Towards a computational model of affective memory

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Hear a sad song and remember a sad time. This phenomenon has been researched for decades, but not always with convincing or reproducible results. Mood-congruent memory is described as recalling memories that have a similar valence to the current mood. The relation between mood and memory appears to be a fickle beast, with results often not reproducible (Bower& Mayer, 1985). Also, a correlation between mood and memory is even less likely to appear in natural moods (as opposed to induced moods) and the results are relatively weak when they do appear (Mayer 1995). However, Mayer did find a higher correlation with mood-congruent judgment - information that is mood-congruent has a greater influence on judgments.

One flaw in most of the studies is that the memories being retrieved often had little to no semantic content. Subjects are often asked to simply recall words (Bower 1981; Brown & Taylor, 1985; Clark & Teasdale, 1985). However, some retrieval tasks involved narratives (Bower, Gilligan &Monteiro, 1981) or personalmemories (Madigan &Bollenbach, 1982; Miranda &Kihlstrom, 2005). The richness of these memories leads to better recall. Mood-congruent memory tasks have also included category recall, which should also be more reliable than word recall because categorization preserves the structure of the exemplars (Kuehne et al., 2000).

Early on, a semantic network model was proposed to describe this phenomena (Bower, 1981), but computational implementations of this model are rare. Most computational models of emotion incorporate mood and memory, but few of these use mood to influence the contents of memory. Appraisal models typically use mood and recent memories to appraise a new situation, but the appraisal is not directly associated to any particular emotion from memory. Also, the appraisal does not cause any additional memories to be brought to mind due to similarities in their appraisal.

Memory recall is highly dependent on both feature and relational similarities between the probe and memory items (Forbus et al., 1995). Assessing mood-congruent memory must recognize the importance of the content of the probe and memories and incorporate their similarities into the overall retrieval process. As such, tasks like basic recall of words will not be addressed in depth in this paper. However, semantically rich content like narratives and personal memories provide a more complete basis for analyzing mood-congruent memory.

In this paper I propose that mood-congruent memory follows the same principles of other memory retrievals (Forbus et al., 1995). The *primacy of the mundane* and *surface superiority* criteria from Forbus et al. require that surface similarities dominate memory retrieval. I propose that congruency of moods can amplify the surface similarity. If we were to assume that events and object in memory are attributed with some appraised affective state (Ortony et al., 1990),

then these affective features of the elements in the memory can increase the surface similarity between a memory and the current situation. As a result, I also propose that the current mood is constructed from the composition of the affective appraisals of elements that are in short-term memory. When a new item is presented (e.g. a word being used to trigger a memory), the new item acquires its own appraisal value and added to the set of appraisals. It is important to note that I am proposing that each appraisal maintains its association with the object or event being appraised. The overall present mood becomes a structure composed of all of the appraisals and their associated elements. This entire mood along with the newly introduced trigger is used to probe memory. As a result, memories that can best map to the structure that includes the mood and the content of the situation are more likely to be retrieved. Similarly, others have shown that the content of the mood-inducing material influences the retrieval (Wyer et al, 1999).

Let me set the stage a little with a brief hypothetical example. Let us assume that one used some emotionally charged stories to induce a mood. For example, if one of the stories were a slightly modified version of the Karla the Hawk story(Gentner et al., 1993)such that Karla showed concern for the hunter and gratitude and hope when the hunter promised not to hunt hawks again, then residing in short-term memory is this story and admiration for Karla and the hunter and a sense of hope associated with the hunter's promise. Then the subject is given a trigger word, "chair" (used by Madigan &Bollenbach, 1982 in study 1b). Given the positive mood that has been induced, "chair" is also favorably appraised. This hedonic "chair" and the other appraisals that led to the positive view of the chair are then used as a probe into memory, mostly likely retrieving remindings of scenarios that have positive views of chairs. One may ask why not only chair and its associated valence be used in probing memory. Some research has shown that recall may be influenced by activation of concepts that are part of the mood-induction procedure (Wyer et al., 1999). This is consistent with my view that the trigger word, its appraisal, concepts from induction stories, and their appraisal collectively create the mood and content used to probe memory.

At this point, many memories have been recalled but it is unclear which one is to get selected. This is equivalent to the set of remindings that are produced from the MAC stage of MAC/FAC (Forbus et al., 1995). The second stage uses a structure-mapping engine (SME) (Falkenhainer et al., 1986; Falkenhainer et al., 1989) to find mappings between the reminding to the probe. A positive chair maps well to a positive chair. Furthermore, the mood still includes the hope and gratitude acquired from the Karla story. A reminding that includes those emotions will be preferred. For example, a memory of not being able to reach a jar of cookies but a friend holding the chair while you stood on it and reached for the cookies has a positive view of the chair and also has the hope of reaching the cookies and the gratitude towards the friend holding the chair.

There is also a bootstrapping process at work with mood-congruent memory. If recalled memories are similar both in structure and mood, then it stands to reason that we can make comparisons between the affective states just as we do with the structure of the cases being compared. Recent research has shown that simulations can infer how one would feel about a new situation given similar memories (Lui, 2003). While Lui did follow some of the principles of structure mapping theory to assess whether memories were similar, Lui failed to allow the

structure mapping to make candidate inferences from the memories to the new events. I propose that analogous reasoning can be used to infer affective relations to elements of a new event based on similar memories. Furthermore, the memories being recalled are already influenced by the current mood and thus influence the inferred affect of the new event. This is a reasonable explanation for mood-congruent judgment (Bless 1996; Mayer et al., 1995; Schwarz &Clore, 1983; Schwarz &Clore, 1996).

There are numerous computational models of affect, but few models address the role of mood on memory retrieval. The lack of computational models for mood-congruent memory may be the result of trying to use the wrong model. In this paper, I propose a similarity-based memory retrieval model that is sensitive to (1) affective expressions and mood and (2) the content of memories. I will describe some early experimental simulations I have done to demonstrate the potential of this being a model of affective memory retrieval. Furthermore, I will show how this model can also explain the link between mood-congruent memory and mood-congruent judgment.

The next section will review some of the research on emotions over the past 30 or so years, including mood-congruent memory and computational models of emotion. Next, I will discuss a model of similarity-based memory retrieval and then an engine for comparison that uses structure and analogy. The fourth section will introduce my proposed approach to mood-congruent memory. This will be followed by a description and discussion of some preliminary experiments to simulate the effects of mood on memory. The section discussespotential extensions, like how the proposed model could explain other experiments in mood-congruent memory, and possible implications and applications for this model.

Background

Background on mood

Mood is traditionally defined as an emotion that is active over a longer period of time. This time is consider to be anything from minutes to days, but most of the research discussed here will use a mood that is relevant over a period of a few minutes. A shorter activation is sometimes referred to an emotion or a feeling. A feeling is more commonly used in the context of responses to physical stimuli (James, 1884) or when referring to *sentic* responses (Clynes, 1977) resulting in the feeling of an emotion. Though the approach discussed here mostly does not rely on either a James-Lange theory or an appraisal theory approach to emotions, I will refrain from using *feeling* and keep to *emotion* and *mood*. The term *affect* will be used in a more broad sense.

Mood-congruent and mood-dependent memory

There is a long history of mood-congruent and mood-dependent memory research. Mood-congruent memory is categorized as recalling previous memories that have a similar valence. This is the situation with which we are familiar: being in a sad mood and remembering past events that are also sad. Mood-dependent memory, on the other hand, is recalling neutral information that was first learned while in the same mood as the current mood. For example,

after learning a list of numbers while in an induced mood, people recalled more of the numbers later when in a similar mood than people who were in an opposite mood (Bower 1981).

Mood-dependent memory has some interesting implications, but the research has often been maligned by various issues. This paper will focus on the role of mood-congruent memory, but the research histories of mood-dependent and mood-congruent memory are quite intertwined. Also, due to experimental methods, mood-dependent memory studies may have accidentally studied mood-congruent memory. As a result, some of the background discussed here will review both phenomena.

Early research on mood-dependent memory was characterized by inconsistent results that were often not reproducible (see Blaney, 1986 for a review). A notable failure to reproduce results (Bower & Mayer, 1985) attempted to replicate one of the more influential early results (Bower, 1981). One flaw in most of the studies is that the memories being retrieved often had little to no semantic content. Subjects are often asked to simply recall words (Bower 1981; Brown & Taylor, 1985; Clark & Teasdale, 1985). However, some retrieval tasks involved narratives (Bower, Gilligan &Monteiro, 1981) or personal memories (Madigan &Bollenbach, 1982). Recall of memories with richer semantic content will lead to greater retrieval due to the richness of the data and more sources of similarities between the probing item and the information in memory. The effect of mood-congruency on these richer memories is more interesting and should lead to more consistent results. I use a set of short narratives in my experiments.

Mood induction and natural moods

Since studying moods in a controlled environment is challenging, investigators usually rely on inducing a mood on the subjects. Techniques for mood induction ranges from hypnosis (Bower, 1981; Bower& Mayer, 1985; Bower, Gilligan &Monteiro, 1981), music (Miranda &Kihlstrom, 2005; Clark & Teasdale, 1985), pictures (Lewis &Critchley, 2003) Velten (Madigan &Bollenbach, 1982; Brown & Taylor, 1985), memory elicitation (Brown & Taylor, 1985), and posturing. Memory elicitation relies on asking the subject to dwell upon a personal memory reflecting the desired mood. Posturing requires subjects to position their face, and sometimes their body, to conform to the desired mood.

At this point, most of the studies relied on induced mood, but naturally occurring moods were rarely investigated. One exception to that is that depression had shown to have a strong and consistent mood-congruent memory effect (Blaney, 1986). Mayer et al. (1995) found a correlation between the naturally occurring mood and memories. Two memory tasks were measured. The first was a category retrieval task in which participants were asked to provide a word from the specified category that started with the given letter of the alphabet. In the association retrieval task participants were asked to provide the first word that came to mind that started either of the two given letters when provided with a key word. Figure 1 shows examples of these tasks that were provided by Mayer et al. (1995).

They found an overall correlation between mood and memory retrieval tasks, but unpleasant mood did not reveal a significant correlation. They also found an even stronger correlation between mood and judgment, which I will discuss further in a moment.

Issues with mood and memory

Getting reproducible and consistent results for the effects of mood on memory has been problematic. There are many possible explanations for the inconsistent results in mood-dependent and mood-congruent memory research. The nature of the content of recalled memories could be one source of problems. Studies often rely on content, either in the memories or the probes to the memory that lack sufficient semantic content to produce consistent memory retrieval results. Autobiographical content is often used because it usually contains content with high arousal, but it is overlooked that this content also has richer semantics than lists of words or numbers.

Category retrieval
Type of Comment: N___
Pleasant: Nice, noble
Unpleasant: Nasty, narrow-minded, naughty, negative, neurotic, no, notorious
Neutral/ambiguous: Narrative, needless, nonchalant, none, nonsense, nonverbal
Weather: C___
Pleasant: Calm, clear
Unpleasant: Chilly, cloudy, cold
Neutral/ambiguous: Cool

Association retrieval
Marriage: D/L_____
Pleasant: Delight, desire, devotion, life, love
Unpleasant: Damned, death divorce, dumb, dull, lame
Neutral/ambiguous: Daddy, license, lifetime, linger, long
Bee: H/S_____
Pleasant: Helpful, honey, sweet
Unpleasant: Hornet, horsefly, hurt, sting
Neutral/ambiguous: Hive, hover, huge, hum, small

Figure 1: Examples of mood-congruent category and association retrieval tasks (Mayer et al., 1995)

Attempts to study mood-dependent memory with autobiographical memories have been difficult because the valence of the memory is often influenced by the mood at the time of the event. However, autobiographical content has been shown to more consistently produce mood-congruent results (Blaney, 1986). Another challenge of autobiographical memories is that the mood of the memory may not always reflect the emotions that were experienced. All participants in an experiment using AffectAura gave examples where the recorded affective information did not match their memory of the event (McDuff et al., 2012). Similarly, retrospective evaluations of pain experienced by patients undergoing a minimally invasive procedure better correlated with peak intensity of the discomfort than the total pain experienced

(Redelmeier&Kahneman, 1996). Also, a symmetrical mood-congruent effect on memory is found to be more likely when considering how the memories were experienced than how they were remembered (Miranda &Kihlstrom, 2005).

Too much of the research has been solely focused on the effect of mood on memory without trying to get a better understanding of the purpose for mood's influence on memory. Mayer et al. (1995) hypothesized that the asymmetrical results they had could have been due to sad people trying to divert their attention to more pleasant memories in an attempt to repair their moods. However, in other cases it is hypothesized that depressed individuals are more likely to recall negative material in order to rebut it (Blaney, 1986). These explanations seem contradictory because we have failed to understand the role of mood in each of these cases. Similarly, Ellis and Moore (1999) have stated in a review of mood-congruent research that has been difficult to identify when mood-congruence will occur. More research is necessary to characterize the roles of mood in order to better predict when mood-congruency will occur. Unfortunately, that is mostly outside the scope of this paper.

Mood-inducing content influences memory retrieval

The effect of the mood-inducing material is too rarely considered in evaluating mood-congruent retrieval. Reviews of experiments have found that many of the mood-congruent recall effects can be explained by an inadvertent activation of concepts involved in the mood-induction process (Wyer et al., 1999). Similarly, asymmetry effects may be the result of a reliance on content that is more accessible while in a positive mood than in a negative (Schwarz &Clore, 1996). Some, however, have recognized the impact of the mood-inducing material. Miranda &Kihlstrom (2005) selected music because of its lack of explicit semantic content.

I not only recognize the effect of content on memory retrieval but rely on it. Mood-congruency is not sufficient for retrieving items from memory, but it can be used to make some memories more accessible. A preliminary result described below will demonstrate how a structurally similar memory can be made more accessible if it has a congruent mood.

Mood-congruent judgment

Judgment is often linked with memory. People demonstrate a bias towards information that is more readily available (Tversky&Kahneman, 1973). A person's mood may cause the availability of similarly valenced memories to be more available and thus alter their judgments. If the information that is brought to mind is affectively charged, it stands to reason that the affect would have influence on judgment, just as the content of what is in memory would (Schwarz &Clore, 1983). If the contents of memory are affected by the current mood, then the current mood has an effect on any judgments being made. Mayer et al. (1995) found the correlation between mood and judgment to be even higher than that between mood and memory. The mood-congruent judgment task conducted my Mayer et al. is similar to the mood-congruent tasks described above, but the participants are given a short list of choices instead of just the first letter to match. In these tasks, the mood-congruency influences which memories come to mind, which in turn influences the decisions that are made. Unlike mood-congruent memory

tasks, the judgment tasks focus on a more pragmatic application of mood-congruency. It is this pragmatic application of mood-congruency, I suspect, that leads to the higher-correlation.

It is clear that mood plays an important role in judgment, and I will extend this to appraisals. My second experiment described later in this paper will demonstrate how a candidate inference resulting from a structure mapping can simulate mood-congruent judgment. Additionally, the judgment being made is the appraisal of an event in a situation.

Background on computational models of affect

For most computational models of affect, recent memories serve as a source of information to appraise new information. However, they do not address the role of other memories that have been brought into short-term memory as a result of the emotions associated to what is already in memory. They use memories exclusively as a source of information for appraisal and not as the result of appraisal. For example, SoarEmote views mood as a "summary of recent situations" (Marinier& Laird, 2007). EMA uses a causal representation of recent events to encode memory. However, their appraisal model focuses on the relationship between the agent and the environment and not the agent's internal affective state (Marsella&Gratch, 2006). While it is important to use mood and recent memories to appraise a situation, the model is incomplete unless it also uses mood to affect which memories are brought into memory and have an influence on the appraisal.

Bower (1981) was one of the first to propose an activation network to explain the phenomena of mood-congruent memory retrieval. In his description of the model, he suggests that an induced mood causes a persistent activation of the corresponding emotion nodes. This persistent activation causes the strength of the activation of related nodes to grow. In addition, nodes of opposing emotions are inhibited, making their associated nodes less active. The following are two recent models that use elements of the activation network found in ACT-R to explain some of the effects of affect on memory.

Cochran et al. (2006) have simulated the effects of arousal on memory retrieval. Their results fit with an experiment in which participants learned word/number pairs. The experiment found that recall performance increased over time with high-arousal words. To simulate this effect, Cochran et al. modified the decay parameter to be a growth parameter in the cases of high-arousal. Since a growth parameter could cause the high-arousal to get activated to the point that all other nodes are inhibited, they have an arbitrary growth threshold of 45 minutes. Their results fit the experimental data, but their approach is not well generalized. Furthermore, focusing solely on activation ignores the other valuable dimensions of emotion. Most 2-dimensional models of affect include arousal and valence. Mood-congruent memory relies on the valence of the content. Valence was not addressed by Cochran et al. Also, the experiments and simulation looked at isolated word/number pairs and not mood at time of encoding and recall.

Another simulation that focuses on arousal provides an alternative explanation of the Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994). Fum et al. (2004) propose that the normal control subjects in the experiment have increased activations as the result of

higher arousal events like losing a large sum of money. The subjects with orbitofrontal cortex lesions do not experience this heightened arousal, and as result do not have the corresponding memories activated as much as the normal subjects. The higher activation in the normal subjects leads to the memories being more accessible during future decisions.

One interesting aspect of this study is that addresses the biasing effect of emotion on decisions. However, their model does not go beyond availability of memories and does not address the role of mood or valence.

Using arousal as the basis of memory recall has been controversial. Ellis and Moore (1999) provide a review of much of the research that argues that the critical mechanism is cognitive priming and not arousal. In the model I propose below, arousal is ancillary but the focus is on the valence of the mood.

Similarity-based memory retrieval

MAC/FAC and SME

Models of similarity-based memory retrieval have simulated various aspects of human memory retrieval (Forbus et al., 1995; Thagard et al., 1990). Memory retrieval uses a probe to compare against items in long-term memory and to find the most similar ones. Remindings in memory may be similar in both structure and features; this is called a literal similarity. If the comparison with the reminding results in only attributes being alike, then this is a surface similarity. Relational matches result in an analogy. Forbus et al. (1995) outlined six criteria for simulating human-like memory retrieval:

- *Structured representation* - must be able to store a structured representation
- *Structured mapping* - must be able to map between representations
- *Primacy of the mundane* - literal similarities are most easily retrieved
- *Surface superiority* - surface similarities are commonly retrieved
- *Rare insights* - occasional occurrence of relational remindings
- *Scalability* - must be able to handle large memory sets.

MAC/FAC demonstrates a computational model of analogical memory retrieval that satisfies all of these criteria. Additionally, simulations were most likely to retrieve literal similarity matches, followed by surface similarities, analogies, and finally first-order relations. These results match the recall preferences seen in human experiments (Forbus et al., 1995). MAC/FAC has been applied to numerous problems, including conversational response generation (Forbus&Kuehne, 2007), transfer learning (Klenk&Forbus, 2007), and learning relationships in sketches (Forbus et al., 2005).

MAC/FAC is a two stage processor to retrieve remindings given a probe item. The first stage does a quick calculation to determine potential matches. To do this, it first constructs from the probe a content vector that contains a count of all of the entites and relations. Using a content vector of each item in LTM, it calculates a dot product to find the closest matches. The memories that are most similar to the probe are passed onto the second stage (Forbus et al., 1995).

The second stage, FAC, uses an analogical processor, SME (Falkenhainer et al, 1986; Falkenhainer et al, 1986), to structurally compare the probe item to each memory that passed through the first phase. SME implements the analogical comparison process described by structure mapping theory (Gentner, 1983). The process finds a structural alignment between two representative cases, where the alignment satisfies to two primary constraints. The first constraint, *structural consistency*, requires that mapped elements must be in a *one-to-one correspondence* and that a *parallel connectivity* maintains correspondence between arguments of a mapped predicate. The second constraint, *systematicity*, looks for lower-order matches that are connected by higher-order relations, such as causal or mathematical relations. Systematicity represents a bias towards mappings that have greater coherence and more predictive power as the result of a deeply interconnected structure. People prefer analogies that exhibit a larger structure and yield a greater systematic interpretation (Clement and Gentner, 1991).

In an analogical comparison, people are able to transfer information about the base of the comparison to the target (Gentner&Markman, 1997; Hummel &Holyoak, 1997). Systematicity naturally leads to potential predictions that can be made about the target of the comparison. Candidate inferences are projections from the base to the target of the domain. These inferences are propositions that are part of the overall structure of the base but are not yet present in the target. In Experiment 2 of Clement and Gentner (1991), subjects preferred inferences about the target that followed from a shared causal system. Systematicity also has shown to be a good indicator for which case in a comparison is the prefered based domain. A greater systematic structure in the base domain allows people to use it to structure the less systematic case (Bowdle and Gentner, 1997).

One powerful implication of candidate inferences generated by SME is that ability to create new knowledge. As a result of the comparison with the base case, information from the base case is projected onto the target case. People often do not distinguish between information that is found in the target and that which was inferred. Participants in a study by Blanchette and Dunbar (2002) consistently included analogical inferences in descriptions of the target. Similarly, I expect appraisals of analogous memories that are recalled would be projected onto a current situation and adopted as the appraisal of the current situation.

Experiments with MAC/FAC

Simulations with MAC/FAC evaluate its ability to satisfy the six constraints described above. For these experiments, the Karla the Hawk story set serves as a standard set of materials for assessing analogical processing (Gentner et al., 1993; Forbus et al., 1995; Gentner et al., 2009). Since I also use these stories in my experiments, I will provide more detail on these stories and related experiments.

The Karla the Hawk story set consists of the original story and four variants that contain specific commonalities with the original. The LS (literal similarity) story shares both higher-order structure and object attributes with the original story. The SF (surface similarity) story shares many object attributes but lacks most of the higher-order structure found in the base story. Conversely, the AN (analogy) story shares higher-order structure with the base story but lacks

commonality in object attributes. Lastly, the FOR (first-order relations) story differs in both attributes and higher-order relations.

The setup of the experiments had the base story along with a set of distractors stored in memory. Each variant is then used to probe the memory and attempt to retrieve the base story. Multiple story sets and sizes for the set of distractors in memory were tested. Results matched human experiments in that the base story was most likely to be retrieved when using the LS story as a probe. The SF story was next most likely to retrieve the base, followed by the AN and FOR stories.

In addition to simulating human preferences in memory retrieval, MAC/FAC has been successfully used in a range of applications. Retrieving similar exemplars from analogical abstraction has been achieved using MAC/FAC (Gentner et al., 2009). Also, transfer learning for problem solving has been facilitated by a retrieval of solutions to similar problems (Klenk&Forbus, 2007). The work of Klenk&Forbus is currently being extended to account for the roles of affect in problem solving.

Proposed model

I propose a model of mood-congruent memory retrieval that utilizes all of the relevant emotions along with the content of the probe and the memory. While mood is commonly defined as a longer lasting emotion, often the result of repeated shorter-term emotion, I propose a slightly different definition. Mood is the composition of all the emotions associated to the various agents, objects, and events involved in a situation. Appraisals of these portions of a situation are common in appraisal theory and best seen in the OCC model (Ortony et al., 1988). My definition does not necessarily contradict the more common definition, but it is in contrast to many of the computational models of affect that aggregate emotions to construct a mood and lose the individual appraisals lose their association to the content of the situation (Gratch&Marsella, 2004; Marinier& Laird, 2007).My definition of mood is especially in contrast to the one found in SoarEmote, which treats mood as a trailing indicator of recent emotions (Marinier& Laird, 2007).

It is important to maintain the relation to the content because the content often plays just as significant of a role in retrieval. Also, the emotions are often linked into the overall causal structure of a situation (Gratch&Marsella, 2004). Also, while a mood may be generally positive, a person may still feel mixed emotions. Picard (1997) gives an excellent example of this with UtaPippig winning the 100th Boston Marathon. Pippig's situation at the end of the race was that she recently completed the race, felt happy about winning but also felt surprised she won. She also felt physically tired and was also concerned about her fellow competitors. Her memory of the situation will likely have many associated emotions. Some of these emotions will relate to each other. Her elation at winning may be magnified by her surprise of winning, and the gratification will be in contrast to the pain during the race. But that pain still led to the eventually joy of winning. The dislike for the physical discomfort she had endured did not lead her to winning, but the resolve to run through the pain led her to winning. Her memory of the event will reinforce the notion she probably already had that enduring through pain can lead to winning and happiness.

Similar to models that aggregate recently felt emotions to compile a notion of mood, my proposed model does account for frequency of an emotion. However, my model represents this frequency as multiple relations to elements of the situation. By capturing the mood with both entities and relations, we can use a memory retrieval system that is sensitive to both the structural and surface properties to find similar memories. MAC/FAC is able to simulate human behavior of mood-congruent memory by finding memories with similar content and attempting to align the structures of the mood and content in the probing situation with that of the memory.

Given a new situation, which will be a new probe to memory, the situation is first appraised to associate any new relevant emotions to elements of the situation. For example, when Karla the Hawk realizes that the hunter simply wanted her feathers, she feels sad. This appraisal may be influenced by other emotions in memory. When the hunter promises to not hunt hawks again, she recognizes his happiness and becomes hopeful. Note here that Karla's hope and sadness are directly related to events occurring. We capture this association with a causal relation between the event and the appraisal.

Once a situation has been appraised, it is ready to be used for retrieval of similar memories. MAC/FAC will first need to construct a content vector of the situation. In addition to the standard content of the situation, the vector will now need to also incorporate the emotions and their relations. No changes to MAC/FAC are necessary to do this because the emotions are simply represented as entities and relations that MAC/FAC recognizes. For example, Karla's expression of sadness is represented as the following:

(cause (realize Karla (desire man1 feathers)) (equals (sad Karla) high))

The experiments that follow use the Karla the Hawk stories. For these experiments, I am assuming that a person's appraisal of a situation would be represented similarly to one of these stories that has been modified to include these appraisals. Further experiments would be necessary to verify this assumption.

Experiment 1

In the first experiment, I used a similar setup to the MAC/FAC Experiment 1 from Forbus et al. (1995). I put 33 stories into memory. One of the stories was an adaptation of the original base Karla story. Coincidentally, the story already included one affective expression, the happiness of the hunter upon receiving feathers from Karla, but one affective expression does not constitute a mood. The memory needed to include a few more affective expressions related to the story. A couple more affective statements were added, and then the mood of the memory can be summarized by this small set of emotions related to the story.

The original variants (literal similarity, mere appearance, and analogy) were first used to probe the memory and verify the previous results. Then I modified each of the variants to add affective elements, as I had done with the base story in memory. However, these added affective statements capture only a portion of the current mood. The mood must also include the emotions relating to recent memories. To replicate this, a few more affective statements are added to each of the probe stories. All of the modified stories can be seen in Figure 2. The

bolded words are the added portions, and the underlined words identify the affective expressions. The additions to the stories were encoded in predicate calculus, which can be seen in the appendix.

To verify results will be consistent with original experiments with MAC/FAC, I used each of the original variants to probe the memory. In all cases, the base story was successfully retrieved. It was also the only case to be returned from the MAC phase. The FAC phase provided a score evaluating the structural similarities of the stories. These results are as expected, with the LS and AN stories being scored significantly higher than the SF and FOR stories.

Table 1: Similarity scores for the original stories

Variant	**Score**
literal similarity	4.8690
analogy	4.8285
mere appearance	2.3850
first-order relations	2.2530

I then replaced the base story in memory with the modified version that has the additional affective expressions. Using the affectively-modified variants of each of the stories as probes, MAC/FAC again retrieved the base story. The similarity score generated reflects the increased similarity between the stories as a result of the added affective expressions.

Table 2: Similarity scores for the affectively-modified stories

Discussion	**Discussion**
literal similarity	5.1240
analogy	5.0180
mere appearance	3.0152
false analogy	Not tested

I then added the affectively-modified variant of the analogy story to the memory. Using the original literal similarity story, the one without the added emotions, the base story was retrieved but the analogy was not. I then used as a probe into memory the literal similarity with the additional affective expressions. The base story was retrieved, as expected. A little more surprising is that the analogy story with the similar affective expressions was also retrieved. In the first case, there was not enough similarity between the original literal similarity story and the

modified analogy story for the MAC phase to bring it into consideration. In the latter case, the similarity in the moods (from the similar affective expressions) resulted in the MAC phase finding sufficient similarity between the stories for it to be passed onto the FAC phase.

Base Story

Karla, an old hawk, lived at the top of a tall oak tree . One afternoon, she saw a hunter on the ground with a bow and some crude arrows that had no feathers . The hunter took aim and shot at the hawk but missed . Karla **was sad for the hunter because she** knew that hunter wanted her feathers. She glided down to the hunter and offered to give him a few . The hunter was so grateful that he pledged never to shoot at a hawk again. He went off and shot deer instead. **Karla was hopeful that the hunter would keep his promise.**

Literal Similarity

Once there was an eagle named Zerdia who nested on a rocky cliff. One day she saw a sportsman coming with a crossbow and some bolts that had no feathers. The sportsman attacked but the bolts missed. Zerdia**was sad for the hunter because she** realized that the sportsman wanted her tailfeathers so she flew down and donated a few of her tailfeathers to the sportsman. The sportsman was pleased. He promised never to attack eagles again.**Zerdia was hopeful that the hunter would keep his promise.**

Analogy

Once there was a small country called Zerdia that learned to make the world's smartest computer.

One day Zerdia was attacked by its warlike neighbor, Gagrach . But the missiles were badly aimed and the attack failed . The Zerdian government was sad for the people of Gagrach because they realized that Gagrach**only** wanted Zerdian computers. It offered to sell some of its computers to the country. The government of Gagrach was very pleased . It promised never to attack Zerdia again. **The Zerdian people were hopeful that their generous gift would be remembered and that Gagrach would keep its promise.**

Mere-Appearance

Once there was an eagle named Zerdia who donated a few of her tail feathers to a sportsman so he would promise never to attack eagles. **Zerdia was hopeful that her generous gift would be remembered and that hunter would keep his promise.**

One day Zerdia was nesting high on a rocky cliff when she saw the sportsman coming with a crossbow .Zerdia**was glad to see the man and** flew down to meet the man, but he attacked and felled her with a single bolt . As she fluttered to the ground Zerdia**became disappointed as she** realized that the bolt had her own tail feathers on it.

Figure 2: Affectively-modified versions of the Karla the Hawk stories

Experiment 2

In experiment 2, the base story remained the same, but the probes were slightly modified. One affective statement in each story was removed. The removed statement was not one that was

added to represent the mood surrounding the story. Instead the emotion removed was moreintegral to the story. The story with the missing affective expression was then used to probe the memory. Despite the missing expression, the remindings retrieved did not change from Experiment 1. What did change is that a new candidate inference was now produced. This inference used the affective expression in the base story to project a possible affect in the probe story. The inferred affective expression exactly matched the expression that was removed.

I created another variation of the literal similarity story that has the added affective expressions except for one. I predicted that the missing affective expression would be inferred from the base story. The probe story was missing the expression of hope seen in the base story, but SME produced a candidate inference for the target story for the expression of hope. To verify that this inference was not the result of the high similarity of the stories (since the stories had both surface and structural similarity), I also tested using a variation of the analogy story that also was missing the expression of hope. SME again produced a candidate inference for the expression of hope in the analogy story.

Discussion

Experiment 1 demonstrates the influence of mood on memory retrieval. Memory retrieval still respects the established criteria, including the primacy of the mundane and surface superiority. This illustrates that the content of the memories is still the greatest influence on memory retrieval. However, mood can make some memories more accessible. As a result, the mood-congruent memory of the analogy story is more readily available than it was without the mood expressions. This demonstrates how the collection of emotions in the probe along with recent emotions come together to create a mood, and how this mood along with the content of the probe lead to remindings that are both similar in content and mood.

Furthermore, this also demonstrates the possibility of mood leading to the retrieval of more useful memories. Analogous remindings are often more useful (or sound) (Clement &Gentner, 1991; Gentner&Markman, 1997). We can see that if the mood of the analogous memory better aligns with the current mood, the analogy is more easily retrieved and thus more accessible. Conversely, this also means mood can have a debilitating effect when the mood more closely matches remindings that have only a surface similarity. The congruent moods will effectively amplify this similarity and prevent other remindings. These remindings may be less useful, and I suspect could lead to false inferences.

Experiment 2 continues to show the effect of mood-congruent memory. However, it also shows the potential influence these memories have on understanding the current situation. The inferred emotion about the probe story demonstrates the possibility of using memories to appraise a new situation. Unlike traditional appraisal theory that will use the elements of the current situation and the mood to calculate an appraisal, this short circuits this process by allowing the memory to project its emotion on the current situation. This is consistent with the effects of mood-congruent judgments (Schwarz &Clore, 1983) in that mood-congruent memories provide information about the new situation. Also, incorrect candidate inferences could lead to the misattribution seen by Schwarz &Clore. Further experiments are necessary to

verify that misattribution could be explained in this way, but it stands to reason that if the memory has certain attributions for an emotion then there would be an inference for this in the target if the target does not have one. The attribution found in the memory may not be relevant to the current situation, but the congruent mood has brought the memory to mind. The memory then has potential to project knowledge onto the current situation.

There is at least one other example of recalled stories altering the knowledge about a new story. Participants in a study by Blanchette& Dunbar (2002) falsely provided identified details as being true about the target story. These details were not present in the story and instead were erroneously inferred from another story the participant had read.

Using analogous stories from the past to infer the reaction to a new story has also been demonstrated by Lui&Maes (2003). They analyzed personal texts (consisting of blogs, instant messages, and more) to construct frames representing an episode and their affective evaluation. When given a new episode, they compared[1] it with those from the past to find similar ones. Based on these similar emotions, they could predict how the person would feel about the new situation. However, they could best predict arousal for the new situation and more difficulty predicting pleasure and dominance. When capturing the affect of an episode, they did not encode the specific relation of the affect to the episode. This may have led to troubles in properly identifying more than arousal in the target episode.

To better assess the influence of mood-congruent memory on judgment, I propose a future experiment that follows a similar setup to that of Blanchette& Dunbar (2002). Participants read a set of stories and after each story are asked to record how they feel about an agent or event in the story. Later, participants read a new story that is analogous and is likely to evoke similar emotions. First, we verify the Blanchette& Dunbar results that participants will associate to the new story information that has been inferred from a base story. Next, we ask the participant to identify how they feel about a particular agent or event in the story. Finally, we check for correspondence between the appraisal in the base story and that in the target story. I would also be curious to find out the impression a participant has about the target story before any further questions are asked. Perhaps the questions will cause them to recall the stories that are similar in structure and mood, and it is then that their attitude to the target story is influenced by the base story.

Extensions and Applications

Extending this to categories

In Mayer et al.'s experiments on category retrieval, subjects were asked to give a word that started with a specified letter and fit the provided category. Examples they provided are

[1] An earlier, unpublished, version of their paper cites structure-mapping as the guiding principle in finding similar episodes from memory.

given in Figure 1. MAC/FAC has been used for construction and retrieval of categories (Kuehne et al., 2000). The process of mood-congruent memory retrieval could be extended to handle this task in the following way. The first step is memory retrieval of a category. When the category is being learned, the mood of the exemplars will affect the contents and the construction of the category. I would expect then the possibility of separate categories for the different moods in combination with the categorized concept. For example, the "type of comment" category may be actually at least two categories. One category includes more positive, or pleasant, notions of a comment. The other category has the unpleasant examples of a category. The neutral or ambiguous types of comments may be standalone exemplars, form their own category, or get bunched in with the other categories. In the context of mood-congruent memory, these latter types are irrelevant.

If we can assume that different categories are created for each affect/comment combination, then the next step is to retrieve this category. Given the current mood and the expression "type of comment", we can use the process described above to see how the more mood-congruent category would be retrieved. Once the correct category has been retrieved, selecting an exemplar from this category that matches the provided pattern is basic reasoning and is not influenced by mood.

Extending this to word association

Word association tasks can sometimes be viewed as a category task. When given a name for a collection of related items, children have shown a preference for choosing items in this category (Gentner& Medina, 1997). As I have described above with the category task, separate categories for different mood/word combinations may be formed. Retrieving the category that best matches the mood can be done with the process I have outlined in this paper.

Some word associations are not necessarily category based. Mayer et al. (1995) used “bee” as a keyword and asked participants to pick another word that started with either a “H” or “S”. Many people will select “honey”, which they have categorized as a pleasant response. This could possibly be explained with the following. Given “bee”, the internal knowledge structure for the concept of a bee is initially retrieved. The concept of a bee may include that it produces honey, lives in a hive, moves in a swarm, has queens and workers, and are yellow and black. Each item in this knowledge structure is compared with the provided pattern. Additionally, the mood of the current situation is compared with any affect related to the concept being compared. Honey will typically be associated with pleasant memories and thus have many positive affective expressions related to it. A person in a pleasant mood is then more likely to respond with “honey”. But a hive could be associated with the comforts of a home and possibly be the retrieved word (“hive” is classified as ambiguous). The question is what leads one to choose “honey” over “hive” if a person relates both of these to pleasant feelings. I argue that in addition to the mood of recent memories that put the person in the current mood, the content of these memories also influence this decision. Experiments are necessary to show whether a person is more likely to choose “honey” after just eating something sweet or answer “helpful” after engaging in a cooperative task.

Extending this to mood-dependent memory

As described above, mood-dependent memory is difficult to study. Despite these challenges, I believe that the process described in this paper would work just as well for mood-dependent memory. One of the greatest challenges in mood-dependent memory is that the neutral memory contents often get tainted by the mood at the time of encoding and no longer are neutral. My approach maintains the neutral content but also represents its association to the mood moment. The similarity in moods between the time of recall and the time of encoding will result in a greater surface similarity of the situations and increase the probability of the memory being retrieved.

Mood-dependent memory has some interesting implications in pedagogical environments where the content being learned is often assumed to be neutrally valenced. Also, the information being learned often needs to be easily retrievable and applied to a new situation. Analogical retrieval and inference can be used to explain this transfer process. However, analogs are not always readily accessible because the lack surface similarities. If a similar mood can be used to amplify the surface similarity of the cases, analogs could become more accessible and more likely to be retrieved.

Other possible implications and applications

There are many other possible implications and applications of mood and memory. I have only briefly touched on mood-congruent judgment. This is an area that is still wrought with research potential. One interesting avenue may be the relation between the view of affect as information (Schwarz &Clore, 1983) and informativity of an analogy (Bowdle&Gentner, 1997).

The effects of mood on memory have potential interesting applications in learning, transfer, and language. I have already addressed the relation between pedagogical environments and mood-dependent memory. Transfer could be enhanced by increasing the availability of analogous remindings through mood-congruency. My simulation with the target analogy story being retrieved on the basis of similar affective expressions needs to be extended and verified in human experiments. Lastly, language development could be influenced by the ability to retrieve language schema that were developed while in certain moods.

Conclusion

In this paper I have proposed a model of memory retrieval that utilizes both similar moods and similar content. A review of the mood-congruent literature has revealed many of the difficulties in producing consistent results, and I have argued that this is due in part to not recognizing the role of the content of the probe and the memory. A memory retrieval model that recognizes the importance of both of these is necessary for understanding mood-congruent memory. Using MAC/FAC I have conducted some preliminary experiments to demonstrate the feasibility of this model to explain the effects of mood-congruent memory and judgment.

Surface similarities remain the most influential force in memory-retrieval. However, these similarities can be amplified with mood congruency. The similarity scores for each retrieval were increased as a result of the common affective expressions. Furthermore, I have

shown the potential of an analogy story - which has low surface similarity - being retrieved as a result of the similarities in the moods.

Congruency of moods, which leads to recall of memories with similar moods, then can lead to judgments that are influenced by the mood-congruent memories. I have demonstrated how a memory that is similar in content and mood can project appraisals onto the current situation. No other appraisal model has attempted to use mood-congruent memories to appraise a situation. The model I have proposed here can be used to supplement the standard methods of appraisal.

The work described in this paper is very early and far from conclusive. However, there is great potential to further this work and demonstrate the effects of mood and emotion on a variety of cognitive processes. Memory plays a vital role in most cognitive processes, and understanding the effects of emotion and mood on memory brings us closer to being able toaccurately describe the influence of emotion and mood on these cognitive processes.

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Appendix

Base story with additional affective expressions
(cause (realize Karla (desire man1 feathers)) (equals (sad Karla) high))
(cause (promise man1 Karla (not (attack man1 Karla))) (equals (hope Karla) high))

Literal similarity story with additional affective expressions
(cause (realize Zerdia (desire man1 feathers)) (equals (sad Zerdia) high))
(cause (promise man1 Zerdia (not (attack man1 Zerdia))) (equals (hope Zerdia) high))

Mere appearnce story with additional affective expressions
(cause (promise man1 Zerdia (not (attack man1 Zerdia))) (equals (hope Zerdia) high))
(cause (see Zerida man1) (equals (happiness Zerdia) high))
(cause (realize Zerdia (used-for feathers cross-bow)) (equals (disappointment Zerdia) high))

Analogy story with additional affective expressions
(cause (realize Zerdia (desire Gagrach supercomputer)) (equals (sad Zerdia) high))
(cause (promise man1 Gagrach (not (attack man1 Gagrach))) (equals (hope Gagrach) high))