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BRIEF REPORT

Goal Conduciveness as a Key Determinant of Memory Facilitation

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The affective dimensions responsible for the modulation of memory by emotion are subject to debate. Several hypotheses have been suggested: The arousal hypothesis of memory facilitation suggests the arousal dimension as the key determinant in whether emotional events are more likely to be remembered than neutral events. The valence hypothesis suggests preferential status for unpleasant, as compared with pleasant, stimuli in memory. The authors tested an alternative hypothesis derived from the appraisal theory of emotion, namely, that events that are relevant to the current concerns of the individual benefit from a memory advantage. In the present study, the authors demonstrate that initially neutral but goal conducive items (for game-related gain) remain stable in memory over time, whereas memory for goal irrelevant and goal obstructive items decline over time. They furthermore found that the affective evaluation of initially neutral items changed as a function of the goal relevance manipulation and that this change was stable over time. Taken together, findings support the relevance hypothesis of memory facilitation.

Keywords: emotion, memory, goal relevance, arousal, valence

Although the scientific community has reached a consensus that memory for emotional—as compared with neutral—stimuli is typically enhanced (D'Argembeau & Van der Linden, 2004; Hamann, 2001; LaBar & Cabeza, 2006; McGaugh, 2000), the underlying mechanisms remain highly debated (Kensinger, 2009; Levine & Edelstein, 2009; McGaugh, 2000; Talmi, Luk, McGarry, & Moscovitch, 2007). Two main issues are still controversial, one pertaining to theories of memory, one to theories of emotion. An important question for theories of memory is whether this emotional advantage is instantiated at encoding (Hamann, 2001; Ochsner, 2000), consolidation (LaBar & Cabeza, 2006; McGaugh, 2000; Sharot & Phelps, 2004), or retrieval (Sharot, Delgado, & Phelps, 2004). Furthermore, the emotional mechanisms responsible for this advantage remain unknown, the major debate centering on the importance of the affective dimensions of valence versus arousal (e.g., Kensinger, 2009; Kensinger & Corkin, 2004; LaBar & Cabeza, 2006; McGaugh, 2000). As evidence for the *valence hypothesis* of memory facilitation, some results suggest a preferential status of unpleasant, as compared with pleasant, stimuli in memory (see Kensinger, 2007). What might be referred to as the *arousal hypothesis* of memory facilitation has been strengthened by many studies indicating that arousing events are more likely to be recognized or recalled than neutral events that are typically less arousing (LaBar & Phelps, 1998; Mather, 2007; Sharot & Phelps, 2004). This evidence is consistent with the finding that arousal is a critical modulator of the consolidation of memory traces for emotional events (McGaugh, 2000). The consolidation of a memory is a process that transforms labile into stable memories. Thus, immediately after encoding, a memory may still be fragile and prone to disruption or forgetting, whereas after a certain time interval (e.g., 24 hr), the memory will be stabilized and more protected from forgetting (Sharot & Phelps, 2004).

Whereas both valence and arousal hypotheses are based on properties of the emotional response, an alternative class of theories of emotion, appraisal theories (e.g., Sander, Grandjean, & Scherer, 2005) focus on an earlier part of the emotion process; that is, the evaluation process that elicits the emotional response (a response that includes the physiological arousal and the valenced subjective feeling). Here we test the idea that these eliciting mechanisms—which are rarely specified by other theories of emotion and memory (see Russell, 2003; for discussion, see Sander, 2013)—may be critical for explaining memory facilitation by emotion. More concretely, in the present study, we tested the *relevance hypothesis* of memory facilitation, which states that relevance detection, as a fundamental mechanism of emotion elicitation, may directly cause the facilitatory effect of emotional events on memory.

We focused on the appraisal of the goal relevance of an event, which can lead to different classes of emotions, depending on the outcome of the evaluation. For instance, an event can be goal conducive; that is, the event helps to reach one's goal. Associated emotions are hope, joy, and interest. Alternatively, an event can be assessed as goal obstructive; that is, the event is an obstacle preventing the achievement of the goal. Related emotions are frustration, anxiety, anger, or determination (Ellsworth, 2009). We tested the effect of

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both goal conduciveness and goal obstructiveness on memory. The general idea that relevant stimuli are better remembered has received surprisingly little empirical attention and has not been integrated into current theories of the emotional modulation of memory (for discussion, see Levine & Edelstein, 2009; Levine & Pizarro, 2006). For instance, this idea is consistent with classic research investigating the self-referential encoding effect, which showed that information relating to the self is favored at encoding and preferentially organized in comparison with other types of information (Conway & Dewhurst, 1995; Rogers, Kuiper, & Kirker, 1977). It has also been suggested that schemas or templates may facilitate memory for expertise-relevant items, demonstrating a top-down modulation of memory by current important goals (see, e.g., Gobet & Simon, 1996). Importantly, to the best of our knowledge, no previous study has manipulated goal relevance independently of stimulus content. For instance, using words that denote personality traits, Conway and Dewhurst (1995) showed that self-reference at encoding increases the probability of recollective experience during recognition. Similarly, Abele and Gendolla (2007) showed that memory for health-relevant information was best for highly active exercisers. Tinti, Schmidt, Sotgiu, Testa, and Curci (2009) showed that more religious individuals developed more flashbulb memories about the death of Pope John Paul II. A recent line of related research investigated the influence of evolutionary relevance on memory. Nairne, Pandeirada, Gregory, and Van Arsdall (2009) manipulated the fitness relevance of their stimuli by framing a task either as a "hunting for survival" task or as a "hunting contest" task. Unexpected memory tests revealed superior memory for words that participants had rated for their relevance for "hunting for survival" (fitness relevance) compared with those rated for relevance to hunting. This effect of survival relevance on remembering is consistent both with the general notion that evolutionary relevant tasks have shaped the functions of memory systems (e.g., Klein, Cosmides, Tooby, & Chance, 2002) and with the relevance hypothesis of memory facilitation derived from appraisal theories of emotion (see Levine & Pizarro, 2006; Sander et al., 2005).

To be able to dissociate the goal relevance of a stimulus from its actual content, in the present study, we used initially neutral stimuli and experimentally manipulated their goal relevance. This allowed us to test the hypothesis that goal relevant stimuli benefit from a memory advantage, independent of their initial emotionality.

To test this hypothesis, we presented participants with goal relevant (either conducive or obstructive) or goal irrelevant items (all items were pretested to be initially neutral for valence and low for arousal) and investigated participants' performance on a subsequent memory test for these items. Participants played a game in which they were required to obtain a maximum number of points (adapted from Moors & De Houwer, 2001). During the game, participants were presented with feedback that indicated a gain (i.e., goal conducive trial), a loss (i.e., goal obstructive trial), or that a new trial would start (goal irrelevant trial). At the end of the experiment, participants were presented with a surprise memory test, allowing us to compare memory performance for the stimuli presented during goal relevant and goal irrelevant trials. Importantly, to investigate whether a potential effect of goal relevance occurs at the stage of encoding or during consolidation, we manipulated the delay of the memory test (either immediately or 24 hr later).

Method

Participants

Sixty-four undergraduate students (48 women, 16 men; *M* age = 23.55 years, *SD* = 3.61) participated in the study for partial credit in an introductory psychology course.

Stimulus Materials

Stimuli consisted of a newly developed homogenous set of images that depicted simple biological and manufactured items (e.g., an apple or a chair). Stimuli were selected from the Internet. Photoshop CS3 was used to replace the background (i.e., all images were simple items without additional information) with a uniform gray. We controlled for grayness, size (350 × 150 dots), resolution (720 dpi), and contrast parameters to obtain the highest homogeny in the set of images. In addition, an analysis of variance (ANOVA) showed no significant difference between the experimental conditions for luminance ($F < 1$) and apparent contrast ($F < 1$), following the procedures outlined in Delplanque, N'diaye, Scherer, and Grandjean (2007).

Three hundred thirty-one stimuli were pretested in a validation study involving 40 participants (37 women and 3 men) between 19 and 69 years (*M* = 24.29, *SD* = 5.46). This pretest was performed using a web experiment platform. Participants were asked to evaluate the valence and arousal dimensions for each image using continuous scales ranging from 0 (*most negative*) to 100 (*most positive*) for valence and from 0 (*very low*) to 100 (*very high*) for arousal. The aim of the pretest was to select neutral images only. Therefore, we selected 60 manufactured and 60 biological images that were evaluated in a valence range from 35 to 65. The means and standard deviations of images selected were 54.59 (*M*) and 5.37 (*SD*) for valence and 24.39 (*M*) and 8.23 (*SD*) for arousal. In the experiment, the same 30 manufactured items and 30 biological items were used for each participant (i.e., 10 biological and 10 manufactured items were presented in goal conducive, goal obstructive, and goal irrelevant conditions). The remaining items were added as distractors in the surprise memory task. For the training session, five manufactured stimuli were added.

Procedure

Participants were informed that the better their performance was, the more likely they would win a prize (i.e., a cinema card to attend movies). They were presented with 65 trials: 5 practice trials followed by 60 experimental trials divided into three blocks. Each trial consisted of three events: a game task followed by a feedback and a categorization task (see Figure 1). The game task was adapted from Moors and De Houwer (2001) and consisted of two letters (*n* and *v*) displayed in quick alternation (each remained on screen for 100 ms). Participants were instructed to press the space bar at the exact moment at which the letter *n* was shown. Next, an item was presented on the screen as feedback, corresponding to our manipulation of goal relevance. The item could be goal relevant (i.e., goal conducive by signaling that the participant won, or goal

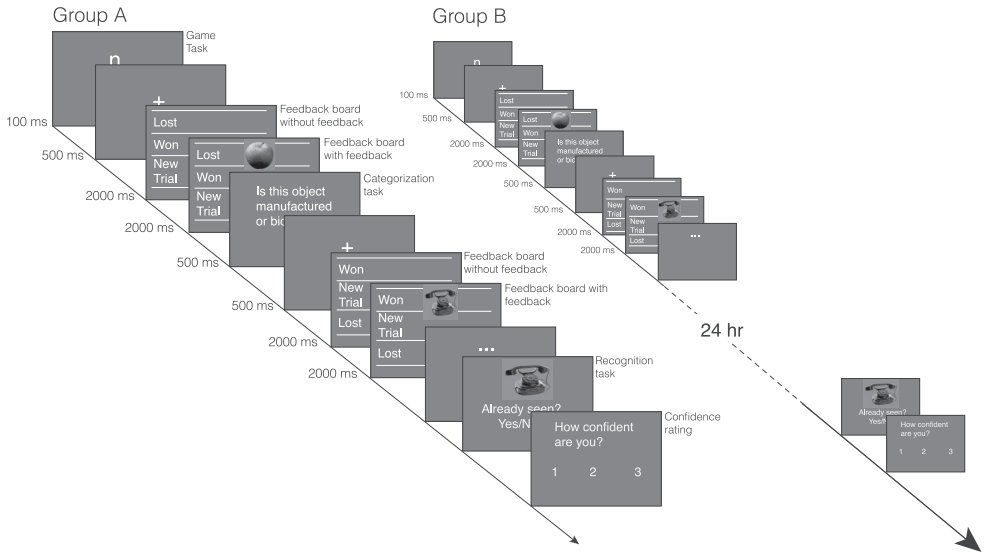

Figure 1. Sequence of the experiment for the two groups: Group A took the recognition test immediately and Group B took it after 24 hr.

obstructive by signaling that the participant lost), or goal irrelevant (i.e., signaling that the trial did not count). This feedback event consisted of one board with three rows that was presented twice. The first time, the feedback board contained only the name of the rows signaling the participant's performance. Next, the item appeared and its location signaled the participant's performance for this trial. For instance, for a given trial, an item appearing in the first row could mean that the participant won, an item in the second row could mean that the participant lost, and an item in the third row could mean that a new trial would start without any gain or loss from the current trial. This feedback item was presented for 2,000 ms in one of the three rows. To avoid pure associative learning between a location in space and the goal relevance of the feedback item, we manipulated the three row names so that a given row that contained a goal conducive item in one trial could contain a goal obstructive or a goal irrelevant item in the next trial. This manipulation was counterbalanced using a controlled randomized sequence. Of note, the feedback did not correspond to the participant's real performance but was controlled in such a way that every participant received the same quantity of "won," "lost," or "new trial." To ensure that participants processed the item, we asked them to perform a categorization task by pressing the letter *m* or *b* to indicate that the item was manufactured or biological, respectively.

After all the trials were completed, participants were invited to perform an unexpected memory task. For half of them, this task took place immediately, whereas for the other half, it took place after 24 hr. During the memory test, 120 items were presented to the participants (60 old items and 60 new items). For each item, participants first made a judgment about whether it was old or new, and then reported their confidence in their answer from 1 (*not confident at all*) to 3 (*very confident*). After the memory task, participants evaluated the stimuli presented during the main task. This evaluation was performed on three different dimensions: (a) valence (on a continuous scale ranging from negative to positive with a median neutral position); (b) arousal (on a continuous scale ranging from very weak to very strong); and (c) subjective relevance (on a continuous scale *from not relevant to extremely relevant,* with the term *relevant* being broadly defined to the participant as "representing something important for you").

Results

The traditional view of the remember–know paradigm suggests that separate processes underlie recognition decisions associated with high confidence and high accuracy (i.e., remembering responses) and decisions associated with lower confidence and lower accuracy (i.e., knowing responses). In contrast, a recent study showed that combining both (i.e., knowing and remembering responses) leads to a stronger memory signal (Mickes, Wais, & Wixted, 2009). We thus decided to compute the accuracy by grouping the responses given with medium and high confidence.

Figure 2A shows the results obtained for mean proportions of correct recognition of goal conducive, goal obstructive, and goal irrelevant items in the immediate and delayed condition, and Figure 2B shows the results for mean item ratings in the postexperimental rating task given to correctly recognized goal conducive, goal obstructive and goal irrelevant items. These results are detailed in the next section.

Recognition Memory

Analyses were conducted for 64 participants, 33 in the immediate and 31 in the delay memory task condition. To test our hypothesis that goal relevant stimuli are better remembered than goal irrelevant stimuli, we conducted a mixed-design ANOVA on the proportion of recognized items, in which we considered goal relevance (conducive, obstructive, and irrelevant) as a within-

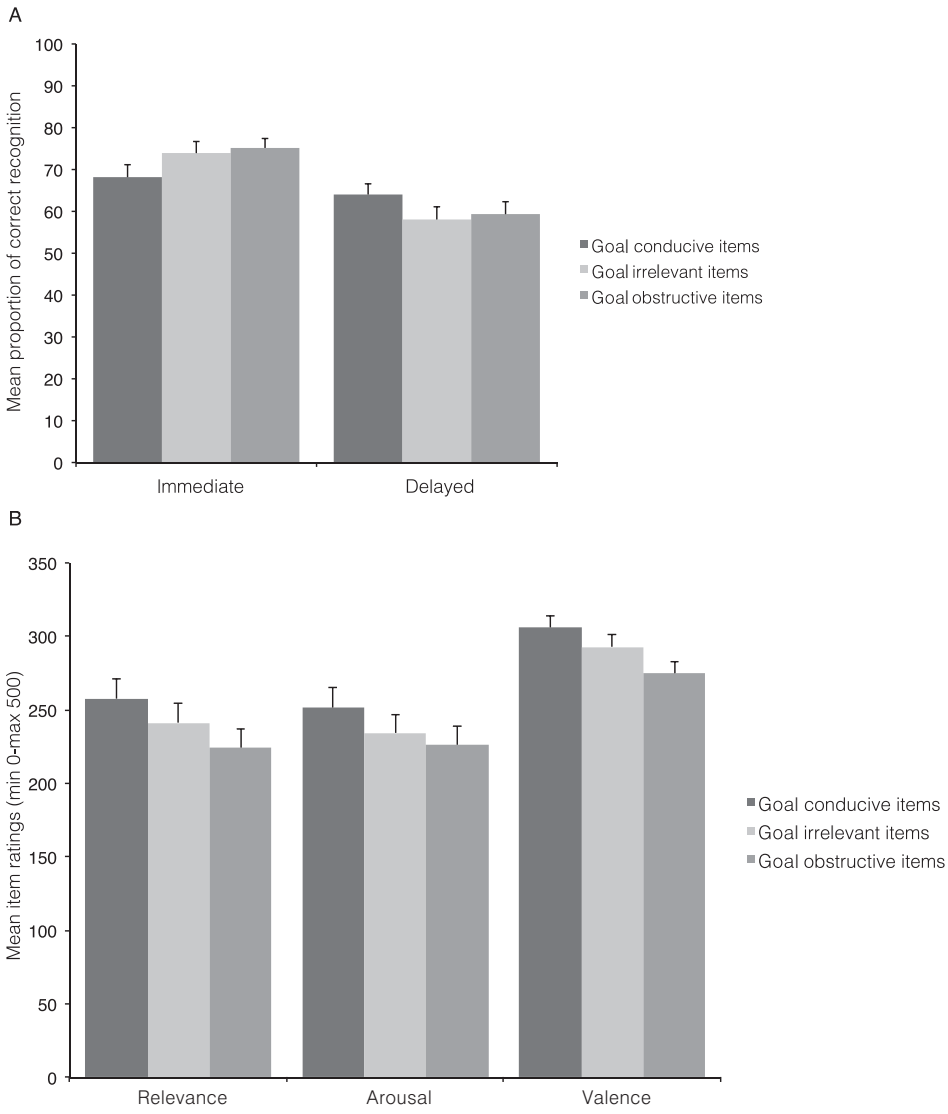

Figure 2. A: Mean proportions and error bars of correct responses for goal conducive, goal obstructive, and goal irrelevant item recognition as a function of the delayed or immediate condition. B: Mean item ratings and error bars for relevance, arousal, and valence dimensions given to correctly recognized goal conducive, goal obstructive, and goal irrelevant items (scale: 0–500). Error bars indicate standard errors of the mean.

subject factor and delay (immediate, delayed) as a between-subjects factor.

Stimuli were better remembered in the immediate ($M = 72.42$) than in the delayed condition ($M = 60.48$), as indicated by a significant main effect of delay, $F(1, 62) = 12.14$, $p < .001$. Importantly, however, this effect was qualified by a significant goal relevance by delay interaction, $F(2, 124) = 8.53$, $p < .001$. To follow up on this interaction, we tested the effect of goal relevance in the two delay conditions separately.

Immediate memory performance. Immediately after the game task, goal irrelevant items ($M = 73.94$) were better remembered than goal conducive items ($M = 68.18$), $F(1, 62) = 6.80$, $p = .011$). Furthermore, goal obstructive items ($M = 75.15$) were better remembered than goal conducive items ($M = 68.18$), $F(1, 62) = 8.76$, $p = .004$.

Delayed memory performance. Twenty-four hours after the game task, goal conducive items ($M = 64.03$) were better remembered than goal irrelevant items ($M = 58.06$), $F(1, 62) = 6.86$, $p = .011$, and marginally better than goal obstructive items ($M = 59.35$), $F(1, 62) = 3.71$, $p = .058$.

Effect of temporal delay on memory performance as a function of goal relevance. When comparing memory performance immediately after the task with performance after 24 hr for each condition, we found that memory performance for goal irrelevant (immediate: $M = 73.94$, delayed: $M = 58.06$) and goal obstructive items (immediate: $M = 75.15$, delayed: $M = 59.35$) declined over time, $F(1, 62) = 15.07$, $p = < .001$ and $F(1, 62) = 18.24$, $p = < .001$, respectively. In contrast, memory performance for goal conducive items (immediate: $M = 68.18$, delayed: $M = 64.03$) did not significantly decline over time, $F(1, 62) = 1.11$, $p = .295$.

Item Ratings

To evaluate the effect of the goal relevance manipulation on the affective evaluation of initially neutral items, we tested whether ratings of arousal, valence, and relevance differed as a function of the feedback manipulation during the game. We conducted a 3 (goal relevance) × 2 (delay) repeated-measures ANOVA for each rating dimension.

We found main effects of goal relevance for relevance, arousal, and valence. The interactions of goal relevance by delay were not significant (all Fs < 1) in any rating dimension. For this reason, the results are described independently of delay.

Relevance

Relevance ratings showed a main effect of goal relevance, $F(2, 124) = 11.60$, $p < .001$. Follow-up tests revealed that items seen in the goal conducive condition ($M = 257.7$) were rated as more relevant than items seen in the goal irrelevant ($M = 241.37$), $F(1, 62) = 6.24$, $p = .015$, and the goal obstructive ($M = 224.06$), $F(1, 62) = 23.45$ $p < .001$, conditions. Items seen in the goal irrelevant condition were rated as more relevant than items seen in the goal obstructive condition, $F(1, 62) = 5.417$, $p = .023$.

Arousal

Arousal ratings showed a main effect of goal relevance, $F(2, 124) = 7.03$, $p = .001$. Follow-up tests revealed that items seen in the goal conducive condition ($M = 251.27$) were rated as more arousing than items seen in the goal irrelevant ($M = 234.39$), $F(1, 62) = 8.93$, $p = .004$, and the goal obstructive conditions ($M = 226.22$), $F(1, 62) = 9.84$ $p = .002$. Items seen in the goal obstructive and the goal irrelevant conditions were not rated as significantly different, $F(1, 62) = 1.597$, $p = .211$.

Valence

Valence ratings showed a main effect of goal relevance, $F(2, 124) = 11.00$, $p < .001$. Follow-up tests revealed that items seen in the goal conducive condition ($M = 305.89$) were given a higher valence rating than items seen in the goal irrelevant ($M = 292.96$), $F(1, 62) = 6.49$, $p = .013$, and the goal obstructive ($M = 274.73$), $F(1, 62) = 17.974$ $p < .001$, conditions. Items seen in the goal irrelevant condition were given a higher valence rating than items seen in the goal obstructive condition, $F(1, 62) = 6.162$, $p = .015$.

Discussion

The aim of this study was to test a specific prediction of appraisal theories of emotion: Goal relevant events benefit from a memory advantage as compared with goal irrelevant items, even if these items are intrinsically neither pleasant nor unpleasant (e.g., Sander, Grandjean, Pourtois, et al., 2005; for discussion, see Levine & Edelstein, 2009). Therefore, we were interested in investigating the extent to which goal relevance appraisal—a basic emotion-elicitation mechanism underlying the emergence of emotional responses, including physiological arousal responses (Sander, Grandjean, Pourtois, et al., 2005)—is a key determinant of memory facilitation.

Two main findings emerged, one related to the effect of goal relevance on memory performance, one to the effect of goal relevance on affective evaluations. Whereas memory performance for goal irrelevant and goal obstructive items declined over time, memory for goal conducive items remained stable over time, and, after a 24-hr delay, these items were better remembered than goal irrelevant and marginally better than goal obstructive items. With regard to the impact of goal relevance on affective evaluation, we found that the evaluation of initially neutral items changed as a function of the goal relevance manipulation and that this change was stable even 24 hr after the game task. The next sections discuss these findings in greater detail.

The main goal of the experiment was to investigate whether goal relevance has a facilitation effect on memory and whether a potential effect of goal relevance occurs at the stage of encoding or during consolidation. Our finding that memory for goal conducive items remains stable after a 24-hr delay suggests an important role of the consolidation process for the memory advantage by goal conduciveness. Our findings closely mirror the results of Sharot and Phelps (2004), where highly arousing words were less well recognized than neutral words at the immediate test but were better recognized than neutral words at a later time (see also Kleinsmith & Kaplan, 1963).

Our findings furthermore demonstrate that stimuli can acquire emotional value as a function of their goal relevance: Initially neutral items that were presented during the goal conducive condition were assessed as more relevant, more arousing, and more positive than the other stimuli after the experiment. Both the memory performance and the changes in ratings suggest that the memory effects of goal relevance appraisal may be linked to arousal-related mechanisms. According to the object-based framework suggested by Mather (2007), the arousal evoked by an object is the source of enhanced memory for emotional objects and their intrinsic features. An important aspect of this framework is that not only negative objects but positive objects have a privileged status in memory. Therefore, this framework would suggest that objects presented in the context of a reward (e.g., Wittmann et al., 2005), or of a goal conducive event, would be subject to memory enhancement because they elicit arousal. In fact, Mather and Sutherland (2011) proposed that arousal modulates the strength of competing mental representations, enhancing memory for items that dominate the contest for selective attention—a notion called arousal-biased competition. Rather than relying on subjective arousal ratings, future research should investigate whether the effect of goal conduciveness on memory observed in our paradigm is mediated by an increase in physiological arousal (McGaugh, 2000).

In contrast to goal conducive items, goal obstructive items did not lead to a lasting improvement in memory performance, which is somewhat inconsistent with a general effect of goal relevance on memory, as expected by appraisal theories. One explanation may be a failure of our goal relevance manipulation for goal obstructiveness. It is possible that items that received a "lost" feedback were not really perceived as goal obstructive. Consistent with this, participants rated the items in the goal obstructive condition as less relevant than items in the goal conducive condition. Alternatively, it is possible that the rewarding experience associated with goal conducive gain trials has a stronger effect on memory than the nongain in goal obstructive trials. Convergent evidence comes

from a study by Wittmann et al. (2005), who presented participants in a scanner with pictures of object that either did or did not predict monetary reward. After a delay, recollection and source memory were found to be better for reward-predicting pictures than for nonreward-predicting pictures. Finally, it is possible that individuals have a positivity bias in memory. For example, basketball fans have been shown to remember more positive than negative memories about games of their favorite team, and these positive events were rated as more emotionally intense than the negative events (Botzung, Rubin, Miles, Cabeza, & LaBar, 2010). This positivity bias has also been observed in aging, with older adults showing better memory performance for positive items than younger adults (Mather & Carstensen, 2005). Indeed, Mather and Carstensen (2005) have suggested that older adults use "emotion regulation goals" and are motivated to encode and remember information in ways that enhance their well-being.

Taken together, our findings are congruent with many findings that show that stimuli leading to increased arousal show memory facilitation and that this facilitation depends on processes occurring during consolidation. In contrast, our findings (and the findings reviewed earlier) are incongruent with the valence hypothesis of memory facilitation, which predicts a memory advantage for negatively valenced information.

Importantly, our findings suggest a causal mechanism that may drive increases in arousal and memory facilitation. According to appraisal theories of emotion, the appraisal of goal relevance (and of relevance in general) is the critical factor underlying the elicitation of emotions (Sander, Grandjean, Pourtois, et al., 2005). Arousal here is conceptualized as part of the emotional response following stimulus appraisal. Thus, we suggest that the appraisal of goal relevance may be a critical factor in memory facilitation, potentially mediated by an increase in stimulus arousal because of its goal relevance (*relevance hypothesis of memory facilitation*). Future research needs to measure physiological arousal, rather than relying on subjective arousal ratings.

Future research should also explore the role of attentional effects at encoding that might help explain memory facilitation for emotional stimuli (see Mather & Sutherland, 2011; Sharot & Phelps, 2004; Talmi et al., 2007). It has been suggested that emotional attention can be triggered by appraisals of relevance (e.g., Brosch, Sander, Pourtois, & Scherer, 2008; Murphy, Hill, Ramponi, Calder, & Barnard, 2010); further studies could explore whether the type of goal relevant event used here could capture emotional attention. Enhanced attention to goal relevant items could explain memory facilitation if driven at encoding, but less clearly if taking place during the consolidation phase.

Finally, future neuroimaging work should investigate the role of the amygdala, a key structure subserving emotional memory (see LaBar & Cabeza, 2006), in the effect of goal conduciveness on memory. In recent decades, various hypotheses concerning the role of the amygdala in affective processing have been tested, including the hypotheses that the amygdala is specific for the processing of negative stimuli (valence hypothesis), of highly arousing stimuli (arousal hypothesis), or of stimuli appraised as relevant given the current individual's goals, needs, and values (relevance hypothesis; for review, see Cunningham & Brosch, 2012; Sander, 2013; Sander, Grafman, & Zalla, 2003). Thus, future experiments should use functional MRI to test whether enhanced memory for goal conducive events is indeed accompanied by specific increases in amygdala activity.

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