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Differential Effects of Arousal in Positive and Negative Autobiographical Memories

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Abstract

Autobiographical memories are characterized by a range of emotions and emotional reactions. Recent research has demonstrated that differences in emotional valence (positive v. negative emotion) and arousal (the degree of emotional intensity) differentially influence the retrieved memory narrative. Although the mnemonic effects of valence and arousal have both been heavily studied, it is currently unclear whether the effects of emotional arousal are equivalent for positive and negative autobiographical events. In the current study, multilevel models were used to examine differential effects emotional valence and arousal on the richness of autobiographical memory retrieval both between and within subjects. Thirty-four young adults were asked to retrieve personal autobiographical memories associated with popular musical cues and to rate the valence, arousal, and richness of these events. The multilevel analyses identified independent influences of valence and intensity upon retrieval characteristics at the within and between subject levels. In addition, the within subject interactions between valence and arousal highlighted differential effects of arousal for positive and negative memories. These findings have important implications for future studies of emotion and memory, highlighting the importance of considering both valence and arousal when examining the role emotion plays in the richness of memory representation.

Autobiographical memories, like the life events they represent, are characterized by a wide range of emotions and emotional reactions. Such emotions are often described as existing on two dimensions: emotional valence (how pleasant or unpleasant the emotion) and emotional arousal (the intensity associated with this emotion; (Duffy, 1934, 1941; Dunlap, 1932; Russell, 1980). Recent research has examined how these differences in valence and arousal may differentially influence the retrieved autobiographical memory narrative.

It has been suggested that the emotional arousal associated with a personal event may play an important role in how that memory is retrieved by an individual (see Holland & Kensinger, 2010 for review). A number of studies have demonstrated that high emotional arousal leads to increased ratings of vividness in memory retrieval (Berntsen, 2001; Bohanek, Fivush, & Walker, 2005; Reisberg, Heuer, McLean, & O'Shaughnessy, 1988) and

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increased retention of memories during a second testing session (Waters & Leeper, 1936). These studies support previous research that memory "emotionality" leads to more vivid memory retrieval (Conway & Bekerian, 1988; Rubin & Kozin, 1984). In fact, it has been argued that arousal is a much stronger predictor of memory richness than the valence of memory (Talarico, LaBar, & Rubin, 2004). The enhanced richness during retrieval of emotional, relative to neutral, autobiographical memories may be caused by increased elaboration of these highly relevant personal experiences (Bower, 1992; Sten et al., 1997).

However, the mnemonic effects of emotion differ based on the valence of the emotion. A number of studies have shown autobiographical memory enhancement for highly positive events relative to highly negative events, including an increase in peripheral details (Berntsen, 2002; Talarico, Berntsen, & Rubin, 2009), sensory and contextual details (D'Argembeau, Comblain, & Van der Linden, 2003; Destun & Kuiper, 1999; Kensinger & Schacter, 2006; Raspotnig, 1997), ratings of vividness (Talarico et al., 2004), and the experience of reliving (Talarico et al., 2004). In addition, individuals tend to retrieve more positive than negative autobiographical memories, whether voluntary (Meltzer, 1930) or involuntary (Berntsen, 1996), and have greater memory for positive memories during a second testing session (O'Kelly & Steckle, 1940).

Positive affect might enhance the richness of memory retrieval for a number of reasons. It has been suggested that, relative to negative emotion, positive affect promotes relational cognitive processing, allowing for the activation of all surrounding information in addition to the emotion-relevant details (Clore & Storbeck, 2006; Clore et al., 2001; Fiedler, 2001). In addition, enhanced richness of positive autobiographical memories might be caused by increased elaboration and rehearsal of these events that are consistent with the generally positive self-schema that most individuals maintain (Taylor & Brown, 1988). Indeed, one recent student demonstrated that positive memories have more self and social function than negative memories, indicating that these memories are typically retrieved in order to enhance self-concept or to facilitate bonding with others (Rasmussen & Berntsen, 2009). However, retrieval of all positive events, regardless of arousal, should satisfy these functions, suggesting that emotional arousal may not have a strong effect on memory richness in positive memories.

Studies have also shown an enhancing effect of negative valence on some components of memory retrieval. Negative autobiographical narratives contain more central details than positive events (Berntsen, 2002; Talarico et al., 2009). In addition, when comparing emotional reactions within a single autobiographical narrative, ratings of vividness were related with feelings of anger and sadness, but not with happiness or surprise (Bluck & Li, 2001). Finally, when comparing positive and negative recollections of the same intense emotional event, negative memories tend to be more accurate and contain more event-details than positive memories (Kensinger & Schacter, 2006).

The research detailed above suggests that increased negative affect enhances memory retrieval in a way that is quite different from the effects of positive emotion. Unlike positive affect, negative affect promotes specific processing of the details of an event (Clore & Storbeck, 2006). This detail-oriented processing may occur because negative memories

signal danger (e.g., Levine & Bluck, 2004; Taylor, 1991) and have a more directive function compared to positive memories (Rasmussen & Berntsen, 2009). In other words, negative events, to a greater extent than positive events, are used to help direct future behavior in order to avoid similar negative situations (Rasmussen & Berntsen, 2009). It has been suggested that high-arousal negative emotions may have different effects on memory compared to low-arousal negative emotions (Holland & Kensinger, 2010). It is possible that high-arousal negative events may have increased directive function relative to low-arousal negative events, leading to a strong relationship between arousal and memory richness in negative events. Such a difference could help explain why many individuals have highly vivid and detailed representations of personal trauma (e.g. Tromp, Koss, Figueredo, & Tharan, 1995) and flashbulb memories (e.g. Brown & Kulik, 1977; Christianson, 1992).

Although the mnemonic effects of valence and arousal have both been heavily studied, it is currently unclear whether the effects of emotional arousal are equivalent for positive and negative autobiographical events. The current analysis focuses on the interaction between valence and arousal to determine whether the effects of arousal on memory richness vary depending on the valence of the particular event. Specifically, we examine three distinct components of memory retrieval: vividness (the amount and clarity of details associated with the memory), reliving (the extent to which the subject re-experiences the event during retrieval), and specificity (the degree to which the memory represents a single event relative to a general category of events).

We also examine how differences *between* individuals may influence phenomenological characteristics of their memories. Previous research has shown that individuals who have been diagnosed with depression have a tendency to retrieve memories that are less specific (i.e. referring to a category of events rather than a single event) than control participants (see Williams et al., 2007 for review). These individuals may attempt to lessen their overall negative affect by reducing the amount of detail retrieved for all memories (both positive and negative; Williams et al., 2007). Studies have shown reduced specificity in individuals with emotional disorders (Williams et al., 2007), and in healthy young adults induced into a negative emotional state (Yeung et al., 2006), but have not examined memory specificity in healthy young adults who tend to retrieve more negative autobiographical memories than average.

Due to the hierarchical data structure (i.e., memories are nested within each participant), a multilevel model was used to examine relationships within subjects as well as between subjects (D'Argembeau, Renaud, & Van Der Linden, 2011; Wright, 1998; but see Rubin, Schrauf, and Greenberg, 2003 for an example of using simple regression to answer similar questions). In other words, the current analysis examines the effect of emotion both at the subject level (e.g., do subjects who retrieve more positive than negative memories also tend to retrieve more detailed memories than other subjects?) and at the individual memory level (e,g., in any given subject, are more positive memories rated as more detailed than negative memories?).

Finally, the differences between positive and negative autobiographical memories have previously been examined using paradigms that explicitly request memories associated with

a particular emotional response (e.g., “retrieve a memory for when you felt particularly happy”). By focusing attention on the emotional components of the autobiographical event, these studies may artificially enhance the effect of the emotion on retrieval characteristics. The current paradigm expanded on these studies by using music to elicit positive and negative memories without explicit instructions, thus examining the effect of emotional valence on memory characteristics during more natural retrieval processes.

Based on previous research, we expect overall enhancements in the richness of memory retrieval for positive, relative to negative, events, and high-arousal, relative to low arousal, events. In addition, we expect that increased arousal will be associated with larger changes in vividness, reliving, and specificity for negative memories than positive memories. In other words, we expect to find a significant valence by arousal interaction at the within subjects level. Between subjects, we expect that individuals who retrieve more negative memories will retrieve memories that are less vivid and specific, extending previous findings in depressed individuals.

Methods

Participants

Data for the current analysis come from neuroimaging investigations focusing on the neural correlates of autobiographical memory (e.g., Ford, Addis, & Giovanello, 2011). Thirty-four healthy young adults between the ages of 18 and 23 (M=20.26 years old; SD= 1.28; twenty-four females)[1] were recruited using flyers posted on the University of North Carolina campus and paid $20 per hour for their participation. Interested subjects contacted the lab and were screened to ensure that all individuals were right-handed native English speakers without a history of psychiatric illness, neurological disorder, or hearing impairment. Before participating in the study, participants gave written informed consent in accord with the requirements of the Institutional Review Board at the University of North Carolina at Chapel Hill.

Materials

Retrieval cues for the experimental trials consisted of 30-second clips from popular songs from the years 1998–2007. The top ten songs were selected from each of the ten years using an internet “top ten” website (http://www.rockonthenet.com). Songs were downloaded from the iTunes music store and recorded using MacStim’s sound recorder. A 30s clip was selected for each of these 100 songs, and the clip contained the chorus and other highly recognizable segments. Popular songs were selected so that participants would have some level of familiarity with all of the stimuli.

All 100 songs were tested in two pilot studies where 34 undergraduate volunteers listened to the music clips and reported memories associated with each song. Based upon the results of this pilot study, we selected 50 songs that consistently elicited autobiographical memories across all participants. The five songs from each year with the highest ratings of familiarity

[1]Three additional subjects were recruited and screened for the study but could not be analyzed. Two subjects (female, ages 20 and 21) terminated the study early and one subject (male, age 19) participated fully, but an equipment malfunction lead to unusable data.

and memory detail were selected as stimuli for the experimental trials in the current paradigm.

For the control task, seventeen songs were selected to match experimental stimuli in all respects, except song popularity. Selection of control stimuli involved identifying a number of songs from 1998–2007 that matched the experimental stimuli in message, rhythm, and genre. A majority of the control stimuli were songs that never reached popularity, but were from the same albums as our experimental stimuli. Selected control songs were then piloted to test for participant familiarity; any songs that were familiar to even one participant were eliminated from the set of control stimuli.

Procedure

The behavioral data reported in the current analysis come from memories collected as part of two neuroimaging studies focusing on the neural correlates of autobiographical memory (Ford et al., 2011, *in preparation*). In both studies, participants listened to fifty 30s clips of popular songs while in the scanner. These songs were presented in five lists that were counterbalanced across subjects. Each list had ten songs in a fixed order. When the song was presented, participants retrieved personal memories, and (silently) elaborated on these memories as if they were reporting the narrative to another person. Participants were instructed to retrieve whatever level of memory naturally came to mind, with no instruction toward any particular level of specificity. Participants were instructed to press a button immediately when a memory had been retrieved and elaboration began. This button press identified the level of specificity that best described their memory at the time of retrieval (1=abstract personal knowledge, 2=category of events, and 3= specific event). To allow for more naturalistic memory retrieval, we allowed for participants' memories to develop and change during the elaboration period and to monitor this change in specificity over time. As such, we instructed participants to indicate via button press any time their memory became more or less specific during the thirty-second retrieval period.

Because these data were collected in the context of neuroimaging investigations, the experimental design also included presentation of two rating scales after each memory trial, as well as control trials (semantic memory judgment regarding the content of the music) interspersed between the memory trials. As the current study does not examine neural activation, these data were not included in any analysis.

After the scan interval, participants engaged in a post-retrieval interview that was audio-recorded. They were re-presented with the musical cues and instructed to recall the memories they generated in response to the cues. Participants then rated each memory on ten characteristics using a 1–4 scale. Three of these measures examined qualities of the song stimuli (i.e., song familiarity, song preference, and genre preference) whereas the other ten measures obtained in this interview evaluated the memory itself (i.e., emotional valence, emotional arousal, vividness, reliving, recency, relation to prior memory, and prior rehearsal). Of interest in the current analysis were ratings of emotional valence, emotional arousal, vividness and reliving.

Data Analysis

Due to the clustered structure of the data (i.e. memories are nested within each participant and, therefore, are not statistically independent), classical data analysis methods (e.g., ANOVA or multiple regression) are not appropriate (Wright, 1998). Specifically, an ANOVA could test individual differences between subjects, but would ignore within subject (memory level) differences. A regression analysis could examine the relationship between retrieval characteristics at the memory level, but would treat each memory as independent, ignoring the similarity between memories within an individual. As such, the model that is the most appropriate for analyzing this type of data is the multilevel model, which can be conceptualized as an extension of multiple regression. The current analysis used three separate multilevel models to investigate how the emotional valence and arousal of memories influenced the three retrieval characteristics of interest: memory specificity, vividness, and reliving. The PROC MIXED function was utilized in the Statistical Analysis Software (SAS; http://www.sas.com/) to examine these relationships independently of one another.

The multilevel model can be estimated to include the overall effects of each dependent variable on the independent variable (called fixed effects) as well as variation across subjects (called random effects). The current analysis utilized a random intercept model, allowing subjects to have varying levels of the dependent variable (i.e., some subjects have higher levels of memory specificity, vividness, and reliving) but the relationships between the independent and dependent variables remain constant across subjects[2].

To isolate the within subjects effects of the independent variables (i.e., emotional arousal and valence), these variables were subject-mean-centered, thereby removing differences between subjects. This mean-centering enables us to examine how within subject differences in arousal and valence may influence retrieval characteristics (i.e., specificity, vividness, and reliving) of a particular memory, controlling for potential differences between subjects. By entering the subject means for the independent variables (i.e., arousal and valence), we examined between subject effects within the same multilevel model. The between subjects analysis examines individual differences in memory emotion and how these differences might influence specificity, vividness, and reliving. Although incorporated within the multilevel framework, the between subjects analysis would operate the same as standard multiple regression or ANOVA.

At both the within and between subject levels, the interaction effect of arousal and valence is also examined. In other words, in addition to examining the effects that arousal and valence have on the three retrieval characteristics, the model includes an interaction term that examines how the effect of arousal on these characteristics differs across levels of valence (and vice versa).

[2]A random slope model (i.e., a model where these relationships were allowed to vary across individuals) was also fit to these data, with nearly equivalent results.

Results

Within subject differences in valence and emotional arousal influence memory characteristics

The within subjects analysis demonstrated that valence and arousal influenced all three memory characteristics when controlling for differences between subjects. Independent of the effects of arousal, one-unit increase in valence (i.e. positivity) was associated with a .12-unit increase in specificity ($p<.0001$), a .26-unit increase in vividness ($p<.0001$) and a .22-unit increase in reliving ($p<.0001$). Similarly, a one-unit increase in arousal was associated with a .25-unit increase in specificity ($p<.0001$), a .54-unit increase in vividness ($p<.0001$), and a .51-unit increase in reliving ($p<.0001$), independent of the effect of valence. These results support previous research in which more positive and more arousing memories are associated with increased richness in the memory representation.

The interaction between valence and arousal was also significant for specificity ($p< .005$) and vividness ($p< .005$), but not for reliving ($p= .28$; See Table 1 for full data summary). This finding suggests that the effect of emotional arousal on vividness and specificity was greater for negative than for positive autobiographical memories, but that there was no difference in the effect of arousal on reliving.

Between subject differences in emotional arousal, but not valence, influence memory characteristics

Individuals who retrieved memories that were more emotionally intense also retrieved memories that were more vivid and subject to greater feelings of reliving. A one-unit increase in average arousal ratings was associated with a .53-unit increase in vividness ($p< .0001$) and a .63-unit increase in reliving ($p< .0001$). However, individual differences in arousal did not influence ratings of memory specificity ($p= .86$). In addition, individual differences in the tendency to retrieve positive memories did not influence memory specificity ($p=.11$), vividness ($p=.79$), or reliving ($p=.47$). The interaction between arousal and valence approached significance for vividness ($p= .09$) and reliving ($p= .13$), but not for specificity ($p= .81$; See Table 1).

Discussion

We used multilevel modeling to examine how emotional valence influences the relationship between emotional arousal and the richness of autobiographical memory retrieval. Specifically, our study focused on the vividness, specificity, and subjective sense of reliving associated with retrieval. Importantly, the multilevel analysis examined these relationships both within subjects and between subjects. We were able to elucidate the independent influences of valence and arousal upon other retrieval characteristics. In addition, the within subject interactions between valence and arousal highlighted differential effects of arousal for positive and negative memories, suggesting that future studies should consider how these two measures interact to produce a memory representation.

The within subjects analysis controlled for differences between subjects to examine memory-level differences in emotional content on ratings of vividness, specificity, and

reliving. This analysis demonstrated that individuals rate positive memories as richer (as measured by all three retrieval characteristics) than negative memories (regardless of the level of emotional arousal), and highly arousing memories as richer than unarousing memories (regardless of valence). The enhancing effect of positive emotion is consistent with previous research that has demonstrated that positive memories are associated with richer memory representations (Berntsen, 2002; D'Argembeau et al., 2003; Destun & Kuiper, 1999; Kensinger & Schacter, 2006; Raspotnig, 1997; Talarico et al., 2004; Talarico et al., 2009). In addition, the numerically larger within subject effect of emotional arousal on these three phenomenological characteristics replicates previous research suggesting that emotional arousal may be a better predictor of memory richness than valence (Talarico et al., 2004).

Importantly, the significant interactions in the vividness and specificity analyses suggest that the effect of arousal on memory richness is greater for negative than for positive autobiographical memories. According to these results, individuals rated positive memories, irrespective of emotional arousal, as highly detailed and specific, suggesting that positive emotion, in general, facilitates retrieval of multiple contextual and sensory details. This finding is consistent with the prediction that all positive memories may benefit from overall memory enhancement, and negative memories may be toned down, in order to maintain a positive self-schema and facilitate social bonding (see Fredrickson, 2001; Ross & Wilson, 2002; Taylor & Brown, 1988).

For negative memories, however, subjects rated highly arousing memories as more vivid and specific. In other words, although positive memories were, on average, richer than negative memories, this difference is smaller for highly arousing events. It is possible that highly arousing negative events benefit from an enhancement of important memory details due to their potential importance for future events. It has been suggested that memory for the central details in a negative event enables the recollection to serve directive functions (Rasmussen & Berntsen, 2009), something that would be particularly important for highly arousal negative events. Consistent with the current finding, a recent comparison of involuntary memories for trauma, peak, non-trauma, and non-peak events, Berntsen (2001) found that trauma memories (i.e., intensely negative) were more vivid than non-trauma memories, but this was not true of peak (i.e., intensely positive) v. non-peak memories. As in the current analysis, this comparison demonstrated that arousal had an effect on vividness for negative memories (i.e., trauma > non-trauma), but not positive memories (i.e., peak = non-peak).

The between-subjects analysis focused on individual differences in the tendency to retrieval positive memories and highly arousing memories. Interestingly, between subjects differences in emotional valence (i.e. differences in how positive an individuals' memories are, on average) had no effect on memory vividness, specificity, or reliving. Previous research would suggest that individuals who tend to retrieve negative memories (e.g., depressed individuals) might utilize controlled emotion regulation processes to retrieve memories that are less vivid, specific, and relived (see Williams et al., 2007 for review). It is possible that the unrestricted retrieval instruction or automatic nature of music-evoked memories reduced any between-subject differences in the effects of negative memory

retrieval. Alternatively, the effect of negative affect on memory richness may be restricted to more significant differences in valence that are not apparent in healthy young adults without mood inducement. Importantly, the multilevel approach allowed us to empirically demonstrate that relationships at the within subject level do not necessarily translate to the between subject level. Specifically, this analysis shows that we cannot make the assumption that individuals who retrieve more negative memories (e.g., depressed individuals) also retrieve less specific memories, just because negative memories tend to be less specific (i.e., an *atomistic fallacy*).

In contrast, individuals who retrieved memories of high arousal also retrieved more vivid memories that were subject to greater levels of reliving. It is possible that increased emotional arousal leads to enhanced activation of the memory representation, allowing for a richer memory experience. Alternatively, retrieval of these vivid details may cause participants to experience greater emotional arousal at the time of retrieval. Future research is required to explore the directionality of this relationship and the others identified in the current analysis.

Summary

The current analysis utilized a multilevel modeling approach to examine the effects of emotional valence and emotional arousal on the richness of autobiographical memory retrieval. Specifically, the multilevel analysis identified the independent influences of valence and arousal upon retrieval characteristics at the within and between subject levels. In addition, the within subject interactions between valence and arousal highlighted differential effects of arousal for positive and negative memories. These findings have important implications for future studies examining the behavioral and neuroimaging effects of emotion on autobiographical memory retrieval. Specifically, they suggest that future studies must consider both valence and arousal when considering the role emotion plays in the richness of memory representation.

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Table 1

Summary of the within and between subject effects of emotional valence and arousal on reliving, specificity, and vividness

	Effect of Emotional Valence	Effect of Emotional Arousal	Valence-by-Intensity Interaction
Within Subject Effects			
Reliving	.22(.03)*	.51(.03)*	−.03(.03)
Specificity	.12(.03)*	.25(.03)*	−.09(.03)*
Vividness	.26(.03)*	.54(.03)*	−.08(.03)*
Between Subject Effects			
Reliving	−.12(.17)	.63(.14)*	−.35(.23)
Specificity	.18(.11)	−.02(.09)	−.04(.15)
Vividness	−.04(.14)	.53(.11)*	−.33(.19)

Standard error in parentheses

* significant at $p<.005$