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Mood-dependent memory

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Have you ever noticed that when you are in a bad mood the whole world seems to be against you? More negative things seem to happen, and you even remember past episodes of your life in a more negative way than usual. Most of us have experienced this phenomenon, but few will have thought about how this mood might interact with our ability to remember. In a recent paper, Susanne Erk *et al.* shed light on a possible neural basis for this phenomena.

Research dating back at least to 1917 (see [1] for an early review) shows that a person's mood at any given time has a strong influence on which aspects of the environment seem most salient, on what is remembered about the past, and on what is encoded about the present episode. Two memory effects relevant to these observations are called mood congruence and mood dependence [2,3]. The first is a phenomenon in which emotional material is remembered more reliably in moods that match the emotional content of the memories (see Fig. 1a). Remembering all of the negative events of our past lives when depressed is an example of mood congruence. Mood dependence on the other hand, is the facilitation of memory when mood at retrieval is matched to mood at encoding (see Fig. 1b). In mood dependence, remembered material normally has a neutral emotional valence.

Studying mood and memory

Studies of the interaction between mood and memory have traditionally been limited to the behavioural domain, with little or nothing known about the neural processes underlying the effect. However, recent neuroimaging studies examining the influence of emotional context on encoding and retrieval have produced data relevant to this question. One such paper, by Erk, Kiefer, Walter and colleagues, shows that the strength of activity associated with the emotional context at encoding correlates with the probability of correct recall [4]. It is important to note that unlike previous investigations, which have examined brain activity associated with memory for *emotional* stimuli (e.g. [5,6]), the stimuli encoded in this study were *neutral* words; only the context at encoding was

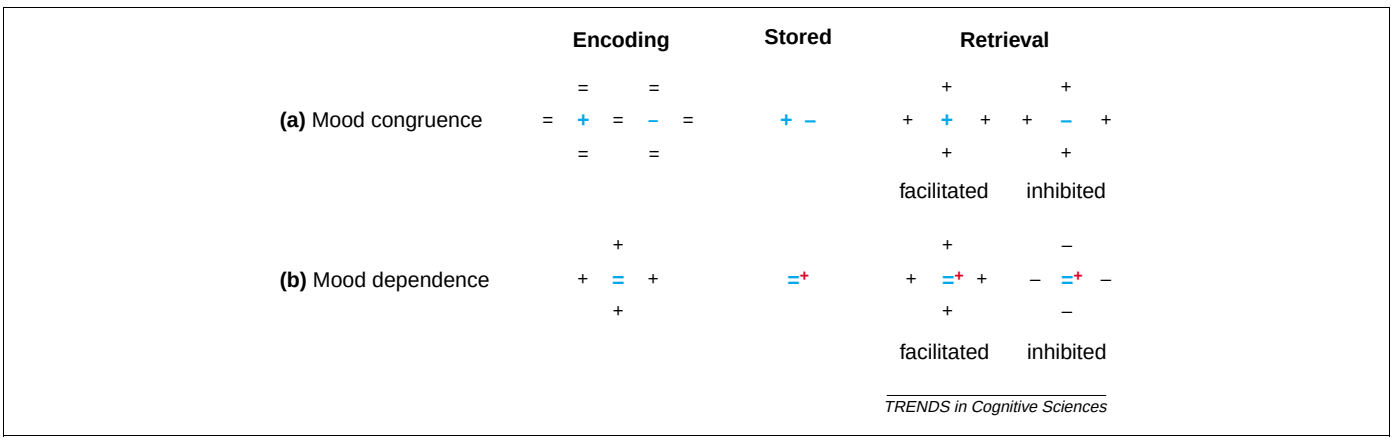

Fig. 1. **(a)** Mood congruence, the facilitation of memory for information with the same emotional valence as mood at the time of retrieval, and **(b)** mood dependence, the facilitation of memory for neutral information retrieved in the same mood in which it was encoded. In each case, incongruence is associated with inhibition. Symbols denote positive (+) negative (−) and neutral (=) emotion, and colours differentiate between encoded material (blue), ambient mood (black), and the valence of encoded material (red) that we propose becomes associated to neutral material as a consequence of the mood at encoding.

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emotional. To create this context, Erk *et al*. showed their subjects pictures taken from the International Affective Picture System. These depicted (for example) accidents, mutilated bodies, erotic scenes, or delicate foods. Subjects were then presented with the neutral words and asked to classify these as abstract or concrete. After presentation of 42 such words (in blocks of 7 with similar emotional valence) subjects were asked to recall the presented words. Two sets of 42 words were used. A subsequent memory effect (SME) analysis was then performed to determine which activity associated with specific emotional contexts predicted subsequent recall. For a positive encoding context, this analysis uncovered activity in right fusiform gyrus (among others regions), an area that, Erk *et al*. argue, has been associated with reward. For a negative encoding context it uncovered activity in right amygdala, an area frequently associated with negative emotion, although also believed to be involved in processing positive emotions [7].

Why is this result interesting to the study of how mood influences memory? Although the authors specify that they did not block emotionally valenced trials in order to induce mood, it is very likely that this arrangement did lead to mood induction. Previous studies have successfully used similar paradigms for exactly that purpose (e.g. [8]). The emotional context related SME results which Erk *et al*. report might well therefore relate, at least in part, to mood at encoding. This result not only suggests a neural basis for the influence of mood at encoding on subsequent recall, it also suggests that this influence is associated with activity in emotion specific regions of the brain.

The semantic-network approach

One popular psychological model of the interaction between mood and cognitive processes is the 'semantic-network approach' [9]. This proposes that emotion-specific memory nodes connect many related aspects of an emotion, such as autonomic responses, expressive behaviours, and description of situations that might evoke the emotion. According to this model, excitation in any of these connections propagates to the node, and thence to the rest of the associated network. It is quite easy to imagine how this arrangement could lead to both mood congruency and mood dependency at the theoretical level. At the neural level, however, several assumptions must be made before the model can begin to sound feasible.

The first assumption is the idea that recall of information while in a specific mood, or of information with a specific valence, leads to activity in the emotional system corresponding to that mood or valence. Results showing involvement of amygdala in recall of emotionally valenced information [6] provide some support for this idea by illustrating a functional role for this structure in retrieval of emotional memories. In the case of mood, the situation is less clear. To our knowledge no study to date has specifically examined the influence of mood at encoding on brain activity during recall. However, at least one study examining something quite similar does exist [10]. Maratos *et al*. showed that the emotional context in which neutral words are encoded was reflected in the pattern of activity observed at retrieval. Specifically, brain regions associated with the emotional system were differentially activated by recall of information encoded in negative (left amygdala) or positive (bilateral orbitofrontal cortex) contexts. Exposure to retrieval cues thus elicited memory for encoding circumstances, apparently including memory of emotional context. As Maratos *et al*. used emotionally valenced sentences as context at encoding, it is not clear whether similar results would be observed for mood, and this question should be examined more directly.

The second assumption for consideration is the idea that mood at retrieval also influences the emotional system. This influence would have to be such that a mood matching the emotional valence of information to be retrieved leads to activity in at least parts of the same network as retrieval of that information would. Some support for this idea has been provided by neuroimaging studies of mood. For instance, Baker *et al*. [11] observed lateral orbitofrontal cortex activity in both positive and negative relative to neutral moods, with midbrain activity increasing in the positive mood only and rostral medial prefrontal cortex activity decreasing in the negative condition only. Other studies have shown amygdala activity corresponding to the degree of sadness induced by a mood induction procedure [12], and with both happy and sad mood induction [13]. However, it should be noted that these data do not provide any real support for the idea that a positive network is more active in happy moods and a negative network more active in sad ones.

Relating the semantic-network to mood-dependent memory

If we temporarily ignore the fact that support for our two assumptions is very shaky, we can think about how they relate to semantic-network theory. Under this framework mood-related activity at retrieval can be expected to propagate to the nodes associated with memory for the congruently valenced encoded information, thus bringing these nearer to some critical threshold for retrieval and providing a mechanism for mood congruency. It is even possible that propagation of this sort suppresses nodes associated with oppositely valenced encoded information, making this harder to remember (Fig. 1a). For mood dependency, the situation is very similar, except that the findings of Erk *et al*. and Maratos *et al*. are crucial. Taken together, these suggest that the valence of mood at encoding may become associated with the otherwise neutral stored information (see Fig. 1b, red symbols). Activity in the emotional network which is elicited by mood at retrieval could then propagate to the nodes associated with mood at encoding, leading to the same facilitation or suppression effect proposed for mood congruency.

Topics for further research

Unfortunately, we must acknowledge that support for the assumptions of the semantic-network approach is still extremely weak. First, although the emotional system appears to be involved in retrieval of emotionally valenced information, it is not clear that this involvement differs for positive and negative valences in the way our model would predict. Second, it is not clear that positive and negative

moods at recall lead to activity in corresponding positive and negative emotional networks. And third, it is not clear that emotional system activity due to mood could interact with emotional activity associated with recall, and facilitate it as predicted. In short, much work remains to be done in the process of testing this hypothesis.

But the good thing about this situation is that it calls for a series of interesting experiments. For instance, a study that manipulates mood at both encoding and recall of neutral information, and searches for a mood-related emotional SME for which parallel activity is also observed at congruent (but not incongruent) recall, would be a welcome examination of mood dependence. For mood congruency, a similar study, but with positive and negatively valenced material encoded in a neutral mood would be appropriate. Of course, any such research is bound to have its frustrations, so experimenters will have to remember not to get too moody about any problems encountered or they might find themselves congruently forgetting about the successes of their field!

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Research Focus Response

Content, context and cognitive style in mood–memory interactions

Response to Lewis and Critchley

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In their comment [1] to our recently published fMRI study, Lewis and Critchely formulate some hypotheses on mood-congruent and mood-dependent memory and suggest future experiments. We here clarify some overlooked details relating to the importance of cognitive style in memory tasks influenced by emotion. Our study set out to investigate the influence of emotional context on the subsequent memory effect (SME) [2]. The SME is defined as the difference between the brain responses during encoding to subsequently remembered and forgotten items (see [3] for review). Note, however, that we did not use any mood-induction procedure during retrieval and thus tested neither mood congruence nor mood dependence directly, as defined by Lewis and Critchley.

We think that the proposals for new experiments put forward by Lewis and Critchley are worth pursuing. However, they have overlooked a crucial aspect motivating our design. We refer to the cognitive styles in memory tasks, which are dependent on mood. According to the theory proposed by Fiedler [4] different affective states trigger different adaptive functions. Positive affective states support assimilation, whereas negative states support 'accommodation', as defined in Piaget's theory of cognitive development. Accommodation is a stimulus-driven, bottom-up process by which organisms adapt to the stimulus input. To accommodate means to assess the environment as accurately as possible. This cognitive style is ecologically important in aversive situations, which require the organism to avoid mistakes. By contrast, assimilation is a top-down process by which the organism imposes its own internal structures onto the environment. Thus, assimilation means to actively transform the input according to internal schemas and structures. This cognitive style is ecologically important in appetitive situations, which induce exploration in organisms required to entertain creative behaviour.

There is strong empirical evidence for the association of these cognitive styles with different affective states (review in [4]). As mood congruency is by definition an assimilative phenomenon that reflects the activation of mood-congruent knowledge structures in memory, it follows that mood-congruent memory effects are stronger

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