (*very complex*), with a rating of 4 indicating moderate complexity. Instructions specified that a photograph could be considered complex either because it has many simple objects that each had little detail, or a few complex objects that each were very detailed, or both. The instructions further specified that after the presentation of each photo, three 7-point rating scales, one for each judgment, would appear on the screen to guide their ratings. Participants were asked to repeat back the instructions to the experimenter to be sure that they understood the nature of the task, and the independent nature of valence and arousal ratings was reiterated.

On each trial, a fixation cross appeared in the center of the screen for 750 ms. After a 500 ms pause, a photo appeared on the screen for 2 s. When it disappeared, a screen with rating scales for valence, arousal, and visual complexity appeared on the screen. Participants made each rating in this order, and the next trial began as soon as the last rating had been completed.

Two weeks later, participants returned and were informed that their memory would be tested for the photos they had seen in the previous rating session. Participants were again seated in front of the computer and read the instructions on the computer screen. The instructions explained that some old (from the previous rating session) and some new photos would appear on the screen, and that the participants' task was to discriminate them by pressing one of three keys: If the photo is new, they should press the key labeled N; if they know the photo is old, but cannot recollect anything specific about its occurrence, they should press the key labeled K; and if they remember that they saw it and can recollect specific details about it during the rating session, they should press the key labeled R. Examples of R and K responses were then given to amplify these initial instructions.

On each trial a fixation cross appeared on the screen for 750 ms followed by presentation of a photo 500 ms later. The photo remained on the screen until participants indicated their response by pressing the N, K, or R keys (the B, N, and M keys with labels placed on top). Participants then wrote an explanation for that response in a response booklet and pressed the spacebar to go on to the next trial.

After completion of the memory test, participants completed a debriefing questionnaire that assessed their compliance with instructions, their thoughts about the purpose of the experiment, and how often they had thought about the photos (and if so, which photos) during the 2 week study–test interval.

Results

Classification of stimuli. To allow analysis of data as a function of arousal and valence, I computed mean encoding ratings of valence, arousal, and visual complexity for each stimulus. Stimuli were then rank ordered along each of these dimensions and grouped into thirds (see Table 1 for mean ratings of each stimulus type along each dimension and Table 2 for correlations between ratings). Thus, for arousal, the third of the photos with the highest mean ratings were classified as high arousal, the third of the photos with the lowest mean ratings were classified as low arousal, and the third of the photos with ratings in between were classified as medium arousal. A similar procedure classified stimuli as negative, neutral, or positive along the valence dimension, and as highly complex, moderately complex, or least complex, along the dimension of visual complexity (these data are discussed in more detail in a later section). Mean ratings were significantly different ($p < .001$) for all pairwise comparisons of stimulus types within a rating dimension (e.g., positive vs. neutral, positive vs. negative, etc.).

These ratings were used to address the important question of how affective valence and arousal impact on the proportion of R and K responses and recollection and familiarity. Care also was taken to make sure that the contents of stimuli in each set were as comparable as possible.

Remembering versus knowing. Was remembering more likely for affective stimuli and especially for negative or highly arousing items? The answer seems to be yes, as indicated by the simple proportions of R and K responses given to old (hits) and new (false alarms) items, shown as a function of valence in Table 3 and as a function of arousal in Table 4. In keeping with predictions, negative photos were remembered best of all, versus positive, $t(14) = 2.21, p < .05$, and versus neutral, $t(14) = 4.96, p < .001$, and although there was a numerical trend for positive photos to be remembered more often than neutral ones, this effect was not significant, $t(14) = 1.48, p < .16$. Remembering also was more common for more highly arousing stimuli. Although

Table 1
Means and Standard Deviations of Encoding Ratings of Stimuli Along Each Rating Dimension Used in Experiments 1, 2, and 3

Stimulus and rating	*M*	*SD*
	Experiment 1	
Valence		
Negative	2.20	0.63
Neutral	4.06	0.38
Positive	5.49	0.38
Arousal		
High	5.29	0.53
Medium	4.39	0.25
Low	3.18	0.62
Complexity		
High	4.68	0.45
Medium	3.54	0.28
Low	2.39	0.44
	Experiment 2	
Distance		
Closer	2.99	0.45
Stay	4.19	0.43
Farther	5.78	0.41
	Experiment 3	
Brightness		
High	5.21	0.59
Medium	3.72	0.42
Low	2.37	0.58

Note. For ratings of desired distance from pictured object, closer = move closer, stay = move very little or not at all, farther = move farther away.

Table 2
Correlation Matrix of Encoding Ratings of Photos

Judgment	A	B	C	D	E
A. Exp. 1: Valence	—	−.28	−.29	−.80	.46
B. Exp. 1: Arousal		—	.48	.36	−.07
C. Exp. 1: Visual complexity			—	.28	−.03
D. Exp. 2: Distance				—	−.32
E. Exp. 3: Brightness					—

Note. All ratings were made on 7-point scales. For arousal, larger values were for larger degrees of arousal; for valence, larger values were for more positive affect; for visual complexity, larger values were for greater detail; for distance, larger values were for moving farther away; and for brightness, high values were for brighter photos. All correlations are significant at $p < .001$ except for the correlation of B (arousal) with E (brightness), which is not significant ($p < .40$), and C (visual complexity) with E (brightness; $p < .73$). Exp. = experiment.

the overall proportion of R responses to high- and medium-arousal photos did not differ, $t(14) < 1$, both were remembered more often than low-arousal photos; high versus low, $t(14) = 3.76$, $p < .002$; medium versus low, $t(14) = 3.63$, $p < .003$.

Interestingly, and contrary to expectation, there were sometimes significant trends toward the opposite pattern in K responses. Positive photos produced more K responses than negative ones, $t(14) = 2.69$, $p < .05$. Although low-arousal photos tended to be given more K responses than either high-, $t(14) = 1.91$, $p < .07$, or medium-arousal photos, $t(14) = 1.34$, $p < .20$, these effects were not significant.

Recollection versus familiarity. For an estimate of the contributions to memory of recollection and familiarity, R and K responses were transformed according to the model of Yonelinas et al. (1998). These data are shown for valence in the center of Table 3 and for arousal in the center of Table 4. The key result was that recollection paralleled the pattern of R responses, whereas familiarity (Fd') showed a very different pattern than did K responses. As a function of valence, recollection was greatest for negative photos; negative versus neutral, $t(14) = 4.84$, $p < .001$; negative versus positive, $t(14) = 2.28$, $p < .04$. Also, there was a numerical but nonsignificant trend for recollection to be greater for positive than for neutral photos, $t(14) = 1.36$, $p < .20$. As a function of arousal, recollection was greater for high- and medium-arousal than it was for low-arousal photos; high versus low, $t(14) = 3.72$, $p < .002$; medium versus low, $t(14) = 3.71$, $p < .002$. In contrast to the pattern of increased K responses for positive and low arousal stimuli, Fd' did not vary significantly either as a function of valence or as a function of arousal (all $ts < 1$). The predicted increase in familiarity for negative or high arousing items thus was not found.

Recognition accuracy and response bias. Previous studies of emotion and memory have used only measures of accuracy when using recognition tests. To allow comparison with these studies, I computed the index of recognition accuracy from signal detection theory (d'). In addition, to determine whether participants had a systematic bias to respond old or new, an orthogonal measure of response criterion (C) also was computed (Snodgrass & Corwin, 1988).[5] These data are shown for valence in the right side of Table 3 and for arousal in the right side of Table 4. A key finding was that for valence the effects of emotion on recognition accuracy paralleled those found for R responses and for recollection: d' was greater for negative than for either neutral, $t(14) = 1.77$, $p < .10$, or positive, $t(14) = 2.12$, $p < .05$, photos. In contrast, for arousal d' did not track recollection and R responses but was greater for medium-arousal photos than for either high-arousal, $t(14) = 2.13$, $p < .05$, or low-arousal photos, $t(14) = 2.84$, $p < .05$. Participant's response criterion was more liberal for negative than for neutral, $t(14) = 3.50$, $p < .01$, or positive, $t(14) = 1.77$, $p < .10$ photos, and it was more liberal for high-arousal, $t(14) = 2.22$, $p < .05$, and medium-arousal, $t(14) = 1.98$, $p < .07$, than it was for low-arousal photos. These data are discussed in relation to recognition performance in other experiments after discussion of the results of Experiment 3.

Debriefing sheets. Examination of debriefing sheets indicated that only a handful of participants ($n = 4$) reported thinking about any of the photos during the 2 week study–test interval. Of these 4, only 2 reported imagery of the photos. The pattern of data for these participants did not differ from that of the rest of the group, and the overall pattern of data did not change significantly when these participants were excluded from analyses. Therefore, it does not seem likely that rehearsal contributed significantly to the present results.

Table 3
Measures of Memory Performance as a Function of Valence in Experiment 1

	Remember		Know				Recognition	
Valence	Hits	FAs	Hits	FAs	Rec	Fd'	d'	C
Negative	.53	.03	.26	.09	0.52	1.75	2.21	0.19
Neutral	.37	.02	.35	.09	0.36	1.44	1.91	0.33
Positive	.42	.03	.35	.13	0.40	1.54	1.88	0.15

Note. At study participants judged the valence, arousal, and visual complexity of each photo. FA = false alarms; Rec = estimate of recollection based on remember responses; and Fd' is the estimate of familiarity based on know responses, used by Yonelinas et al. (1998); d' is the standard signal detection measure of overall recognition accuracy, and C is the complementary measure of response bias (Snodgrass & Corwin, 1996).

Table 4
Measures of Memory Performance as a Function of Arousal in Experiment 1

	Remember		Know				Recognition	
Arousal	Hits	FAs	Hits	FAs	Rec	Fd'	d'	C
High	.48	.03	.31	.13	0.47	1.58	1.97	0.11
Medium	.48	.02	.30	.08	0.47	1.66	2.27	0.28
Low	.36	.02	.36	.11	0.35	1.49	1.79	0.26

Note. At study participants judged the valence, arousal, and visual complexity of each photo. FAs = false alarms; Rec = recollection based on remember hits and FAs; and Fd' is familiarity based on know hits and FAs, estimated according to Yonelinas et al. (1998); d' and C are measures of accuracy and bias from signal detection theory (Snodgrass & Corwin, 1996).

Discussion

The most important result of Experiment 1 was that affective stimuli tended to be richly reexperienced in memory

[5] D' is the signal detection statistic that takes into account false alarm rates, and C is the corresponding and orthogonal measure of response bias advocated by Snodgrass and Corwin (1988). D' varies from zero to infinity with larger values indicating greater sensitivity to discriminating old from new items and hence greater recognition accuracy. C can vary continuously around zero, with larger positive values indicating an increasingly conservative criterion and larger negative values indicating an increasingly liberal response criterion.

more often than neutral or nonarousing stimuli. This conclusion was supported by evidence that (a) larger proportions of *R* responses were given to more highly arousing, negative, and to a lesser extent, positive stimuli and (b) estimates of the contribution to performance of a consciously mediated recollection process (Yonelinas et al., 1998) produced the same pattern of results. These data provide initial support for the hypothesis that affect leads to increases in the distinctiveness with which stimuli are encoded and reexperienced in memory later on and suggests that previous failures (Bradley et al., 1992; Reisberg et al., 1988) to detect an impact of valence on memory may have been due to the use of memory measures that were not sensitive to differences in the experience or process of recognizing past events.

The pattern of K responses and familiarity was somewhat unexpected, however. For both valence and arousal, R and K responses seemed to trade off against one another: Larger proportions of R responses for negative and high-arousal items contrasted with larger proportions of K responses for positive and low-arousal items. In contrast, familiarity was not significantly influenced by differences in either valence or arousal. These data run counter to the small predicted increase in familiarity-based knowing for affective stimuli in general and negative and high-arousal stimuli in particular. The independent dual-process model of Yonelinas et al. (1998) suggests a reason why different patterns of results may have been obtained for K responses and familiarity. This model posits that some items which are recollected also may be familiar but because the R/K procedure instructs participants to respond only R to such items, K responses will drop and R responses will rise whenever items both familiar and recollectable are present. As a consequence, K responses can underestimate the contribution to performance of familiarity, which seems to have been the case for negative and high arousal photos.

The interaction of affect with recollective experience suggests that when participants are asked to classify their subjective sense of recognition using the R/K method, positive and low-arousal stimuli are reexperienced in memory quite differently than their negative and high-arousal counterparts. Analysis of these data in terms of the processes that give rise to recognition suggest that when a negative or high-arousal item is richly reexperienced and given an R response, that experience is rich because the item was both recollected and familiar.

Experiment 2

Although Experiment 1 provided encouraging confirmation of initial hypotheses, one concern is that having participants attend to and rate the valence and arousal elicited by each stimulus could have differentially influenced memory for different types of photos; furthermore, it is possible that the observed effects of valence and arousal on remembering could occur only when participants explicitly attend to and rate these stimulus dimensions. For example, having participants explicitly rate the valence of stimuli could differentially favor the distinctive encoding of negative photos (Skowronski & Carlston, 1989), and having participants explicitly rate arousal could differentially favor the distinctive encoding of high- and medium-arousal photos. Therefore, the next task was to determine whether recollective experience, recollection, and familiarity vary as a function of valence and arousal ratings in the same way as in Experiment 1 when participants are not asked explicitly to attend to and rate the stimuli along these dimensions.

Experiment 2 was identical to Experiment 1 in all ways except one: Instead of having participants explicitly rate the valence and arousal of their emotional reaction to each photo (as well as its visual complexity), participants performed a single encoding rating that asked them to imagine standing next to the photographer as the photo was being taken and then to decide if they would want to move closer to, or farther away from, the central object in the photo. This *distance* encoding task was chosen because (a) it mapped nicely onto the functional categorization of emotion-related responses in terms of approach/withdrawal advocated by some emotion theorists (Davidson, 1992) and as such (b) it was thought to ensure that participants were engaging the stimulus by appraising its personal relevance (which was accomplished through ratings of valence and arousal in Experiment 1).

Compared with Experiment 1, it was expected that use of this encoding task should decrease overall recognition because participants were completing a single encoding rating instead of three. More importantly, as deliberative elaboration of stimuli decreases, if emotion continues to impact primarily upon R responses and recollection, then it would suggest that distinctive encoding does not require explicit notation and encoding of the valence and arousal elicited by a stimulus.

Method

Participants. Eight male and 8 female undergraduate students at Harvard University received $15 for their voluntary participation. All participants were right-handed and between 17 and 21 years of age.

Design and materials. The design and experimental materials were identical to Experiment 1.

Procedure. The procedure was identical to Experiment 1 with the exception of the encoding task. During the study session, participants were instructed that while viewing each photo their task was to imagine that they were standing next to the person who took the photograph as the photograph was being taken and then to decide if they would (a) feel like moving closer to the subject of the photo, (b) feel like moving farther away from the subject of the photo, or (c) not feel like moving at all. After the photograph disappeared from the screen, participants were asked to rate on a 7-point scale how far they would like to move. On the scale, a 1 (*very close*) indicated that they would move to within a few feet of the object, a 7 (*very far*) indicated that they would move far away, perhaps more than 100 feet from the main object, and a 4 (*not move at all*) indicated that they would not move. The rating scale appeared after the photo had been on the screen for 2 s, and both the scale and photo remained on the screen until participants pressed the key corresponding to their choice. The next trial then began automatically.

Results

Classification of stimuli. The normative ratings from Experiment 1 were used to classify stimuli according to their valence, arousal, and visual complexity. Mean distance ratings (shown in Table 1) were highly correlated with valence ratings (as shown in Table 2) and produced similar patterns of data; they will not be discussed further here.

Remembering versus knowing. The key finding of Experiment 2 was that despite the change of encoding conditions, the pattern of R and K responses was quite similar to that observed in Experiment 1. Negative photos once again were given more R responses than positive ones, $t(14) = 2.29, p < .04$, but unlike Experiment 1, positive photos were now given significantly more R responses than neutral photos, $t(14) = 3.01, p < .01$. Arousal showed a fairly linear relation to R responses, with Rs given more often to high- than to medium-arousal photos, $t(14) = 4.05, p < .001$, and marginally given more often to medium than to low-arousal photos, $t(14) = 1.94, p < .07$. In Experiment 1, high and medium arousal photos were remembered equally often. Although K responses appeared to be more common for positive and low-arousal photos, these effects did not approach significance ($t < 1.30$).

Recollection versus familiarity. Analyses of derived measures of recollection and familiarity support those found for R and K responses. Recollection was greatest for negative photos, negative versus neutral, $t(14) = 4.68, p < .001$, negative versus positive, $t(14) = 2.41, p < .03$, and although there was a trend for positive items to be recollected more often than neutral ones, this effect was not significant, $t(14) = 1.67, p < .12$. The independence model estimates recollection by correcting R responses for guessing, and as shown by Table 5, the rate of R false alarms to positive photos was greater relative to overall numbers of R responses than it was for either negative or neutral photos. As in Experiment 1, familiarity did not vary significantly as a function of valence (all $p > .33$), although the pattern of Fd' values did parallel those for recollection and was consistent with our initial hypothesis that negative photos should be more familiar.

For arousal, recollection was greater for high- than for medium-arousal photos, $t(14) = 3.14, p < .01$, whereas recollection had been equal for these item types in Experiment 1. Recollection for medium-arousal photos was in turn greater than for low-arousal photos, $t(14) = 1.75, p < .10$. Interestingly, the results for familiarity had the same pattern as in Experiment 1, except that the advantage for medium-arousal items was not significant rather than just a trend: Fd' was greater for medium-arousal than it was for high-arousal, $t(14) = 2.62, p < .02$, or low-arousal photos, $t(14) = 3.17, p < .01$. As Table 6 shows, the heightened sensitivity to degrees of familiarity seemed to be due to an increase in K false alarms for both high-arousal, $t(14) = 2.56, p < .03$, and low-arousal photos, $t(14) = 2.17, p < .05$, compared with medium-arousal photos. This finding does not replicate across experiments, and in general there is more variability in memory for medium-arousal photos, possibly because of more variability in the stimuli that make up the medium-arousal category and the way in which they are encoded.

Recognition accuracy and response bias. For valence, recognition accuracy paralleled the estimates of *recollection:* d' was greater for negative than it was for either positive, $t(14) = 2.12, p < .05$, or neutral, $t(14) = 1.77, p < .10$, photos. For arousal, recognition accuracy did not track recollection and was greater for medium-arousal photos than for either high-arousal, $t(14) = 2.66, p = .02$, or low-arousal photos, $t(14) = 3.01, p < .01$. Somewhat similar to Experiment 1, the response criterion was more conservative for neutral than for negative, $t(14) = 3.61, p < .005$, or positive photos, $t(14) = 2.50, p < .03$, and was more liberal for high-arousal than for medium-arousal, $t(14) = 4.51, p < .001$, or low-arousal photos, $t(14) = 5.08, p < .001$. These data are discussed in the context of recognition performance from the other two experiments after discussion of Experiment 3.

Debriefing sheets. In keeping with the results of Experiment 1, debriefing sheets indicated that only a few participants ($n = 5$) reported thinking about or imaging ($n = 3$) any of these photos during the 2-week study–test interval. Data from these participants did not differ from participants not reporting thoughts about the photos, and the overall pattern of data did not change when these participants were excluded from analyses.

Table 5
Measures of Memory Performance as a Function of Valence in Experiment 2

	Remember		Know				Recognition	
Valence	Hits	FAs	Hits	FAs	Rec	Fd'	d'	C
Negative	.44	.05	.30	.12	0.41	1.41	1.80	0.19
Neutral	.27	.03	.33	.09	0.25	1.20	1.47	0.45
Positive	.35	.06	.34	.11	0.31	1.31	1.48	0.25

Note. At study participants judged how close or far from the object depicted in each photo they would like to be. FAs = false alarms; Rec = recollection based on remember hits and FAs; and Fd' is familiarity based on know hits and FAs, estimated according to Yonelinas et al. (1998); d' and C are measures of accuracy and bias from signal detection theory (Snodgrass & Corwin, 1996).

Table 6
Measures of Memory Performance as a Function of Arousal in Experiment 2

	Remember		Know				Recognition	
Valence	Hits	FAs	Hits	FAs	Rec	Fd'	d'	C
High	.46	.07	.28	.14	0.42	1.13	1.54	0.10
Medium	.34	.03	.36	.07	0.32	1.60	1.84	0.41
Low	.26	.03	.34	.11	0.24	1.08	1.34	0.43

Note. At study participants judged how close or far from the object depicted in each photo they would like to be. FAs = false alarms; Rec = recollection based on remember hits and FAs; and Fd' is familiarity based on know hits and FAs, estimated according to Yonelinas et al. (1998); d' and C are measures of accuracy and bias from signal detection theory (Snodgrass & Corwin, 1996).

Discussion

The key finding from Experiment 2 was that even when valence and arousal were not rated explicitly, the pattern of key results obtained in Experiment 1 remained essentially unchanged. Most significantly, the prediction that valenced and more arousing photos would be recollected and remembered most often once again was supported. Also, as predicted, this effect was more pronounced for negative photos than for positive photos. However, positive photos were not recollected significantly more often than neutral ones, although there once again was a trend in this direction. In addition, the prediction that negative and high-arousal stimuli would be at least slightly more familiar once again was not supported: Neither negative items nor high-arousal items were significantly more familiar. The one difference between the results of Experiments 1 and 2 was that whereas more K responses were given to positive than to negative stimuli in Experiment 1, a trend in this direction was not significant in Experiment 2. It seems that some items that were both familiar and recollectable once again were given only R responses, although this pool of items was not as large as in Experiment 1.

Experiment 3

The first two experiments converged on the same basic conclusions. However, in both of them encoding tasks were used that either explicitly (Experiment 1) or implicitly (Experiment 2) required participants to evaluate directly the personal relevance and significance of stimuli when they first were viewed. It is possible that the instruction to judge how far from a pictured object one would like to be directed participants' attention to information about the valence of stimuli in each photo. The strong correlation of distance ratings in Experiment 2 with valence ratings from Experiment 1 (if negative, move far away, see Table 2) underscores this point. Thus the possibility remains that the observed advantages in recollection and remembering for negatively and highly arousing stimuli are obtained only when participants explicitly judge the personal relevance of each photo as it appears. Given that part of the memory advantage for personally significant, and especially negatively valenced, information can come from greater elaboration and rumination about this information (Skowronski & Carlston, 1989; Thomas & Diener, 1990), and that part of the process of appraising a stimulus as negative or positive can be consciously directed (Lazarus, 1991), it is quite plausible that remembering negative events requires that encoding focus explicitly on appraising the affective significance of a stimulus.

To test this interpretation, I conducted a third experiment in which participants encoded stimuli by judging their subjective brightness. Pretesting had shown that the photos varied reliably and fairly normally in terms of how bright each photo appeared to be and that this was a readily discernible attribute of each photo (see Footnote 6). A brightness judgment was selected because it focused attention on the photos but only directed participants to globally analyze the photos' perceptual features. To limit the amount of time participants could devote to additional analysis of the photos, I had them make this judgment under greater time pressure than in the previous experiments: Stimuli remained on the screen for 1 s as opposed to 2, it was emphasized that judgments should be made as quickly as possible, and pretesting indicated that participants felt pressed to respond under these conditions. It was predicted that if encoding of the information that supports enhanced remembering for emotional photos requires explicit assessment of their affective properties, then the pattern of R responses observed in the first two experiments should no longer pertain; judging the brightness of a photo presumably does not involve such assessments and so might not lead to enhanced recollection/remembering.

There were reasons to suspect, however, that the recollection/remembering advantage for emotional stimuli would be found even when using an encoding task that involves an analysis of only global perceptual characteristics. The first steps toward generating an affective response can take place automatically, without conscious direction of attention or evaluation (Christianson, 1992; LeDoux, 1996). Simply looking at a photo or word for a fraction of a second elicits an automatic evaluation of it (Bargh, Chaiken, Govender, & Pratto, 1992; Williams et al., 1996), and physiological responses that may compose part of one's emotional reaction can be elicited even when stimuli are not consciously recognizable, including SCRs (e.g., Ohman, 1988) and activation of the amygdala (Whalen et al., 1998). Lesions to the amygdala (either functional or permanent) have been shown to eliminate the memory advantage that affective stimuli enjoy over neutral ones (Cahill, Babinsky, Markowitsch, & McGaugh, 1995). Given that the cognitive evaluations and physiological responses that uniquely seem to contribute to remembering an affective event can take place automatically, or at least with minimal conscious cognitive effort, it is quite possible that the affective charge of a stimulus could be encoded without much effort as participants scan a photo and judge its brightness. Whether or not what is encoded under conditions in which attention is directed away from the affective properties of stimuli can support remembering and recollection is what this experiment is designed to find out.

Method

Participants. Eight male and 8 female undergraduate students at Harvard University received $15 for their voluntary participation. All participants were right-handed and between 17 and 21 years of age.

Design and materials. The design and experimental materials were identical to Experiment 2.

Procedure. Participants were asked to rate stimuli in terms of their perceived brightness along a 7-point scale. Participants were instructed that on this scale, a 1 (*not at all bright*) corresponded to the amount of light given off by a small night light in a very large room at night, a 7 (*very bright*) corresponded to the amount of light present on a sunny, cloudless day, and a rating of 4 (*moderately bright*) corresponded to a level of brightness intermediate to these two extremes.

Two modifications were made to the procedure relative to Experiment 2. The first was designed to help ensure that participants took approximately the same amount of time to make each judgment. Participants were told to make their judgment as quickly as possible as soon as the photo appeared on the screen and were instructed that if they did not respond quickly enough the next trial would begin automatically. Photos were presented for 1 s, and after a 1-s pause, the next trial began. It was thought that this procedure would help minimize and equate the amount of time available to participants for elaborative encoding of the stimuli beyond that required to make their assigned encoding judgment. The second modification was necessitated by the first. Pretesting indicated that the use of a single encoding task and more rapid study presentations substantially reduced memory so that a 2-week study–test interval resulted in chance recognition performance. Additional pretesting helped titrate the interval to one day so that memory performance was above chance but below ceiling and comparable with that in Experiments 1 and 2 for all encoding groups.

Results

Classification of stimuli. As for Experiments 1 and 2, mean ratings of valence, arousal, and visual complexity from Experiment 1 were used to classify photos. To compare encoding across experiments, mean ratings of brightness from this experiment (shown in Table 1) were correlated with ratings from previous experiments. These data are shown in Table 2, and the most important finding was that brightness ratings were not correlated with arousal, visual complexity, or distance ratings but were correlated with valence such that positive photos were judged to be more bright.[6]

Remembering versus knowing. Importantly, the proportions of R and K responses fit the pattern previously observed. As shown in Table 7, negative photos were remembered more than either positive, $t(14) = 2.56$, $p < .02$, or neutral photos, $t(14) = 5.43$, $p < .001$. Positive photos were not remembered significantly more often than neutral ones. Somewhat like Experiment 1, positive, $t(14) = 2.08$, $p < .06$, and neutral photos, $t(14) = 3.49$, $p < .01$, produced more K responses than negative ones.

As shown in Table 8, the effects of arousal on recollective experience also were in keeping with those observed previously as R responses increased consistently as a function of arousal. Thus, high-arousal photos were remembered more often than medium-arousal photos, $t(14) = 2.71$, $p < .02$, which in turn were remembered more often than low-arousal photos, $t(14) = 3.19$, $p < .01$. In general, K responses did not increase or decrease significantly as a function of arousal, although more K responses were given to low- than to high-arousal photos, $t(14) = 2.62$, $p < .02$. This pattern was the reverse of that shown for R responses.

Recollection versus familiarity. Patterns of recollection and familiarity were similar to those found in Experiments 1 and 2. As shown in the center of Table 7, recollection paralleled remembering and was greater for negative than for positive, $t(14) = 2.38$, $p < .03$, or neutral photos, $t(14) = 5.26$, $p < .001$. Recollection for positive photos was marginally greater than for neutral photos, $t(14) = 1.84$, $p < .08$. Familiarity, indexed by *Fd'*, showed no significant variation (all *p*s > .30). As was the case for remembering, recollection increased nearly linearly with arousal, with greater recollection shown for high- than for medium-arousal photos, $t(14) = 2.89$, $p < .01$, and for medium- than for low-arousal photos, $t(14) = 2.83$, $p < .01$. These data are shown in the center of Table 8. In contrast to the results of Experiment 2, however, *Fd'* did not vary significantly with arousal (all *p*s > .22).

Recognition accuracy and response bias. In keeping with the previous two experiments, and as shown in Table 7, *d'* was greater for negative as compared with either neutral, $t(14) = 2.13$, $p = .05$, or positive photos, $t(14) = 2.10$, $p =$

Table 7
Measures of Memory Performance as a Function of Valence in Experiment 3

	Remember		Know				Recognition	
Valence	Hits	FAs	Hits	FAs	Rec	*Fd'*	*d'*	*C*
Negative	.53	.04	.26	.13	0.51	1.34	1.85	0.07
Neutral	.34	.03	.36	.14	0.32	1.32	1.61	0.23
Positive	.41	.02	.34	.18	0.40	1.22	1.64	0.07

Note. Participants judged the brightness of each photo at study. FAs = false alarms; Rec = recollection based on remember hits and FAs; and *Fd'* is familiarity based on know hits and FAs, estimated according to Yonelinas et al. (1998); *d'* and *C* are measures of accuracy and bias from signal detection theory (Snodgrass & Corwin, 1996).

Table 8
Measures of Memory Performance as a Function of Arousal in Experiment 3

	Remember		Know				Recognition	
Valence	Hits	FAs	Hits	FAs	Rec	*Fd'*	*d'*	*C*
High	.53	.03	.28	.17	0.52	1.25	1.79	0.01
Medium	.43	.04	.31	.12	0.41	1.33	1.72	0.16
Low	.33	.02	.37	.15	0.31	1.38	1.65	0.22

Note. Participants judged the brightness of each photo at study. FAs = false alarms; Rec = recollection based on remember hits and FAs; and *Fd'* is familiarity based on know hits and FAs, estimated according to Yonelinas et al. (1998); *d'* and *C* are measures of accuracy and bias from signal detection theory (Snodgrass & Corwin, 1996).

[6] The reason why positive photos were judged to be brighter is not entirely clear, although the objective brightness of photos did vary somewhat as a function of valence. Average luminance values were computed (using the program Adobe Photoshop) for each type of photo as a function of valence, and although positive photos ($M = 112.41$, $SE = 5.08$) were not significantly brighter than either neutral ($M = 106.71$, $SE = 4.98$) or negative ($M = 109.71$, $SD = 4.82$) photos ($t < 1$ for all comparisons), there was a trend in that direction. The range of luminance values extended into higher values for positive (minimum = 42.26, maximum = 199.90) than for negative (minimum = 37.25, maximum = 186.18) or neutral (minimum = 46.00, maximum = 170.97) photos and measures of median (positive = 110.55, negative = 106.51, neutral = 105.46) luminance values showed a similar pattern. It seems likely that ratings of subjective brightness picked up on some of the actual variation in luminance for the photos.

.05. Positive and neutral photos were recognized with statistically equivalent accuracy in all groups. Survey of the mean d' values for different levels of arousal, shown in Table 8, shows a tendency for d' to be greatest for high- or medium-arousal photos and least for low-arousal photos, although these differences were not significant. Comparisons of C for different levels of valence or arousal yielded patterns that also were generally consistent with the results of previous experiments. C was more conservative for neutral than for either negative, $t(14) = 2.03, p < .06$, or positive, $t(14) = 2.00, p < .07$, photos and was more conservative for low- than for high-arousal photos, $t(14) = 2.91, p < .01$. C for medium-arousal photos was situated between that for high- and low-arousal ones.

Debriefing sheets. Debriefing sheets indicated that groups of participants slightly larger than those in the previous experiments had either thought about ($n = 7$) or imaged ($n = 5$) some of the photos during the 1 or 3 day study–test interval. Exclusion of these participants did not affect the direction of the observed effects, although the drop in power rendered the effects of interest statistically insignificant.

Discussion

The most significant finding of Experiment 3 was that having participants simply judge the subjective brightness of a photo was enough to produce the same basic pattern of results observed earlier: Recollection and remembering were greater for negatively valenced or high-arousal items, whereas know responses and the contribution to those responses made by familiarity did not vary consistently. The presence of these effects when participants judge only perceptual aspects of the photos that were uncorrelated with their affective properties strongly suggests that explicit encoding of affect is not necessary for enhanced recollection to follow. It is important to note, however, that the design of the present experiments may have placed limitations on the extent to which cognitive elaboration could have impacted on performance. In all three experiments the retention intervals were relatively short and the stimuli used did not have long-term personal consequences for participants, all of which may have made extensive evaluation, rehearsal, and imaging of the photos unlikely. Indeed, few reports of doing so were found in participants' debriefing reports. In real-world situations where personal ramifications are not immediately clear, it is likely that rehearsal and continued consideration of the meaning of an event will help make traces of it more distinctive and hence more "rememberable" (Thomas & Diener, 1990; Skowronski & Carlston, 1989).

It is possible that when making the brightness judgment participants still could note the way in which they were reacting, but it is unlikely that this notation could be elaborated very much because the stimuli were advancing quickly and participants were under time pressure to respond as quickly as possible. It is perhaps safest to say that the present experiment demonstrates that simply judging the perceptual characteristics of a stimulus is sufficient for its affective properties to be encoded and later support better recollection/remembering of it and suggests further that these affective properties can be encoded without much effort.

Recognition Accuracy and Response Criterion

Measures of overall recognition accuracy (d') and response criterion (C) were computed as a function of valence and arousal in each experiment. Values of d' can be compared with previous research which has used only measures of accuracy and has provided information about participants' ability to detect differences between studied and nonstudied items, regardless of whether a given item was recollected or familiar or whether it led to an R or K type of subjective experience. C provides information about how decision processes influence recognition and indicates whether affect changed the way in which participants made their recognition judgments.

The relationship between recognition accuracy and valence was straightforward and consistent with initial hypotheses that performance should be enhanced for valenced stimuli, especially negative ones: Across experiments, d' seemed to track recollection and remembering, with negative items recognized most accurately and recollected and remembered more often than either positive or neutral items. Although positive items were neither consistently recognized more accurately nor recollected more often than neutral items, there often were trends in this direction. Given that familiarity did not show significant variation as a function of valence, it seems that negative photos were recognized more accurately primarily because they were recollectable. As was the case for valenced as opposed to neutral stimuli, high- as compared with low-arousal photos were recognized more accurately.[7] The fact that recollection showed a very similar pattern, whereas familiarity tended not to vary significantly with arousal, suggests that high-arousal items were recognized more accurately because they

[7] Interestingly, recognition of medium-arousal photos tended to be a bit variable, with accuracy rising above, matching, or dipping below that for high-arousal photos. It is possible that medium-arousal photos are encoded with more variability than high- or low-arousal photos, which could lead to increased variability in memory for them. This was borne out in the inconsistent relationships between the various performance measures across experiments for medium-arousal photos: Although there were sometimes consistent patterns for a given measure across encoding conditions (e.g., in all three experiments response criteria were equally conservative for medium- and low-arousal photos and fewer K false alarms were made for medium-arousal photos), but these patterns did not coincide in a predictable or meaningful way (e.g., although the pattern of false alarm rates was constant, familiarity for medium-arousal photos varied across experiments). The correlation of valence and arousal (see Table 2) could suggest a reason for some of this variability. If negative items tend to be more, and neutral items less, arousing (with positive items falling somewhere in between), then moderately arousing items will encompass a more heterogeneous mixture of positive, neutral, and negative photos. Increased variety in the kinds of items that fall into the medium-arousal group could increase the variability in memory for them.

were more recollectable. These data are consistent with previous findings that arousing and valenced stimuli are recognized or recalled quite accurately (e.g., Cahill et al., 1995; Christianson, 1992; Loftus et al., 1987) but go beyond them by demonstrating that greater accuracy is due primarily to better recollection of them and suggests that accurate recognitions are accompanied by different kinds of experience for positive and negative stimuli.

Interestingly, across experiments, response criteria tended to be more liberal for positive and negative than for neutral items, and for high-arousal as opposed to low-arousal items, indicating that participants had a bias to judge that nonstudied items that were valenced or arousing had been seen previously. This pattern was present and significant for arousal in each experiment but was significant for valence only in Experiment 1. As shown in Tables 2, 5, and 7, this bias seems primarily to be due to an increase in know rather than remember false alarms. This intriguing pattern is discussed in more detail in the following section.

Independent Effects of Valence and Arousal

Because ratings of valence and arousal were significantly correlated (see Table 2), it is not clear how much the advantage in recollection and remembering shown for each type of item is due to the independent influence of one affective attribute or the other. Therefore, it is important to examine the effects of arousal or valence on memory when variation in the other dimension is held constant. Furthermore, the photographs in the IAPS differ widely in their content and vary in the amount of visual detail (e.g., some depict single objects, such as a lamp, and others complex scenes, such as a cityscape), and differences in memory for these details could confound the effects of emotion on memory (a fact seldom taken into account in other studies). To determine how much variation in visual information was present in each photo, participants in Experiment 1 also were asked to rate the visual complexity of each stimulus during the study session. These ratings, along with the ratings of valence and arousal, were used to select two sets of 30 pairs of stimuli each. One set differed only in terms of valence (all $ps < .001$) and was equated for mean level of arousal and visual complexity (all $ps > .24$). Stimuli in the second set differed only in terms of arousal[8] ($p < .001$) and were equated for mean levels of valence and visual complexity ($p > .40$). The mean ratings along each dimension for each set are shown in Table 9, and the mean proportions of *R* and K responses and process estimates for familiarity and recollection are shown for valence and arousal in Tables 1 and 2 of the Appendix.

The outcome of these analyses is that the effects of valence and arousal on memory hold even when variations in the other affective variable and in visual complexity are factored out. Across all three experiments, negative photos were recollected and remembered more often than neutral photos, all $ts(14) > 2.5$, all $ps < .05$, and although there were numerical trends toward a similar effect for positive photos, it was never significant. In addition, negative photos

Table 9
Mean Ratings of Separate Sets of Stimuli Selected to Differ Only in Terms of Valence or Arousal

	Dimension selected to differ				
	Valence			Arousal	
Stimulus type	Negative	Neutral	Positive	High	Low
Valence	2.52	4.05	5.41	4.16	4.14
Arousal	4.29	4.16	4.33	5.13	3.41
Complexity	3.81	3.47	3.56	3.43	3.33

consistently were recollected more often that positive ones, all $ts(14) > 2.5$, all $ps < .05$. The previously observed trade-off of R and K responses for negative and positive items also was significant in all groups, all $ts(14) > 2.5$, all $ps < .05$, indicating that negative items tended to be remembered and positive photos tended to be known. However, in no case did familiarity differ as a function of valence, which runs counter to the expected increase in familiarity for negative items. According to the dual-process independence model of Yonelinas et al. (1998), the relative decrease in K responses for negative photos suggests that a proportion of these photos were *familiar* and also were *recollectable* but, as dictated by the R/K procedure, were given only an R response.

Also in keeping with the results described earlier, high-arousal items were recollected and remembered more often than low-arousal items in all cases, all $ts(14) > 2.3$, $p < .05$, except Experiment 1. In this experiment, participants performed three encoding ratings on stimuli, and it is likely that low-arousal items differentially benefited from such deep encoding conditions. The fact that low-arousal items were recollected and remembered less well in all other experimental conditions that used only a single encoding rating supports this interpretation. Neither K responses nor estimates of familiarity, by contrast, differed significantly for high- and low-arousal items, which runs counter to the initial prediction that familiarity should increase as a function of arousal.

Comparing the patterns of response criteria across experiments, it was clear that response criteria were more liberal for affective stimuli in all cases except one: In Experiment 3 when participants judged the brightness of photos at study the effects of arousal and valence on response criteria were not significant. In fact, the pattern of response criteria as a function of valence was unlike that shown in the first two experiments, with a trend for criteria to be more conservative for negative rather than neutral stimuli. The brightness judgment did not ask participants to judge how they felt about or would act toward the objects depicted in each photo. This suggests that the lax response criteria for affective items found in other conditions was due, at least in part, to the fact that participants in those conditions had

[8] Because of the potential for increased variability in encoding for medium-arousal items (see Footnote 6) only high- and low-arousal photos were used in these comparisons.

Table 10
Effect Sizes (r) and Significance Values (p) for Impact of Valence and Arousal on Recollection and Familiarity

	Recollection						Familiarity					
	Negative		Positive		Arousal		Negative		Positive		Arousal	
Experiment	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Experiment 1	.82	<.001	.43	<.10	.74	<.001	.35	<.18	.26	<.34	.26	<.33
Experiment 2	.81	<.001	.48	<.06	.79	<.05	.37	<.16	.30	<.26	.22	<.42
Experiment 3	.84	<.001	.51	<.09	.85	<.001	.22	<.41	−.32	<.23	.33	<.23
Combined	.82	<.001	.48	<.01	.80	<.001	.31	<.11	.08	<.43	.26	<.26

Note. Effect size *r*s and associated *p* values are for comparisons of negative and positive items against neutral items and high- against low-arousal items.

thought about how they felt about stimuli at study. Attention to affect as a characteristic of study items may have made participants more likely to judge that any test item which elicited an affective response had been seen previously. In this way, participants may have attributed the fluency with which nonstudied affective stimuli were processed as an indicator of familiarity on the basis of prior experience with them (cf. Kelley & Jacoby, 1996). The degree of visual complexity in each stimulus also influenced the setting of response criteria: As discussed in the previous section, *C* was more liberal for affective stimuli in Experiment 3 when visual complexity was not factored out.

Magnitude of Impact of Affect on Recollection and Familiarity

Of the predicted effects of affect on the experience and process of recognition, only the impacts of negative valence and high arousal on recollection/remembering were consistently statistically significant. However, predicted increases in recollection for positive items, and in familiarity for all affective stimuli in general, often were present even though they did not achieve significance. As shown in Table 10, effect sizes were always large and highly significant for recollection of negative and highly arousing stimuli. In contrast, effect sizes were small or moderate and approached significance in a couple of cases for recollection of positive stimuli and only occasionally if at all for familiarity for all stimulus types. This suggests that these effects may be reliable, if somewhat small relative to the large effects of negative valence and arousal on recollection.[9] To increase power, meta-analytic procedures were used to pool effect size estimates and associated probabilities across the three experiments to provide a stronger test of the hypothesis that positive valence should boost recollection and both valence and arousal should boost familiarity (Rosenthal & Rosnow, 1991).

As shown in Table 10, after increasing power by pooling across experiments, recollection was significantly greater for both negative ($r = .82$, $p < .001$) and positive ($r = .48$, $p < .01$) photos than for neutral ones and was significantly greater for high- than low-arousal photos ($r = .80, p < .001$). In contrast, there was a marginal trend for familiarity to be greater for negative ($r = .31, p < .11$) photos, a smaller and nonsignificant trend for arousing photos ($r = .26, p < .26$), and no effect for positive photos ($r = .08$, $p < .43$). To determine whether these effects were influenced by the correlation between valence and arousal, or by variations in visual complexity, data for the sets of stimuli selected to differ only in terms of valence or arousal also were combined. As shown in Table 11, these combined analyses generally produced effect size estimates for the relationship of affect and recollection that were approximately 20–25% smaller, and they produced effect size estimates for the relationship of negative affect or arousal and familiarity that were 10–25% larger than those that were obtained in the prior analyses which did not correct for the effects of other variables. It is important that the effect sizes for the impact of negative valence increased enough to approach significance ($r = .40, p < .07$) and that the trend toward an effect of arousal became stronger as well ($r = .30, p < .14$). The magnitude of the relationship between positive affect and familiarity, which was very small to begin with, did not significantly change in magnitude although it changed in sign. Taken together, these results indicate that both negative affect and increases in arousal will boost recollection, and to a much lesser degree, familiarity. In contrast, positive affect selectively boosts recollection, albeit to a lesser extent than negative valence, and has no effect upon familiarity.

General Discussion

The departure point for this article was the hypothesis that affective events would be recollected and remembered more often than neutral events, that because they were more fluently processed they might be more familiar and hence

[9] Power analyses were conducted to determine how large a group would be needed to detect the smallest effect size for each comparison that was not significant but had demonstrated consistent trends toward significance. For the effect of positive valence on recollection the *r* was .43, and for the effects of negative or positive valence or arousal on *familiarity* the effects sizes were $r = .22$, .26, and .22, respectively. Results indicated that groups of approximately 30 to 50 participants would be necessary to these effects, which would require two to three times as many participants as were used in any single experiment. Pooling across studies thus provided a means of increasing power to a level at which effects of this size could be detected.

Table 11
Effect Sizes (r) and Significance Values (p) for Impact of Valence and Arousal on Recollection and Familiarity in the Selected Sets of Stimuli That Equate for Levels of Visual Complexity and Differ Only in Terms of Either Amount of Arousal or Kind of Valence

	Recollection						Familiarity					
	Negative		Positive		Arousal		Negative		Positive		Arousal	
Experiments	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Experiment 1	.69	<.01	.20	<.46	.32	<.23	.23	<.39	−.44	<.10	.26	<.34
Experiment 2	.59	<.01	.36	<.39	.64	<.01	.47	<.16	−.23	<.39	.32	<.23
Experiment 3	.67	<.01	.42	<.11	.57	<.05	.33	<.21	.30	<.27	.32	<.24
Combined	.65	<.001	.40	<.10	.52	<.001	.40	<.07	−.13	<.84	.30	<.14

Note. Effect size *r*s and associated *p* values are for comparisons of negative and positive items against neutral items and high- against low-arousal items.

would be more likely to be known, and that these effects would be most pronounced for negative and highly arousing stimuli. The data from three experiments suggest that most of these predictions were correct: Recollection and remembering were enhanced by negative affect, arousal, and to a lesser extent, positive affect. However, increases in familiarity were found only for negative affect and arousal, and these effects were marginal at best and only half as large as their effect on recollection. K responses showed the opposite pattern from familiarity, increasing for positive and decreasing for negative items; this is discussed more fully in the next section. It is important that the effects of valence and arousal occurred independently of one another and were not attributable to differences in the amount of visual detail present in the stimuli, which has not been demonstrated clearly in previous studies. These data are consistent with the idea that distinct states of remembering and knowing may be exclusive experientially, but the processes of recollection and familiarity that give rise to them may operate independently.

The presence of the recollection and familiarity advantages for affective stimuli even when participants did not explicitly evaluate the affective properties of the photos at study suggests strongly that such assessments are not necessary for encoding the information that leads one to recollect and richly remember them later on. This also suggests that the mechanisms which cause affective stimuli to be better recollected may not be substantially influenced by the way in which we initially think about them. However, the decision criteria used to judge whether an affective stimulus was seen previously might be so influenced. In these experiments, participants' criteria for judging an affective stimulus to be old were more liberal when participants had judged the affective properties of stimuli at study. This finding could have important implications for the debates about the capacity to falsely recognize emotional events that have never taken place (e.g., Loftus, 1993; Schacter, 1996b). It is possible that thinking about how we react to emotional events could make future events that evoke similar emotions seem more familiar.

The Relationship Between Recollective Experience and Recognition Processes

One striking finding was that negative stimuli tended to be remembered more often than positive stimuli, whereas positive stimuli tended be known more often than negative ones.[10] This occurred despite the relative insensitivity of familiarity to variations in affect. If K responses are thought to provide a direct readout of familiarity, as the exclusivity model of the R/K relationship has held, then this pattern would be somewhat confusing. However, the dual-process signal detection model of Yonelinas et al. (1998, for precursor see Jacoby et al., 1997) suggests a straightforward way to interpret this pattern: According to this model the proportion of K responses will underestimate how many items are familiar because items that are both more familiar and more recollectable can be given only an R response under the R/K procedure. The data indicate that there is a larger pool of such familiar and recollectable items that are negative as opposed to positive, which leads to conscious reports of knowing for negative items to decrease relative to such reports for positive items.

The R/K procedure is designed to tap into what seem to be qualitatively distinct states of subjective experience, and it is possible that when an item is recollected and generates a rich sense of remembering, the details which come to mind swamp the more diffuse and weak familiarity signals that might also be present. Thus, any time an item is both recollectable and familiar, the sense of remembering might dominate. In this way, the experiences of remembering and knowing might be mutually exclusive, whereas the processes of recollection and familiarity that underlie them are operationally independent. It is unlikely that the inability to

[10] The effect size for the K advantage of positive over negative photos was .58 in Experiment 1, .33 in Experiment 2, and .48 in Experiment 3. The nonsignificant effect in Experiment 2 could have been due to a lack of power (approximately 32 participants would have been needed to detect an effect of that magnitude), but the robustness of the effect in Experiments 1 and 3 (the effect could have been detected with approximately 10 and 15 participants, respectively) demonstrates the reliability of the effect.

detect the familiarity of an item in the presence of strong recollection has detrimental consequences because for most purposes when an item is recollectable it is unlikely that being able to judge it familiar would be of much additional use. The details that come to mind during recollection allow an individual to have the experience of richly remembering that an event took place and afford knowledge and control over behavior not possible if one simply knows that event took place on the basis of familiarity. As Gardiner and Java (1993, p. 177) stated, "Conscious recollection provides not only a basis for decision but also a mainspring for action and a foundation for social relationships."

Greater Recollection and Familiarity for Negative Than for Positive Stimuli

Given that a primary function of emotion is to guide action and social interaction (Lazarus, 1991), it might make sense for memory encoding mechanisms to have evolved a means for encoding and remembering the affective details from interactions that are most relevant to one's goals (Lazarus, 1991; LeDoux, 1996). Being able to reexperience a threatening, disgusting, or otherwise unpleasant event in its absence could offer a distinct advantage in planning for future such enounters (LeDoux, 1996). The fact that negatively valenced photos consistently led to more recollection/remembering than positively valenced ones is consistent with this notion. Indeed, the attention-capturing power of negative information belies the diagnostic power of this information for the survival of an organism (Ohman, 1988; Pratto & John, 1991). Encoding mechanisms may work more effectively for negative stimuli, enabling them to "pop out" at us, commanding attention to encode their significant properties and our reactions to them. Usually this enables details to return to us later for use as the "mainspring for action" (Gardiner & Java, 1993, p. 177), but even when details do not come back, negative stimuli are more familiar than positive ones, which may confer some advantage in detecting past threats more quickly.

But why would positive information be less likely to be recollected and remembered? It seems plausible that "positive" events like the pleasant families, bucolic landscapes, and delicious foods depicted in the photos used here do not contain the same kind of survival-relevant information conveyed by the guns, mutilated bodies, and threatening animals depicted in the negative photos.[11] A chocolate sundae might not predict happiness in quite the same way as a snake bite could determine unhappiness. However it very well might, depending on whether a particular positive stimulus is of equal importance to one's current goals as a particular negative stimulus. In fact, when positive and negative stimuli are equated for degree of relevance to one's current concerns they show equal amounts of Stroop interference (Riemann & McNally, 1995).

This suggests that a more general factor influencing remembering might be the personal significance of a stimulus, and not its absolute negativity, per se, which makes sense given that the kind and strength of affective reaction one has to a stimulus depends on the importance of that stimulus in the context of current goals and needs (e.g., Lazarus, 1991). The scenes depicted in the negative photos may, on average, have been more relevant to chronically important goals (e.g., to identify stimuli that threaten, elicit fear, or are disgusting) than were the positive stimuli. The relevance of positive photos to personal goals may have been more idiosyncratic, which consequently may have led them to be, on average, less distinctive and hence less recollectable. Conway and Dewhurst (1995) found that words rated as most self-relevant were remembered more often than were words rated as having less personal import, and in future experiments, researchers could relate the significance of stimuli to a person's current goals or needs independent of the valence or arousal of these items to determine what impact each has on memory.[12]

The Basis for Distinctive Encoding and Robust Recollection of Affective Stimuli

The recollection advantage for affective and arousing stimuli is consistent with the idea that affective stimuli are encoded more distinctively than neutral and nonarousing stimuli. Affective stimuli elicit physiological responses, activate semantic information, engage interpretive appraisal processes and elicit valenced subjective states not evoked by other stimuli, all of which can imbue memory representations of affective stimuli with relatively unique constellations of representational attributes (Ekman & Davidson, 1994; Lazarus, 1991). It is desirable to know which component or components of an emotional response led participants to encode more distinctively and remember/recollect affective stimuli more often. Unfortunately, because no independent means were used to assess the magnitude of different affective response components, the present experiments do not permit a direct answer to this question. However, it is known that in addition to being reliably

[11] Another interpretation of better remembering for negative photos is that positive photos were less strongly positive than the negative photos were negative and so were remembered less often. This argument seems unlikely for at least two reasons. First, ratings of valence for positive and negative photos were equivalently different from the mean valence ratings given to neutral items (t values for each comparison < 1). And second, if positive photos were less strongly valenced than were negative photos, overall recognition accuracy for positive photos should have been less than that for negative ones, as was the case for neutral photos which always were recognized least accurately. But this was not the case: Overall recognition rates for positive and negative photos were often equivalent, even though the proportion of underlying R and K responses differed.

[12] These present studies also relied on a particular dimensional conceptualization of affect, which some have argued may gloss over important qualitative differences between discrete emotional states, each of which involve the appraisal of specific kinds of person–goal relationships (see Ekman & Davidson, 1994, for discussion). In the future, it could be valuable to study the nature of recollective experience for stimuli that elicit different emotion-specific appraisals to reveal ties between what information is most relevant for a particular kind of affective appraisal and how it is reexperienced later on (Lazarus, 1991; Levine, 1997).

classifiable in terms of kind and degree of affect (e.g., Lang et al., 1993), the photos used in the present experiments elicit physiological changes involved in emotion, such as increases in skin conductance, heart rate, and muscle activity (e.g., Bradley et al., 1992; Lang et al., 1993). Furthermore, viewing negative photos like those used here activates the amygdala, even when participants cannot consciously perceive them (Whalen et al., 1998), and amygdala activity has been shown to directly mediate the memory enhancement for stimuli like those used here (Cahill et al., 1995).

It could be argued that it is not the unique affective value of the arousing and valenced photos that makes them more distinctive but rather some other property that they might share with nonaffective stimuli that was not strongly present in the neutral stimuli used in the present experiment. For example, it could be argued that affective stimuli are more unusual, more interesting, more novel, or less expected, and that one or more of these attributes make stimuli more distinctive and hence more recollectable (cf. Pickel, 1998; Wollen, Weber, & Lowry, 1971).

This problem is not uncommon and it is always difficult to know whether the variables one has measured are causally related to an observed effect. In some cases, it is not clear whether additional measures would tap into unique sources of variance. Indeed, it is very likely that interesting photos will also be rated as more emotional, and that ratings of interestingness and other variables would tap into the same underlying attributes that lead one to judge a stimulus as emotional and respond accordingly. In other cases, measures such as bizarreness or unusualness may tap into a source of variance orthogonal to that tapped by judgments of affect. Some recent imaging work has shown that different neural systems are activated by arousing and emotionally meaningful as opposed to bizarre but emotionally meaningless photos that were highly distinctive (e.g., a fluorescent rhinoceros). Hamann, Ely, Grafton, and Kilts (1999) found that the amygdala activity during encoding was correlated with memory for both positive and negative emotional photos, whereas amygdala activity was not correlated with memory for the bizarre images. This suggests that emotional and bizarre photos may be distinctive and remembered well for different reasons. The message is that there are many reasons a stimulus could be well recollected but on the present view it is the emotional meaning of the photos, however imperfectly assessed by the ratings used here, that made them more distinctive and more recollectable.[13]

Implications for Other Findings and Memory Phenomena

The present results are consistent with previous studies that have found that increases in either valence or arousal tend to enhance the accuracy of memory. However, they go beyond previous findings by demonstrating that it is the ability to recollect affective stimuli that makes memory more accurate for them. Furthermore, they demonstrate that the experience of recognizing positive and negative stimuli is quite different because familiarity and recollection contribute differently to this experience for each type of stimulus. The fact that in these studies valence differentially influenced recognition accuracy, recollection/remembering, knowing, and familiarity suggests a number of reasons why previous studies may have failed to find a relationship between valence and memory. First and foremost is the failure to use measures of the subjective experience of memory. In these experiments the sense of remembering dominated recollection for negative items, whereas the sense of knowing dominated recollection of positive items, even though recognition accuracy was often comparable and not significantly different. Previous studies, some of which used the same stimuli used here (Bradley et al., 1992), may have failed to detect valence differences because they used only overall measures of recall or recognition accuracy that were not sensitive to the primarily qualitative effects of valence on memory.

Second, the impact of valence on recollection and remembering was larger and more consistent than its effect on recognition, which suggests that it is more difficult to detect valence-driven differences in accuracy than it is to detect differences in recollective experience or the processes which underlie it. Third, some previous failures to find effects of valence on memory have used recall rather than recognition tests (e.g., Reisberg et al., 1988; Thomas & Diener, 1990). Recall tests either may not present retrieval cues strong enough to elicit differences in phenomenal experience between negative and positive items or they may not use measures (e.g., rating vividness) that are sensitive enough to detect differences in this experience. In addition, recall tests may involve strategic retrieval processes different from those studied here, and those processes may be subject to different influence by valence or arousal. Fourth, if field studies and laboratory tasks do not carefully measure valence and arousal at encoding, then it cannot be determined whether differences (or the lack thereof) in memory for positive and negative events are due to differences in arousal.[14] Finally, if another factor such as the immediate personal significance of stimuli mediates the effects of valence, then whenever stimuli are equally relevant to one's

[13] Another reason affective events might be distinctive is because they occur less often in everyday life, but that is not the case in the present studies because affective photos were presented just as often as neutral ones, with equal frequency in the early, middle, and latter portions of the study and test lists. Also, contrasts verified that the recollection advantage for affective stimuli was of the same magnitude for stimuli that had been presented in the first, middle, and final thirds of the study list (p for both comparisons $> .40$). Also, arguing against an account of the present findings in terms of the contextual uniqueness or "surprisingness" of affective stimuli are the results of a pilot study ($n = 8$) in which negative, neutral, and positive stimuli were blocked into groups of 10 each during the study list. The impact of valence and arousal on recollection and remembering was essentially identical to that reported here.

[14] In studies of autobiographical memory for emotional events it may be impossible to assess how one may have rated the valence and arousal of an event when it happened some time in the past. For this reason, retrospective reports of how valenced and arousing an event was at the time of its occurrence are often collected. A problem with such reports, however, is that aspects of the current retrieval environment can bias memory for the past (Levine, 1997; Ochsner & Schacter, in press; Ochsner, Schacter, & Edwards, 1997).

current goals no differences in memory will be found. Future research may serve to test this notion but for the time being the message is that simple measures of performance accuracy do not tell the whole story of how emotion can influence memory.

The finding that negative affect and arousal affected familiarity to a much lesser degree than they affected recollection may be related to failures to consistently find enhancements of implicit memory for emotional disorder-relevant information in psychiatric populations (or their controls, see McNally, 1998 for review). Both the conscious sense of familiarity and nonconscious or implicit effects of memory for past events have been thought to depend upon the fluency with which stimuli are processed (Kelley & Jacoby, 1996), although it now appears that the neural systems supporting perceptually driven implicit memory and familiarity are different (Wagner, Stebbins, Masciari, Fleischman, & Gabrieli, 1998). It is possible that for both systems affect enhances the processing of nonstudied stimuli so much that studying an affective word or picture in the context of a laboratory experiment does not boost fluency very much above this already elevated baseline. If this is the case, then it could be difficult to discriminate the sense of fluency-based familiarity generated by affective stimuli that have been studied from the highly similar signals generated by stimuli that are new, thereby reducing the magnitude of Fd' in the present experiments. Furthermore, fluent processing of nonstudied affective stimuli also could make it difficult to detect affect-related performance biases on implicit tests of memory. It is important to note, however, that study of affective stimuli does increase the distinctiveness of the item in memory, thereby enhancing recollection and remembering. Fluent processing of affective stimuli at study likely contributes to this effect.

Finally, it could be interesting to apply the present studies to understanding the kinds of debilitating experiential recollection shown by patients with emotional disorders that provided some of the initial impetus for this research. For example, the R/K procedure could be used to determine the relationship between either recollection or familiarity of disorder-related images and the severity of clinical symptoms. In this way, the tendency to recollect disorder-relevant information could be used as an index of symptom severity and a model of intrusive imagery, just as the emotional Stroop has been used both as a measure of treatment efficacy and a model of intrusive thought (Williams et al., 1996).

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Appendix

Memory Performance for Stimulus Sets Equated for Differences in Valence or Arousal

Table A1
Measures of Memory Performance in All Experiments for a Set of Stimuli Selected to Vary Only in Terms of Valence, and Equated for Level of Arousal and Amount of Visual Complexity

Experiment and photo type	Remember		Know				Recognition	
	Hits	FAs	Hits	FAs	Rec	*Fd'*	*d'*	*C*
Experiment 1								
Negative	.58	.02	.27	.07	0.57	1.82	2.68	0.12
Neutral	.40	.01	.34	.06	0.40	1.73	2.34	0.41
Positive	.42	.04	.30	.14	0.41	1.19	1.76	0.22
Experiment 2								
Negative	.40	.04	.31	.07	0.37	1.67	1.95	0.38
Neutral	.30	.04	.32	.09	0.27	1.32	1.54	0.46
Positive	.34	.03	.34	.12	0.32	1.38	1.78	0.35
Experiment 3								
Negative	.48	.04	.26	.08	0.46	1.67	1.98	0.25
Neutral	.34	.04	.39	.13	0.31	1.45	1.68	0.19
Positive	.39	.02	.36	.15	0.38	1.61	1.94	0.12

Note. FAs = false alarms; Rec = recollection based on remember hits and FAs; *Fd'* = familiarity based on know hits and FAs, estimated according to Yonelinas et al. (1998); *d'* and *C* are measures of accuracy and bias from signal detection theory (Snodgrass & Corwin, 1996).

Table A2
Measures of Memory Performance in All Experiments for a Set of Stimuli Selected to Vary Only in Terms of Arousal, and Equated for Valence and Amount of Visual Complexity

Experiment and arousal	Remember		Know				Recognition	
	Hits	FAs	Hits	FAs	Rec	*Fd'*	*d'*	*C*
Experiment 1								
High	.41	.40	.03	.14	0.39	1.79	2.03	0.06
Low	.37	.35	.02	.10	0.36	1.68	1.97	0.31
Experiment 2								
High	.44	.30	.05	.11	0.41	1.29	1.80	0.17
Low	.28	.30	.03	.09	0.27	1.02	1.47	0.54
Experiment 3								
High	.43	.35	.03	.14	0.42	1.67	2.06	0.14
Low	.33	.37	.01	.14	0.32	1.48	1.78	0.24

Note. FAs = false alarms; Rec = recollection based on remember hits and FAs; *Fd'* = familiarity based on know hits and FAs, estimated according to Yonelinas et al. (1998); *d'* and *C* are measures of accuracy and bias from signal detection theory (Snodgrass & Corwin, 1996).

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