Aging and recognition memory for emotional words: A bias account

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The present study investigated age-related differences in the locus of the emotional enhancement effect in recognition memory. Younger and older adults studied an emotion-heterogeneous list followed by a forced choice recognition memory test. Luce's (1963) similarity choice model was used to assess whether emotional valence impacts memory sensitivity or response bias. Results revealed that the emotional enhancement effect in both age groups was due to a more liberal response bias for emotional words. However, the pattern of bias differed, with younger adults more willing to classify negative words as *old* and older adults more willing to classify positive words as *old*. The results challenge the conclusion that emotional words are more memorable than neutral words.

Emotionally evocative stimuli (e.g., events, images, faces, words) are processed differently than neutral stimuli (see Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001). Our focus herein is the effect of emotional valence on memory and, in particular, age-related differences in this valence effect. Researchers have previously shown that younger and older adults perform better in memory tasks to emotionally evocative stimuli than to neutral ones (e.g., Kensinger & Corkin, 2003; Murphy & Isaacowitz, 2008). Even so, there are age-related differences. Younger adults perform better on negative stimuli than on positive ones, whereas the reverse holds for older adults (e.g., Charles, Mather, & Carstensen, 2003).

Although better performance on memory tasks to emotionally evocative words would seemingly indicate better memory for these stimuli, this conclusion is not necessarily warranted. This pattern may reflect superior memory for emotionally evocative stimuli, or alternatively, it may simply reflect response biases favoring these items (Dougal & Rotello, 2007; Grider & Malmberg, 2008; Windmann & Kutas, 2001). These response biases can conceivably arise from several different mechanisms, such as the propensity to guess that the emotionally evocative probe was indeed studied when one is unsure or a lowered criterion setting on the evidence needed to classify an emotionally evocative probe as studied.

One conventional approach to separating bias effects from mnemonic sensitivity is to apply the theory of signal detection (Green & Swets, 1966) to old/new recognition memory judgments. Dougal and Rotello (2007) and

Grider and Malmberg (2008) are both examples of this approach. Unfortunately, they reached diverging conclusions. Dougal and Rotello found a response bias effect favoring emotional words. In two different experiments, they found no mnemonic effects in one and a mnemonic effect that favored neutral items over emotional ones in another. Grider and Malmberg found the same response bias effect but, in addition, found mnemonic enhancement for emotional over neutral items. Grider and Malmberg attributed the divergent findings to differences in analysis. Dougal and Rotello used an equal-variance signal detection model to analyze the data, whereas Grider and Malmberg used an unequal-variance version. The fact that subtle differences in modeling can lead to substantially different conclusions serves as a substantial drawback to the old/new judgments.

A better paradigm for separating sensitivity and response bias effects is Zeelenberg, Wagenmakers, and Rotteveel's (2006) forced choice paradigm. Zeelenberg et al. examined whether emotionally evocative words are better identified than neutral words, and if so, whether this gain reflects enhanced perceptual processing or a response bias. Participants viewed a briefly flashed target that was subsequently backward masked. Then they were presented two words, and their task was to identify the word that matched the target. One of the alternatives was always the target; the other was a lure. Zeelenberg et al. factorially manipulated the valence of targets and lures.

Table 1 illustrates why this paradigm is well suited for assessing sensitivity and response bias effects. Rows and

Table 1
Characteristic Data Patterns

Lure Valence	Target Valence			Average
	Negative	Positive	Neutral	
A. Response Bias Effects				
Negative	M	L	L	L
Positive	H	M	L	M
Neutral	H	H	M	H
Average	H	M	L	
B. Sensitivity Effects				
Negative	H	M	L	M
Positive	H	M	L	M
Neutral	H	M	L	M
Average	H	M	L	
C. Emotional Mirror Effects				
Negative	H	H	M	H
Positive	H	M	L	M
Neutral	M	L	L	L
Average	H	M	L	

columns correspond to the valence of the lures and targets, respectively. Cell entries indicate whether performance is high (H), medium (M), or low (L). The orderings of sample data in Tables 1A–1C are meant for illustration purposes only and are not meant to endorse specific predictions. Table 1A shows an example of a response bias effect, and in this example, the bias is greatest for negative items, followed in turn by positive and neutral ones. If the effect is due to response bias, this ordering is apparent in the marginal average across target valences (see the rightmost column). The response bias account also predicts a reverse ordering for the marginal average lure valences (see the reverse ordering for the bottom row and the rightmost column). It is this reversal of orderings that is characteristic of a response bias effect. Another characteristic is that there is no effect on the diagonal, a fact used by Grider and Malmberg (2008), as will be discussed subsequently.

Table 1B shows an example of sensitivity effects; in this example, participants best remember negative items, followed in turn by positive and neutral ones. This ordering is apparent in the marginal average across lure valences (see the bottom row). Moreover, this account predicts no effects in the marginal averages across target valence (see the rightmost column). Table 1C shows a different example of sensitivity effects. The ordering is the same, but in this example, there is a mirror effect (Glanzer & Adams, 1990). Negative items are not only remembered best when studied; they are also not chosen when serving as lures. The key characteristic of sensitivity effects is that the orderings on row and column margins do not reverse. Either the orderings are the same (Table 1C) or the marginal ordering averaged across target valences is not ordered (Table 1B). Overall, although response bias and sensitivity cannot be disentangled by considering the effect of valence on the target or the lure in isolation, they can be disentangled by assessing the pattern across the factorial table of results.

Zeelenberg et al. (2006) observed a pattern similar to the one portrayed in Table 1B, which led directly to the conclusion that emotional valence facilitates perceptual processing by influencing sensitivity rather than response bias. Grider and Malmberg (2008) used a restricted version of the Zeelenberg et al. forced choice paradigm to supplement their findings in the yes–no recognition paradigm. Specifically, they used the three diagonal cells in Table 1A, in which the target and the lure had the same valence. They reasoned that any differences along the diagonal could not be due to response bias and must, therefore, be due to sensitivity. Grider and Malmberg found modest effects (accuracies of .76, .79, and .80 for neutral, negative, and positive words, respectively). Because they had a relatively large sample of 80 participants for such a simple design, these modest effects provided p values just below the .05 criterion [$t(79) \approx 2.15$, $p \approx .02$]. We note that inference by p values is most suspect when the p values are not much smaller than the significance level and the sample size is large (see Selke, Bayarri, & Berger, 2001; Wagenmakers, 2007). Roudier, Speckman, Sun, Morey, and Iverson (2009) computed a Bayes factor for Grider and Malmberg's tests and found about equal support for the null of no effect and an alternative of a reasonably sized effect.

We performed an experiment similar to that in Grider and Malmberg (2008), although we collected data from all nine cells in Table 1 to provide a more full view of both response bias and sensitivity effects. To formally decompose these effects, we developed a variant of Luce's (1963) similarity choice model (SCM). The SCM has been successfully applied in a wide range of domains, including categorization (Nosofsky, 1986), letter recognition (Roudier, 2001), and, most recently, gender differences in decoding sexual intent (Farris, Treat, Viken, & McFall, 2008).

The model is as follows: Let A_i denote the activation of a target at the i th valence level (i = negative, neutral, positive) and B_j denote the activation of the lure at the j th valence level (j = negative, neutral, positive). The probability of choosing a target at the i th valence level over a lure at the j th valence level is

$$p_{ij} = \frac{A_i}{A_i + B_j}.$$

Target activation is given as $A_i = d_i c_i$, where d_i and c_i denote sensitivity and response bias, respectively, for the i th valence level.¹ Lure activation is given as $B_j = c_j$. Substituting yields

$$p_{ij} = \frac{d_i c_i}{d_i c_i + c_j}. \quad (1)$$

The value of p_{ij} is invariant to multiplying all response bias parameters by a scaling factor. Hence, we set $c_{\text{positive}} = 1$ to gain identifiability. The status of d as the sensitivity parameter may be seen by setting $c = 1$ for all valence levels (a setting with no bias toward either alternative). The resulting value of p_{ij} is a function only of d_i and increases with it. Likewise, the status of c as the

response bias parameter may be seen by setting $d = 1$ for all valence levels. With $d = 1$, targets and lures are equally memorable. In this case,

$$p_{ij} = \frac{c_i}{c_i + c_j},$$

the probabilities are the relative amount of response bias for an alternative. The model in Equation 1 is inconsistent with Table 1C, in which there is an emotional mirror effect. We constructed an alternative SCM model that accounts for such mirror effects.² The analysis of the data with the alternative mirror effects model in note 2 is highly similar to that with Equation 1 and is omitted for brevity.

METHOD

Participants

Thirty younger (age range, 18–22 years; $M = 19.86$, $SD = 1.07$) and 30 older (age range, 60–76 years; $M = 67.74$, $SD = 4.99$) adults participated in this experiment. The younger adults were traditional-aged college students, and the older adults were recruited from advertisements placed in local newspapers. Older adults were carefully screened to exclude those with a history of neuropsychological or psychiatric disorders or other serious chronic illness.

Materials and Design

The stimuli were 40 neutral (mean valence = 5.71, $SD = 0.75$; mean arousal = 4.10, $SD = 0.67$), 30 negative (mean valence = 2.45, $SD = 0.60$; mean arousal = 5.87, $SD = 0.94$), and 30 positive (mean valence = 7.84, $SD = 0.54$; mean arousal = 5.96, $SD = 0.96$) words selected from Bradley and Lang's (1999) Affective Norms for English Words (ANEW) set. Positive and negative words were matched on emotional arousal, but they were more arousing than neutral words. The words were matched for frequency. Ten of the neutral words were randomly selected to serve as buffer words and occupied the first and last five positions of the study list. The remaining words were randomly divided into two lists of 45 (15 neutral, 15 negative, and 15 positive) words. Next, the valences of the targets and foils were manipulated independently, resulting in a design with nine conditions, each with five trials. The study list consisted of 45 target words (15 positive, 15 negative, and 15 neutral) that were preceded and followed by 5 buffer words. The status of the test words (target or lure) was counterbalanced across participants. The experiment was based on a $2 \times 3 \times 3$ mixed factor design. The between-subjects variable was age group (younger or older), and the within-subjects variables were target type (neutral, negative, and positive) and lure type (neutral, negative, and positive). The dependent variable was the proportion of correct responses in each condition.

Procedure

The participants were instructed to learn the list of study words for an unspecified memory test. The study words were presented one at a time for 1.5 sec, separated by a blank screen for 500 msec. The two-alternative forced choice recognition memory test, which immediately followed the study phase, consisted of word pairs displayed side by side, with target and lure items distributed evenly between left and right choices. The participants pressed the "z" key to indicate that the left-hand word had appeared on the study list and the "m" key to indicate that the right-hand word had appeared on the study list. Each recognition trial began with a blank screen for 500 msec, followed by the recognition probe, which remained on the screen until the participants responded.

RESULTS

Table 2 shows the resulting accuracy as a function of target valence, lure valence, and age group. In presenting

Table 2
Mean Accuracy As a Function of Age and Emotional Valence of Targets and Lures

Lure Valence	Target Valence			Average
	Negative	Positive	Neutral	
Younger Adults				
Negative	.87 (.87)	.81 (.83)	.78 (.77)	.82
Positive	.91 (.90)	.85 (.87)	.81 (.82)	.86
Neutral	.90 (.93)	.94 (.91)	.87 (.87)	.90
Average	.89	.87	.82	
Lure Valence	Target Valence			Average
	Positive	Negative	Neutral	
Older Adults				
Positive	.81 (.83)	.79 (.78)	.71 (.72)	.77
Negative	.86 (.87)	.75 (.83)	.81 (.78)	.81
Neutral	.91 (.90)	.88 (.87)	.85 (.83)	.88
Average	.86	.81	.79	

Note—Values in parentheses are predictions from a constant-sensitivity similarity choice model.

the results for the two age groups, we permuted the order of the rows and columns in Table 2 so that the column orders go from high to low (see the bottom row). An inspection of Table 2 reveals that the pattern displayed is more similar to the response bias pattern displayed in Table 1A than to the sensitivity patterns in Table 1B or Table 1C. Emotional valence influences younger and older adults' memory performance by influencing response bias, with younger adults displaying a more liberal response bias for negative words and older adults displaying a more liberal response bias for positive words. We performed inferential tests within the context of the SCM analysis.

The SCM was fit as follows: Let S_{ij} and N_{ij} denote the number of successes and the number of trials for the i th target and j th lure valence condition, respectively. The number of successes is modeled conventionally as a binomial:

$$S_{ij} \sim \text{Binomial}(p_{ij}, N_{ij}). \quad (2)$$

Equation 2 is a vacuous model, since there is a separate probability parameter for each cell. It is useful as a general model for testing the constraints implied by the SCM. The SCM is obtained by substituting values of p_{ij} from Equation 1 into Equation 2:

$$S_{ij} \sim \text{Binomial}\left(\frac{d_i c_i}{d_i c_i + c_j}, N_{ij}\right). \quad (3)$$

The model in Equation 3 has five free parameters: a sensitivity parameter for each valence level and response bias parameters for negative and neutral items (recall that the response bias for positive items is set to $c_{\text{positive}} = 1$). The model was fit to the data by finding the parameters that maximize the likelihood of the observed data (Hogg & Craig, 1978). The model in Equation 3 is properly nested within the model in Equation 2 and, therefore, may be tested with a likelihood ratio test (Bishop, Fineberg, & Holland, 1975). This test reveals that for both younger and older adults, the SCM in Equation 3 fits well [younger adults, $G^2(4) = 4.93$, $p \approx .29$; older adults, $G^2(4) = 4.54$,

$p \approx .34$]. Consequently, we may interpret the SCM sensitivity and bias parameter estimates with confidence.

SCM parameter estimates are shown in Figure 1. Error bars denote 95% confidence intervals and are derived from the Hessian evaluated at the maximum likelihood estimates (Hogg & Craig, 1978). For the younger adults (shaded bars), the results are clear. There is a minimal effect of valence on sensitivity and a large effect on response bias. The sensitivity effect is tested by constructing a submodel in which sensitivity is constrained to be constant across valence level. Likewise, response bias is tested by constructing a submodel in which response bias is constrained to be constant across valence levels. For younger adults, the constant sensitivity model cannot be rejected [$G^2(2) = 0.13, p \approx .94$] while the constant response bias model can be rejected [$G^2(2) = 13.2, p < .0005$]. Bias is greatest for negative materials and least for neutral ones. Predictions of the constant sensitivity model are shown in parentheses in Table 2.

The results are similar, although not as pronounced, for older adults. There is a nonsignificant trend of sensitivity effects [$G^2(2) = 3.59, p \approx .17$], with least sensitivity to negative items and greatest sensitivity to neutral ones. Although the sensitivity effect is not reliable, the response bias effect is [$G^2(2) = 19.8, p \approx .0001$]. Bias is greatest for positive materials and least for neutral ones.

The overall pattern is that emotionally charged words affect a response bias locus, rather than a sensitivity one, and this pattern holds for younger and older adults. What differs across the age groups is the nature of this bias. Although both groups have a tendency to choose emotionally evocative items over neutral ones, they differ in their bias toward positive and negative words. Younger adults have a bias toward negative words over positive words; older adults exhibit the reverse bias. Because the positive-item bias is set to 1.0, the statistical significance of this effect may be assessed by inspection of the confidence intervals (error bars) for the negative-item bias parameters.

The model analyses reported above are based on data aggregated across participants and items. This aggregation was necessitated by the relatively small numbers of items used per target-by-distractor-valence condition. This design choice was made to ensure reasonable levels of performance for older adults. Although necessary in this context, aggregation has substantial drawbacks, including inflation of Type I error rates above nominal values (Clark, 1973; Rouder & Lu, 2005). For our purposes, aggregation implies that the p values are artifactually too small; they overstate the evidence against the null hypotheses. We ran simulations to assess the amount of Type I error inflation in the SCM. Data for each of 30 hypothetical participants were generated from the SCM. "True" pa-

Figure 1. Estimates of sensitivity and response bias for each stimulus type and both age groups.

parameter settings varied greatly across participants; thus, particularly troublesome scenarios were simulated. The true Type I error rate was much higher than the nominal rate, often as high as .3 for a .05 nominal rate. These high Type I error rates indicate that p values much lower than .05 are needed to ensure a true Type I error rate of .05. In our simulations, this value is .002; that is, for the sample sizes in the reported experiment, we can be confident that the true Type I error rate does not exceed .05 when the p value does not exceed .002. Fortunately, all significance tests reported above correspond to p values less than .002. Hence, the probability that our response bias effects were due to Type I errors seems no larger than a conventional .05 level.

DISCUSSION

The empirical data patterns and the SCM analysis yield a similar story: The locus of the emotional enhancement effect in both younger and older adults was due to a more liberal response bias for emotional words. These results are, by and large, consistent with Dougal and Rotello (2007) and somewhat discordant with Grider and Malmberg (2008). Moreover, the pattern of bias differed across age groups, with younger adults more willing to classify negative words as old (a negativity bias) and older adults more willing to classify positive words as old (a positivity bias). This differential bias effect is consistent with Carstensen's socioemotional selectivity theory, which states that as people get older, they seek information that promotes emotional well-being (Carstensen & Mikels, 2005). This study shows that age differences in recognition memory for emotional words may simply reflect age-related shifts in processing biases for emotional information.

The obtained bias effects in recognition memory contrast with Zeelenberg et al.'s (2006) sensitivity effect in perceptual processing. The discrepancy between Zeelenberg et al.'s results and our results can be reconciled in light of a growing body of research in recognition memory that indicates that items that are processed more fluently are more likely to be judged *old* (e.g., Whittlesea, Jacoby, & Girard, 1990). Specifically, we posit that emotional items are processed more fluently by the perceptual system and this fluent processing, in turn, is interpreted as a cue of prior occurrence. Moreover, the interpretation of perceptual fluency as a cue to recognition is subjective and depends on participants' expectations and motivational goals (e.g., Westerman, Lloyd, & Miller, 2002). In addition, research investigating the effects of emotion on attention indicates that younger adults attend more to negative stimuli than to positive stimuli, whereas older adults show the opposite pattern (Thomas & Hasher, 2006). In the context of the present study, it may be that during a memory test, younger adults are drawn to negative stimuli, whereas older adults are drawn to positive stimuli. This difference results in a heightened sense of fluency, which is subsequently misattributed to familiarity, resulting in the subjective experience of remembering.

Finally, a possible limitation of our findings lies in our choice of stimulus materials. The word lists were constructed so that semantic relatedness and arousal were not equated across valence class; that is, the emotional words were more arousing and may have been more related to each other than were the neutral words. Studies investigating the effects of these variables have yielded inconsistent results, with some showing an attenuation of emotional effects and others not (see Dougal & Rotello, 2007; Grider & Malmberg, 2008; Talmi & Moscovitch, 2004; Windmann & Kutas, 2001). Additional research is needed to clarify the interaction of these variables, bias, and valence on memory performance.

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NOTES

1. An alternative derivation for Equation 1 is as follows. Let S_{ij} be the similarity of alternative with valence j to the memory of an item with valence i . SCM is given as

$$p_{ij} = \frac{S_{ij}c_i}{S_{ij}c_i + S_{ij}c_j}.$$

It is conventional to set $S_{ii} = 1$. Letting $d_{ij} = 1/S_{ij}$ be the sensitivity of the memory, the SCM model can be expressed as

$$p_{ij} = \frac{d_{ij}c_i}{d_{ij}c_i + c_j}.$$

The model in Equation 1 results if d_{ij} is a function of study only—that is, $d_i = d_{ij}$. In this formulation, the only effect of valence on lures is in response bias, c_j .

2. A model to account for this mirror effect is

$$p_{ij} = \frac{d_i c_i}{d_i c_i + \frac{c_j}{d_j}}.$$

In this model, the activity of the lure is scaled by sensitivity. Hence, if valence corresponds to high activity when an item is remembered, it will have low activity when the item serves as the lure.

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