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Brief article

Emotion and memory: A recognition advantage for positive and negative words independent of arousal

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ABSTRACT

Much evidence indicates that emotion enhances memory, but the precise effects of the two primary factors of arousal and valence remain at issue. Moreover, the current knowledge of emotional memory enhancement is based mostly on small samples of extremely emotive stimuli presented in unnaturally high proportions without adequate affective, lexical, and semantic controls. To investigate how emotion affects memory under conditions of natural variation, we tested whether arousal and valence predicted recognition memory for over 2500 words that were not sampled for their emotionality, and we controlled a large variety of lexical and semantic factors. Both negative and positive stimuli were remembered better than neutral stimuli, whether arousing or calming. Arousal failed to predict recognition memory, either independently or interactively with valence. Results support models that posit a facilitative role of valence in memory. This study also highlights the importance of stimulus controls and experimental designs in research on emotional memory.

1. Introduction

Among the oldest psychological intuitions is that emotion enhances memory (James, 1890), and indeed much evidence now supports this hypothesis (Buchanan, 2007; Kensinger, 2009; Mather, 2007). Emotion influences memory at multiple levels, from perceptual recognition and identification (Estes & Adelman, 2008a; Zeelenberg, Wagenmakers, & Rotteveel, 2006) to explicit recognition and recall of emotional stimuli and their perceptual properties (Doerksen & Shimamura, 2001; Kensinger & Corkin, 2003). Two basic dimensions of emotion are arousal and valence: Arousal describes how exciting ("sex") or calming ("sleep") a stimulus is, whereas valence describes how positive ("smile") or negative ("frown") it is. Our understanding of how emotion enhances memory relies on the currently disputed effects of these factors.

Current theories largely attribute emotional memory enhancement to arousal. The underlying assumption is that our limited memorial resources are preferentially allocated to behaviorally significant stimuli (Nairne, 2010), with arousal acting as a primary index of behavioral significance (McGaugh, 2000). In contrast, valence is hypothesized to exert a lesser influence on memory, if any at all. For instance, some researchers attribute the emotional memory enhancement entirely to arousal (Hamann, 2001; Mather, 2007; Phelps, 2006), with valence having little or no influence independent of arousal (Mather & Sutherland, 2009). By this account, memory can be enhanced for both negative and positive stimuli, provided they are sufficiently arousing. Others similarly emphasize the role of arousal in emotional memory, but additionally propose that valence can facilitate memory only in the absence of arousal (Kensinger & Corkin, 2003, 2004; LaBar & Cabeza, 2006), or that valence influences memory for perceptual details of the stimulus (Kensinger, 2009; Kensinger & Schacter, 2006, 2008).

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1.1. Limitations of prior research

Thus, there is consensus that emotion facilitates memory, but current theories are based on experimental research that has several limitations:

(i) Most prior experiments examine few stimuli per condition, and include analyses by participants but not by items, thus providing limited evidence of generality across stimuli.
(ii) Most prior experiments include only extreme cases of valence and/or arousal. This overlooks the atypicality of extreme stimuli and the potential influence of extremity.
(iii) Many prior experiments compare neutral stimuli to either negative or positive stimuli, but not both, and results with a given valence (e.g., negativity) are often overgeneralized to the other valence (e.g., positivity) without testing this assumed generality.
(iv) Most prior experiments include a high proportion of emotional stimuli (typically 50% or 67%), which are relatively rare in natural language (see Whissell, 2009). Such high proportions of emotional stimuli induce participants to attend to emotion more than they would ordinarily (Everaert, Spruyt, & De Houwer, 2011). And critically, when participants attend to emotion, their memory for emotional stimuli improves (Greenberg, Tokarev, & Estes, 2012). Thus, the typical experiment with an unnaturally high proportion of emotional stimuli inadvertently renders emotional factors more likely to exert effects.
(v) Many prior experiments confound valence and arousal, because neutral stimuli tend to be less arousing than negative and positive stimuli. Thus neutral stimuli often differ from negative and positive stimuli in both valence and arousal. It is unclear whether results from such studies are due to arousal, valence, or both (Mather & Sutherland, 2009).
(vi) Few prior experiments controlled important lexical and semantic variables such as word length, word frequency, and imageability, which are known to influence recognition memory (Cortese, Khanna, & Hacker, 2010). Emotional memory effects may be partially or wholly attributable to such non-emotional factors.

Thus, the current knowledge of emotional memory enhancement is based mostly on small samples of extremely emotive stimuli presented in unnaturally high proportions without adequate affective, lexical, and semantic controls. Although some studies avoid some of these limitations, to our knowledge, no prior study avoids all of these limitations. By addressing these limitations, the present study was designed to provide clearer evidence regarding emotional memory enhancement.

1.2. Current research

We merged recognition memory scores for over 2500 words (Cortese et al., 2010) with emotionality ratings for the same words (Adelman, Marquis, Sabatos-DeVito, & Estes, 2013), and tested whether arousal and/or valence predicted recognition memory while controlling a large variety of lexical and semantic factors. This stimulus sample is substantially larger than prior experiments on emotional memory, and rather than only including extreme cases, it spans the full ranges of arousal and valence, as they naturally occur in a sample unselected for emotional characteristics. This is the largest and most well-controlled study to date of emotional memory enhancement. Results of this study will critically discriminate models that attribute the emotional memory enhancement solely to arousal (Hamann, 2001; Mather, 2007; Phelps, 2006) from models that also posit a contribution of valence to emotional memory (Kensinger, 2009; LaBar & Cabeza, 2006).

2. Method

2.1. Outcome variables

The outcome variables are from Cortese et al. (2010), in which 117 undergraduates each intentionally learned 15 lists of 50 words, with immediate recognition tests (with 50 foils) after learning of each list. Note that because Cortese et al. excluded 22 additional participants with accuracy below 60%, our results may not generalize to individuals with relatively poor memory. The outcome variables were hit rate, false alarm rate, hits minus false alarms, d' (sensitivity) and C (criterion). We analyzed the 2507 words for which all predictor variables were available.

2.2. Predictor variables

First, the variables used by Cortese et al. (2010) were taken as control variables. *Objective word frequency* was calculated as the log.-transformed frequency of occurrence of a given word in a large corpus of text samples (Zeno, Ivens, Millard, & Duvvuri, 1995). *Subjective word frequency* was measured as participants' estimates of word frequency (Balota, Pilotti, & Cortese, 2001). *Age of acquisition* is the estimated age at which a word is learned; ratings were obtained from Cortese and Khanna (2008). *Imageability* is the ease with which a given word evokes a mental image; ratings were obtained from Cortese and Fugett (2004). *Orthographic similarity* is the extent to which a given word is similar in spelling to other words; it was calculated as the average Levenshtein distance of spelling of the twenty closest words (Yarkoni, Balota, & Yap, 2008). *Phonological similarity* is the extent to which a given word is similar in pronunciation to other words; it was calculated analogously with the phonemic transcription. *Phonological-to-orthographic rime neighborhood size* is the number of words sharing both the orthographic and phonological rime (i.e., vowel and subsequent consonants) with the given word. *Word length* was measured as the number of letters in the given word.

To these we added *arousal* and *valence* measures (Adelman et al., 2013), on which each word was rated by 40 Amazon Mechanical Turk workers (see Buhrmester, Kwang, & Gosling, 2011) with a mean age of 33.22 years

($SD = 10.69$). All participants had a registered US postal address, completed the task on a computer with a US IP address, and identified English as their first (native) language in a pre-screening test. Instructions were based on Bradley and Lang (1999). The relevant part read as follows: "AROUSAL is the extent to which the word makes you feel calm (relaxed, bored) or excited (stimulated, agitated), whereas VALENCE is the extent to which the word makes you feel negative (sad, scared) or positive (happy, contented). For each word you must choose one response among 7 levels of arousal (from extremely calming to extremely exciting) and one response among 7 levels of valence (from extremely negative to extremely positive)."

Because the valence scale is from 1 ("extremely negative") to 7 ("extremely positive"), the *valence* variable tests for a difference between negative and positive stimuli, whereas an *extremity of valence* variable (absolute distance from the scale midpoint) tests whether both negative and positive stimuli are better remembered than neutral stimuli. We also added the (centered, multiplicative) *arousal* × *valence interaction*. For each outcome variable a separate multiple regression was conducted, using all of these predictor variables.

2.2.1. Validation of predictors

We cross-validated our measures of arousal and valence with the most commonly used source of emotional word ratings, the Affective Norms for English Words (ANEW; Bradley & Lang, 1999). Of the 2820 words in our list, 300 are also in ANEW. Among those 300 overlapping words, our arousal ratings ($r = .76$, $p < .001$) and valence ratings ($r = .96$, $p < .001$) were strongly positively correlated with the ANEW ratings. Thus, our arousal and valence ratings were cross-validated.

2.2.2. Relationships among predictors

Although arousal correlated with both valence ($r = -.31$, $p < .001$) and extremity of valence ($r = .24$, $p < .001$), the strength of these correlations did not approach levels at which problems of collinearity arise ($|r| > .8$; Field, 2009). Moreover, the observed collinearity tolerances of arousal (.84), valence (.83), and extremity of valence (.91) all far exceed the threshold (.10) below which collinearity is typically identified (Field, 2009). Thus arousal, valence, and extremity of valence were not multicollinear, and hence regression analyses are appropriate.

We used split-halves to estimate the reliability of the measures as .93 for arousal, .98 for valence, and .94 for extremity of valence. According to Kristof's (1973) method, the (absolute) correlation of the true scores for the different measures was significantly less than 1 ($ts > 85$), implying that each contained unique non-noise variance. These analyses confirm that arousal and extremity of valence are different constructs.

3. Results

Fig. 1 summarizes the patterns of covariate-adjusted mean recognition. Table 1 presents regression coefficients for the control variables — whose pattern of significance

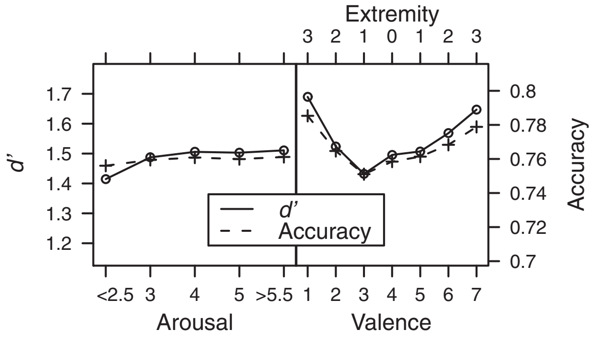

Fig. 1. Adjusted mean recognition (d' and accuracy = proportion correct = .5 + (Hits − FAs)/2) as a function of arousal, valence, and extremity of valence in bands.

replicated Cortese et al. (2010) — and the emotion variables.

Arousal showed no effect on recognition. The same result held in an analysis excluding extremity of valence. *Valence* only exerted its influence via a criterion shift (change in C): Participants were more likely to report a negative word as old, regardless of whether it was in fact old (a hit) or new (a false alarm). The *arousal* × *valence interaction* was not significant in any analysis. *Extremity of valence* affected accuracy (both d' and hits minus false alarms): Participants were more likely to report words of extreme valence as correctly old (hits) and less likely to report them as incorrectly old (false alarms). Accuracy was around 5% higher for extreme than for neutral items.

Given that arousal failed to predict recognition memory, we sought to establish predictive validity of these arousal ratings: We regressed lexical decision response times (RTs) from the English Lexicon Project (Balota et al., 2007) on the same predictor variables as in the main analyses. As shown in Table 1, valence and extremity of valence both significantly predicted RTs: Positive and negative words elicited faster responses than neutral words, with positive words eliciting the fastest responses. Valence and arousal did not interact. This pattern replicates prior results (Estes & Adelman, 2008a, 2008b; Kousta, Vinson, & Vigliocco, 2009). Notably, arousal significantly predicted RTs (see also Estes & Adelman, 2008a, 2008b; Kousta, Vinson, & Vigliocco, 2009). Thus, the failure of arousal to predict recognition memory was not attributable to an inadequacy of the arousal ratings.

Finally, we examined whether the most extremely negative items were recognized better than the most extremely positive items — as Fig. 1 appears to suggest — in ANCOVAs comparing the 5% (or 10% or 20%) most negative items with the 5% (or 10% or 20%) most positive in terms of d' and hits minus false alarms, whilst partialing out the control variables. None of these analyses reached significance, $Fs < 1.4$.

4. Discussion

Our results revealed that negative and positive stimuli were remembered better than neutral stimuli, even after

Table 1
Regression coefficients for the effects of control variables and emotion variables on measures of recognition memory and lexical decision times.

Predictor	Hit rate	FA rate	Hits minus FAs	d'	C	Lexical decision
Control variables						
Objective frequency	−0.316***	−0.081*	−0.201***	−0.155***	0.234***	−0.199***
Subjective frequency	−0.115***	−0.124***	−0.006	0.043	0.148***	−0.300***
Age of acquisition	0.218***	−0.161***	0.293***	0.308***	−0.052	0.135***
Imageability	0.387***	−0.071**	0.365***	0.323***	−0.200***	−0.229***
Phon.-Orth. Neigh.	0.001	0.139***	−0.098***	−0.109***	−0.093***	0.012
Orthographic similarity	0.187***	−0.135***	0.250***	0.267***	−0.019	0.093***
Phonological similarity	0.013	0.075***	−0.041	−0.049*	−0.056*	0.006
Length	−0.081***	0.393***	−0.349***	−0.384***	−0.226***	−0.029
Emotion variables						
Arousal	0.010	0.003	0.006	0.013	−0.015	−0.087***
Valence	−0.064***	−0.123***	0.037	0.042	0.120***	−0.035*
Extremity of valence	0.040*	−0.029	0.054**	0.051**	−0.009	−0.042**
$A \times V$ interaction	−0.012	0.012	−0.020	−0.014	0.003	0.010
Model fit						
R^2 (%)	47.0	16.6	29.3	23.8	33.2	48.5

Note: FA = false alarm; Phon.-Orth. Neigh. = phonological-to-orthographic rime neighborhood size.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

controlling for arousal and several other lexical and semantic factors. We found no evidence that memory for negative stimuli is superior to memory for positive stimuli, nor that arousal enhances memory either independently or interactively.

4.1. Valence

Extremity of valence clearly facilitated recognition memory accuracy, in terms of hits (correct recognition), hits minus false alarms (recognition corrected for response bias), and d' (sensitivity). As the stimulus words became more extreme – that is, more negative or positive – recognition improved.

In contrast, the valence factor ranging from negative to positive did not predict recognition accuracy. That is, negative words were no better remembered than positive words. However, negative words did elicit a significant criterion shift: Both hit rates and false alarm rates were higher. Essentially, participants were prone to claim recognition of negative words regardless of whether they had actually studied them. This observation is consistent with prior evidence from the remember/know paradigm (e.g., Dougal & Rotello, 2007; Mickley & Kensinger, 2008; Ochsner, 2000), which reveals a tendency toward overconfidence rather than superior memory for negative stimuli over positive stimuli.

4.2. Arousal

We found no evidence that arousal enhances memory, either independently or interactively with valence. Whilst the absence of an arousal effect may seem theoretically surprising, in fact several influential studies have also found no effect of arousal on memory accuracy (e.g., Kensinger & Corkin, 2004; Ochsner, 2000; Sharot, Delgado, & Phelps, 2004). One factor that might explain the null effect of arousal in this study is the reliability of arousal ratings. Recall that our arousal ratings correlated less strongly ($r = .76$) than our valence ratings ($r = .96$) with the corresponding ratings in the ANEW database (see also Kousta et al., 2009). Thus, arousal ratings might simply be less reliable than valence ratings, and hence statistical power is lower for detecting arousal effects than valence effects. Notably however, these arousal ratings did have a high split-half reliability, the large sample of items yielded very high statistical power, and the arousal ratings did significantly predict lexical decision times. Another factor that might minimize the effect of arousal in this study is our use of word stimuli. That is, words might be substantially less arousing than images, so that arousal levels were generally too low or too restricted to exert effects. On the other hand, again, these arousal ratings were sufficiently varied to predict lexical decision times. Moreover, many prior demonstrations of arousal effects have used words as stimuli, and in a direct comparison of words and images, Kensinger and Schacter (2006) found highly similar levels of neural activation by arousing words and pictures.

4.3. Theoretical implications

Some models attribute emotional memory enhancement entirely to arousal (Hamann, 2001; Mather, 2007; Phelps, 2006). Because our analysis revealed no effect of arousal on memory accuracy, these results contradict such arousal-based models. However, arousal may nevertheless influence other aspects of memory, such as participants' recollective experience (e.g., Kensinger & Schacter, 2008) and their memory for perceptual details (e.g., Mather, 2007). Further, arousal might only influence memory under different research conditions, such as when participants are particularly attentive to emotion (Everaert et al., 2011; Greenberg et al., 2012). That is, whilst arousal showed no effect under these conditions with these stimuli and these measures, its effect may appear under other circumstances.

These results more directly support models of emotional memory that posit an independent role for valence

(Kensinger, 2009; Kensinger & Schacter, 2008). Some models posit a role for valence, but assume valence affects memory only when arousal is low (Kensinger & Corkin, 2003, 2004; LaBar & Cabeza, 2006). Such models therefore predict an interaction of arousal and valence, but critically, our analyses found no interaction. These results thus fail to support such interactive models. Other models claim a role of valence that is independent of arousal. For example, Kensinger (2009) concludes that negative valence enhances memory for focal details of the stimulus but hinders memory for contextual details, whereas positive valence elicits a general sense of familiarity without detailed recollection. The net result is that both negative and positive valence enhance memory relative to neutral stimuli, but the precise nature of those memorial enhancements may differ (i.e., central versus peripheral details). These results thus generally support such models that include valence as a critical, independent factor of emotional memory.

On the other hand, such models also posit an influential role of arousal in emotional memory (Kensinger, 2009; LaBar & Cabeza, 2006), but we found no evidence for this claim. So ultimately our results indicate that valence is more important for memory than any current model supposes: All current models emphasize arousal, but our results show valence to be more influential. Below we suggest methodological explanations why prior studies have found arousal effects that, according to our results, do not emerge among a larger set of words that vary more naturally in emotionality.

4.4. Methodological implications

The present results highlight three important limitations of previous studies. First, some effects that were truly due to valence might have been misattributed to arousal, or indeed vice versa. For instance, to investigate how emotion affects memory, Sharot et al. (2004) compared neutral stimuli (i.e., low arousal, moderate valence) to emotional stimuli (i.e., high arousal, negative valence) that differed in both arousal and valence. In such designs, one cannot conclude whether observed differences are due to arousal or to valence. And unfortunately, this confounding of arousal and valence has been common in prior research (Mather & Sutherland, 2009). Second, many lexical and semantic factors that are rarely controlled in studies on emotional memory (see Table 1) significantly predict recognition accuracy (see also Cortese et al., 2010). Emotion effects observed in prior studies may be wholly or partly attributable to these confounding factors. Third, the design of a typical emotional memory experiment may artificially induce or inflate emotional memory effects. In a typical experiment, an unnaturally high proportion of the stimuli are extremely emotion-inducing. Such high proportions of extremely emotional stimuli increase participants' attention to emotion (Everaert et al., 2011), which in turn improves their memory for emotional stimuli (Greenberg et al., 2012).

Conversely, this research illustrates the utility of mega-study databases, which allow novel and complex analyses of large datasets as new hypotheses and new measures emerge (see Balota, Yap, Hutchinson, & Cortese, 2012). Here, Cortese et al.'s (2010) mega-study of recognition memory allowed us to examine independent effects of arousal and valence as they vary naturally across thousands of words, while also controlling more lexical and semantic factors than prior studies. This analysis demonstrates that valence, whether negative or positive and whether exciting or calming, enhances recognition memory.

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