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Emotional State and Local versus Global Spatial Memory

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Abstract

The present work investigated the effects of participant emotional state on global versus local memory for map-based information. Participants were placed into one of four emotion induction groups, crossing high and low arousal with positive and negative valence, or a control group. They then studied a university campus map and completed two memory tests, free recall and spatial statement verification. Converging evidence from these two tasks demonstrated that arousal amplifies symbolic distance effects and leads to a globally-focused spatial mental representation, partially at the expense of local knowledge. These results were found for both positively- and negatively-valenced affective states. The present study is the first investigation of emotional effects on spatial memory, and has implications for theories of emotion and spatial cognition.

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Emotional State and Local versus Global Spatial Memory

Consider visiting a university campus and studying a large map situated near the entrance, perhaps in an effort to find the department of psychology. The map likely depicts a large amount of information, your acquisition of which is guided by your goals, intentions, and study time (cf., Brunyé & Taylor, in press). In addition to these influences, other factors such as your levels of happiness and arousal may also determine how you gather and organize map-based information in memory. The present work examines this possibility by placing participants into positive and negative affective states, crossed with high and low arousal, and testing whether these emotional states influence people's ability to gather and use information from a common spatial information source: campus maps.

The potential interactions among emotion and memory in the domain of spatial cognition remain relatively unexplored; if affective valence and arousal lead to differential processing and representation of spatial information, such findings have large theoretical and practical implications. There are several circumstances under which emotional state could play a large role in a person's ability to perform complex spatial tasks. Some examples might be a Soldier planning a mission in a remote and degraded environment, a paramedic attempting to navigate to the site of an emergency, or a young college graduate racing excitedly to a first job interview in a new city. In these and similar cases the emotional states evoked by an individual's tasks and circumstances may affect how well they are able to learn and think about environments and subsequently perform complex spatial tasks. The present work assesses this possibility, and is motivated by research in two primary areas. First, we review research suggesting that emotional state can have wide-ranging influences on attention and memory for verbal and non-verbal information, motivating our application of this work to spatial cognition. Second, we review research suggesting both the malleability of spatial memory, and the potential utility of using the symbolic distance effect to assess memory organization.

Emotional State and Memory

Emotional state can be divided into two orthogonal and bipolar continuums: valence (positive versus negative) and arousal (high versus low) (Revelle & Loftus, 1992). Inducing particular valence and arousal states can influence how people process and store information. One particular construct that has received wide attention is the levels-of-focus hypothesis, which predicts that positive and negative affective cues induce relational and item-specific processing, respectively (Clore, Wyer, Dienes, Gasper, Gohm, & Isbell, 2001). For instance, a happy mood during study in the Deese, Roediger, and McDermott (DRM) false memory paradigm increases associative semantic activation and causes individuals to produce more false memories relative to when they are in a relatively negative mood (Storbeck & Clore, 2005). Similarly, Gasper and Clore (2002) found that participants in an induced positive mood state were more likely to base object similarity judgments on global features and those in a negative mood state were more likely to base their judgments on local features. A negatively-valenced affective state is thus generally associated with a focus on local item-specific information whereas happiness tends to increase focus on global associative information (see also Basso, Schefft, Ris, & Dember, 1996; Fredrickson, 1998, 2001; Gasper, 2004; Wadlinger & Isaacowitz, 2006).

There are two primary approaches for investigating arousal influences on attention and memory. First, research can assess attentional focus and memory biases for arousing versus neutral stimuli. Much of this work finds that arousal-inducing elements of a scene produce a narrowing of attention and reduced memory for details (Easterbrook, 1959; Loftus, 1979; Loftus & Burns, 1982; Loftus, Loftus, & Messo, 1987; Siegel & Loftus, 1978). For instance, when participants view an arousing scene of a bank robbery they tend to remember fewer overall details than those viewing a relatively neutral version of the robbery (Loftus & Burns, 1982); memory for specific visual details directly within the arousing area of a scene, however, tends to be heightened (Christianson & Loftus, 1991; Kensinger & Schacter, in press; Kensinger, Garoff-Eaton, & Schacter, 2006).

A second approach, and the one used in the present work, is to place participants into high or low arousal states and investigate memory for neutral stimuli. Work in this area suggests that induced emotional arousal states can lead to global processing biases. For instance, high arousal increases associative semantic memory during word list learning, leading to high rates of false recall and recognition relative to low arousal states (Corson & Verrier, 2007). Further, post-traumatic stress disorder (PTSD) patients characterized by the presence of heightened basal arousal levels show global processing advantages and local disadvantages in visual attention paradigms, relative to controls (Vasterling, Duke, Tomlin, Lowery, & Kaplan, 2004). Finally, soccer players experiencing high arousal states demonstrate global visual attention biases and increased fluidity in switching from local to global tasks (Pesce, Tessitore, Casella, Pirritano, & Capranica, 2007).

Based on the above work, it is clear that a distinction exists between processing characteristics elicited by (and memory for) an arousal-inducing stimulus itself, versus the effects of an induced arousal state on the processing of neutral stimuli. The former may narrow attention towards and increase memory for the arousal-inducing elements of a scene, whereas the latter appears to induce global processing of otherwise neutral stimuli. Given the seemingly large effects of induced emotional state on the processing and representation of geometric figures (Gasper & Clore, 2002), word lists (Corson & Verrier, 2007; Storbeck & Clore, 2005), and

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hierarchical number stimuli (i.e., global number figures comprised of many local numbers; Vasterling et al., 2004), we hypothesize that spatial memory for maps might be similarly affected. To our knowledge only one study to date has examined the effect of emotion on spatial memory. In a picture-learning paradigm, Crawford and colleagues (2006) found that memory for the location of valenced images was biased by valence direction (positive versus negative) such that participants tended to show biases towards representing positive images in higher screen positions relative to negative images. This study provides the first evidence suggesting that valence may carry implications for the representation of spatial information. If so, such a finding holds theoretical importance towards understanding the form and function of spatial memory, and practical implications for the design and development of navigation devices (e.g., Wickens, Vincow, & Yeh, 2005). To assess this possibility we evaluate the extent to which spatial memory might be more or less locally- or globally-biased as a function of participant emotional state.

Spatial Memory

Given the identified effects of emotional state on visual attention and verbal memory, happiness and arousal may prove to play a role in how individuals memorize spatial information. Indeed recent work demonstrates that spatial memory is highly susceptible to various encoding manipulations including instructions, goals, limited study time, individual differences, and dual-task interference (e.g., Brunyé & Taylor, 2008a, 2008b, in press; Brunyé, Rapp, & Taylor, in press; Denis, 2008; Noordzij, Van der Lubbe, & Postma, 2005, 2006; Pazzaglia, De Beni, & Meneghetti, 2007).

Work with maps and spatial descriptions suggests that spatial memory is best-characterized as hierarchical, analog, and often incomplete (Denis, 2008; Denis & Kosslyn, 1999; Noordzij & Postma, 2005; Tversky, 2005). Hierarchical organization can be defined by both spatial and non-spatial information types, such as street layout, topography, coordinate axes, landmarks, neighborhoods, building functions, and even racial demographics of area residents (Brunyé, Taylor, & Worboys, 2007; Huttenlocher, Hedges, Corrigan, & Crawford, 2003; Maddox, Rapp, Brion, & Taylor, 2008). The analog organization of spatial memory has been likened to that of mental images, or structural analogues representing original perceptual experiences (Denis & Zimmer, 1992). These characteristics of spatial memory increase performance, with both higher accuracy and faster response times, when participants are tasked to compare distances between landmarks that are relatively far as opposed to close to one another (Denis, 2008; Hirtle & Jonides, 1985; Noordzij & Postma, 2005). This phenomenon is called the *symbolic distance effect* (i.e., Moyer, 1973), and has received much attention in the cognitive psychology literature, particularly with regard to the ongoing debate about the analog versus propositional nature of human memory (Borst, Kosslyn, & Denis, 2006; Pylyshyn, 2002).

In spite of the evidence that human spatial memory is differentially well-suited for proximal versus distal spatial relationship judgments, we also know that comprehensive knowledge of *both* close and far landmark locations is critical for navigation success (Foo, Warren, Duchon, & Tarr, 2005; Loomis, Klatzky, Golledge, & Philbeck, 1999). Considering the importance of accurate local and global spatial representations towards real world navigation, we are interested in the extent to which emotional state might affect local versus global spatial memory biases. If indeed emotional states can induce local and global processing biases in memory, such an effect might modulate the symbolic distance effect.

The Present Study

We ask whether changes in participant emotional state might modulate the symbolic distance effect during spatial statement verification. To do so, we crossed valence (positive or negative) and arousal (high or low) and assessed their influences on spatial memory. Participants learned a map of a large-scale environment while in one of four emotional states (or a control group) and then completed two memory tests. The first test was verbal and involved free recall, allowing us to assess the completeness and organization of verbal memory following emotional state induction. The second test was spatial and involved the verification of spatial statements, allowing us to assess performance on fine-grained local (i.e., knowledge of proximal landmark interrelationships) or holistic global (i.e., knowledge of distal relationships) spatial knowledge using both accuracy and response times.

The present procedure for assessing the symbolic distance effect is quite different from traditional procedures. Specifically, earlier work has examined participants' ability to judge whether a second of two provided distances is shorter or longer than the first, as the crow flies (e.g., Noordzij & Postma, 2005). For instance, participants would be provided with a first (e.g., "Louvre – Musée d'Orsay") and a second landmark pair (e.g., "Eiffel Tower – Vincennes"), and asked whether the second pair represents a shorter or farther distance than the first (in our example, the second pair describes a farther distance). The general finding is that greater distances between the two pairs lead to faster and more accurate judgments of relative distance. This result has been replicated across a variety of studies, and is often cited as strong evidence for the analog nature of spatial memories resulting from both maps and spatial descriptions (e.g., Denis, 2008; Denis & Zimmer, 1992; Noordzij & Postma, 2005; Péruch et al., 2006). The present study capitalizes on this finding but uses a different paradigm that is designed to allow the comparison of relatively global and local emphases in spatial memory. Specifically, the present task asks participants to confirm or disconfirm spatial statements comparing proximal and distal landmarks. For instance, a participant responds ‘true’ or ‘false’ to the statement “The Louvre is south of the Musée d’Orsay.” We expect to find an effect analogous to the symbolic distance effect in that proximal landmark interrelationships are more difficult to confirm than moderately-spaced and distal ones; this effect should be evident in our control group. With regard to the emotional state manipulation, enhanced global spatial memory should amplify this effect, and enhanced local spatial memory should attenuate it.

As reviewed above, we expect to find evidence for a symbolic distance effect in that control participants will have overall difficulty confirming the relative canonical coordinates of map landmarks when they are closer together than when moderately- or far-spaced. The *levels-of-focus* hypothesis (Clore et al., 2001) predicts that map learners should more accurately represent global than local spatial relationships when in a positive mood, perhaps amplifying symbolic distance effects found in the control group; in contrast, this hypothesis also predicts that the opposite should hold true when they are in a relatively negative mood, potentially reducing or even reversing the symbolic distance effect. However, some arousal research has suggested that many of the past studies identifying positive versus negative affect as an important modulator of attention and memory have confounded this variable with arousal (cf., Corson & Verrier, 2007; Dolcos, LaBar, & Cabeza, 2004; Gayle, 1997; Gorn, Pham, & Sin, 2001). Whereas positive mood is typically associated with high arousal levels, and negative mood with low arousal, the opposite is also possible – positive mood can be associated with low arousal (as in the case of serenity) and negative mood can be associated with high arousal (as in the case of fear or disgust). In fact, when valence and arousal are fully crossed, some work shows minimal effects of valence and reliable global focus effects with high arousal (Corson & Verrier, 2007). In line with this work, we expect that high arousal might amplify symbolic distance effects relative to neutral controls, regardless of the corresponding valence.

Method

Participants & Design

84 Tufts University undergraduates (41 female, mean age 18.4 years) participated for partial course credit. There were five groups: a control group and four groups crossing valence and arousal in a 2 (valence: positive, negative) x 2 (arousal: high, low) between-participants design. The procedures were fully approved by the Tufts University Institutional Review Board (IRB).

Materials

Mood Induction Images. 72 images were chosen from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999), eighteen for each condition. The mean ratings for the images in each condition were completely crossed in terms of valence and arousal (see Table 1). The positive valence and high arousal images depicted adventure, sports, and erotic couples. The positive valence and low arousal images depicted nature, babies, and family portraits. The negative valence and high arousal images depicted animal threats, human threats, and accidents. The negative valence and low arousal images depicted illness, pollution, and despair. As such the four image conditions are best characterized as eliciting happiness (positive valence, high arousal), serenity (positive valence, low arousal), fear (negative valence, high arousal), and sadness (negative valence, low arousal), respectively (see Bradley & Lang, 2006). The two positive-valence states are approach states and the two negative-valence states are avoidance states; arousal, however, crosses approach and avoidance. This design allows us to examine the effects of arousal without confounding this variable with avoidance (which has been found to narrow attention; Derryberry & Reed, 1998) or approach (which typically leads to a global focus; Basso et al., 1996).

To ensure that the mood induction images comprising these four conditions did not differ in visual complexity, a ratings study asked 6 naïve participants to rate each of the 72 images on a scale from 1 (very low complexity) to 5 (very high complexity). Our intention was to evaluate the likelihood that consistently evoked eye movement patterns over each of the four image sets could carry over onto map study. For instance, high visual complexity might lead to correspondingly complex eye movements that could influence eye movement activity during subsequent map study. The mean ratings for each image type were: positive valence & high arousal ($M = 3.08$, $SD = .33$), negative valence & high arousal ($M = 3.11$, $SD = .38$), positive valence & low arousal ($M = 3.13$, $SD = .31$), negative valence & low arousal ($M = 3.14$, $SD = .26$). A 2x2 repeated-measures ANOVA confirmed that the four image types did not differ in rated visual complexity as a function of valence, $F(1, 5) = .01$, $p > .05$, or arousal, $F(1, 5) = .28$, $p > .05$, and the two variables did not interact, $F(1, 5) = .11$, $p > .05$.

A second ratings study was conducted during which 6 naïve participants identified (by circling) the highest complexity region of each of the 72 images. Our intention was to ensure that the four image types did not differ in terms of whether highest complexity regions were central or peripheral. The percentages of circled responses falling into the central area of the images were as follows: positive valence & high arousal ($M = .52$, $SD = .11$), negative valence & high arousal ($M = .51$, $SD = .16$), positive valence & low arousal ($M = .51$, $SD = .09$), negative valence & low arousal ($M = .48$, $SD = .14$). A 2x2 repeated-measures ANOVA confirmed that the four image types did not differ in rated visual complexity as a function of valence, $F(1, 5) = .18$, $p > .05$, or arousal, $F(1, 5) = .19$, $p > .05$, and the two variables did not interact, $F(1, 5) = .29$, $p > .05$.

Corresponding control images were developed by randomly selecting and pixel scrambling (in 10x10 segments) 18 of the 72 images, rendering the original scenes imperceptible.

Manipulation Check. We used the Brief Mood Introspection Scale to assess the impact of the IAPS images on valence and arousal state (BMIS; Mayer & Gasche, 1988). The BMIS involves rating affective adjectives, eight of which are of interest here, corresponding to our 2 (valence: positive "happy, lively", negative "gloomy, sad") x 2 (arousal: high "active, peppy", low "calm, content") design.

Maps. Three maps were adapted from Grinnell, St. Olaf's, and Occidental campus maps (i.e., Brunyé et al., 2007). Maps were 1280x1024 in size at 200 pixels/inch. Each map included 14 labeled buildings, 6 labeled roads, and a compass rose; the three maps had similar spatial densities for landmarks ($M = 3407$, $SD = 12.6$) and streets ($M = 3797$, $SD = 28.5$), and landmarks were evenly distributed across central and peripheral map regions. We chose to use three different maps in order to increase the generality of our results.

Memory Tests. Two memory tests were used: verbal free recall and spatial statement verification.

Free recall was done on plain white paper; we chose to use verbal free recall rather than map drawing for two reasons. First, to minimize the likelihood of carry-over effects between two consecutive spatial measures, and second, to allow us to replicate general findings that valence and arousal levels do not affect overall verbal recall performance (without introducing spatial task demands) (e.g., Corson & Verrier, 2007; Storbeck & Clore, 2005).

A spatial statement verification task was created for each of the three maps, each containing 56 trials probing for canonical (i.e., N, S, E, W) landmark interrelationship knowledge (e.g., *Harris Center is north of Steiner Hall*). Nineteen of the trials related landmarks relatively close to one another (proximal), 18 medium distance (medium), and 19 far (distal)[1]. No single landmark to landmark relationship was repeated, and each landmark was related to a total of four others. For each of the three maps, the proximal, medium, and distal comparisons differed from each other in inter-landmark distance as measured from center points on each landmark: Grinnell (proximal: $M = 1.06$, $SD = .14$; medium: $M = 2.39$, $SD = .72$; distal: $M = 3.78$, $SD = .39$; $F(2, 55) = 154.84$, $p < .01$; all t-test p's $< .01$), St Olaf's (proximal: $M = 1.1$, $SD = .24$; medium: $M = 2.24$, $SD = .54$; distal: $M = 3.84$, $SD = .52$; $F(2, 55) = 175.38$, $p < .01$; all t-test p's $< .01$), and Occidental (proximal: $M = 1.21$, $SD = .34$; medium: $M = 2.38$, $SD = .63$; distal: $M = 4.05$, $SD = .53$; $F(2, 55) = 147.38$, $p < .01$; all t-test p's $< .01$). Half of the trials were presented as true and half false by reversing the coordinate term. Because past work has demonstrated that landmark presentation order can influence similar tasks (Hazen, Lockman, & Pick, 1978; Taylor, Naylor, & Chechile, 1999; Tversky, 1977), a second task version for each map presented the trials in the reverse direction (e.g., *Steiner Hall is south of Harris Center*).

Procedure

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[1] We thank M. Denis for the suggestion to divide trials into short, medium, and long distances, rather than only short/long. This modification increases the applicability of the present work to existing research examining symbolic distance effects.

Participants were randomly assigned to one of five experimental conditions. The BMIS was administered immediately prior to and following mood induction (see Corson & Verrier, 2007). Mood induction involved viewing a series of 18 images presented one at a time for 6 seconds each (100 ms ISI), centered on a computer monitor. Participants were instructed to stare at the center of the screen and watch each image as it appeared, trying their best not to look away. Participants were then presented with one of the three (counterbalanced between participants in a Latin square) maps on the computer screen for 5 minutes and instructed: "Learn everything you can about the environment during the next five minutes."

The free recall task was given to participants on a plain white sheet of paper with the instructions to recall as many verbal details (landmarks and roads) as possible within 5 minutes. Free recall always preceded statement verification to avoid relearning landmark names during the latter. Statement verification trials were presented in random order one at a time, centered on the screen. Participants were instructed to respond as quickly as possible without compromising accuracy, by pressing keys labeled TRUE and FALSE (C and M, respectively).

Results

For all analyses we collapsed across the three map versions after confirming no effects of map version in four omnibus ANOVAs: two each for free recall and statement verification data (all *p's* < .05, all *F's* < 1).

Mood Manipulation Checks

The post-induction BMIS was scored by separately averaging responses for adjectives associated with positive and negative valence and high and low arousal (see above; Mayer & Gaschke, 1988). Because valence and arousal are often considered bipolar and orthogonal

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constructs, we averaged the scores for positive and negative valence (reversed-scored) to achieve a single bipolar valence index, and high and low arousal (reverse-scored) to achieve a single bipolar "arousal" index (Revelle & Loftus, 1992; Feldman Barrett & Russell, 1998). Participants whose BMIS scores did not increase or decrease (in correspondence to the intended manipulation), or remain stable from pre to post, were removed from further analysis (n = 3). Table 2 details the resulting groups' post-induction ratings and confirmatory analyses. In the control group, participants tended to rate adjectives associated with 'happy' higher than those associated with 'sad,' and adjectives associated with 'calm' higher than those associated with 'energetic' (thus the positive valence and negative arousal composite scores). To confirm the effectiveness of our mood induction, we compared each of the four groups' composite scores to those of the control group; in all cases valence and arousal scores differed from those of the control group (all *p's* < .05). We note that composite scores should not necessarily be considered absolute indices of arousal or happiness, but only relative to the control group; indeed, at baseline participants tend to show a moderate degree of happiness without any induction (i.e., Diener & Diener, 1996).

Free Recall

For the Free Recall task, we assessed proportion recalled for landmark and street names; we also assessed the spatial distance (on map, in inches) of successively recalled landmarks for each participant; this scoring procedure allowed us to assess the extent to which verbal retrieval was schematized using a relatively local or global spatial framework (Kalakoski & Saariluoma, 2001). To test whether the free recall patterns were specifically due to a spatial and not a linguistic conceptual framework, we applied two verbal techniques: orthographic similarity (using Dice's Coefficient; van Rijsbergen, 1979) and phonological similarity (using the ALINE method; Kondrak, 2000) between successively recalled words.

The present manipulation did not affect the *quantity* of verbal information retrieval (see Table 3a). For building recall, a 2x2 ANOVA did not reveal an effect of valence, $F(1, 64) = .03$, $p > .05$, or arousal, $F(1, 64) = .11$, $p > .05$, and the two variables did not interact, $F(1, 64) = .01$, $p > .05$. Similar results were found for street recall, with no effect of valence, $F(1, 64) = .374$, $p > .05$, or arousal, $F(1, 64) = .151$, $p > .05$, and no interaction, $F(1, 64) = .02$, $p > .05$. As seen in Table 3a, building and street recall means for these four groups were also quite similar to those from the control group (as confirmed by one-way ANOVAs; building names: $F(4, 80) = .17$, $p > .05$, and street names: $F(4, 80) = .15$, $p > .05$).

The present manipulation did change the *organization* of verbal information retrieval (see Table 3b). A 2x2 ANOVA revealed that the average distance (on the map) between successively recalled landmarks increased with higher levels of arousal, $F(1, 64) = 35.59$, $p < .01$, $\eta^2 = .37$. Valence did not show an effect, $F(1, 64) = .43$, $p > .05$, and the two variables did not interact, $F(1, 64) = .36$, $p > .05$. Relative to the control group, high arousal was associated with higher average distances between successively recalled landmarks for both valence conditions: positive, $t(31) = 3.64$, $p < .01$, $d = 1.26$, and negative, $t(31) = 4.26$, $p < .01$, $d = 1.47$. Low arousal did not differ from the control group for positive valence, $t(31) = 1.12$, $p > .05$, or negative valence, $t(22) = 1.17$, $p > .05$.

Neither of the verbal scoring procedures revealed differences between groups (see Table 3c); this result supports work showing that spatial chunking during free recall of map- and route-based information is distinct from verbal chunking mnemonics (cf. Kalakoski & Saariluoma, 2001). Further, it supports the notion that the spatial scoring procedure reveals recall differences driven by organizational differences in spatial rather than verbal memory.

Spatial Statement Verification

The statement verification task allowed us to assess performance on trials comparing spatially proximal landmarks that necessitate fine-grained local knowledge, medium-distance landmarks, and spatially distal landmark comparisons that rely upon relatively global knowledge. We scored this task by calculating hit rate, false alarms, and sensitivity (*d'*, see Table 4), and response time[2] means (for correct trials), for each group and for proximal, medium, and distal comparisons.

Control Group Symbolic Distance Effects. Our first two analyses were conducted on control group data only, and consisted of a repeated-measures ANOVA and paired t-tests on proximal, medium, and distal performance, using a Bonferroni correction term (α = .017); the intention was to confirm the presence of a symbolic distance effect in both sensitivity and response times. In line with recent work (i.e., Denis, 2008; Noordzij & Postma, 2005), we replicated a symbolic distance effect with sensitivity data (see Figure 1), which changed as a function of landmark distance, $F(2, 32) = 7.59$, $p < .01$, $d = .32$. Paired t-tests revealed higher sensitivity when making distal relative to proximal comparisons, $t(16) = 5.4$, $p < .017$, and distal relative to medium comparisons, $t(16) = 2.9$, $p < .017$; proximal did not differ significantly from medium ($p = .45$). Some further support was found with response time data (see Figure 2; $F(2, 32) = 2.12$, $p < .10$), with

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[2] Log_{10}-transformed response times revealed the same results pattern.

marginally faster responses during distal versus proximal comparisons, $t(16) = 1.75$, $p < .10$.

Emotional State Symbolic Distance Effects: Sensitivity. A 3 (within: proximal, medium, distal) x 2 (between: positive, negative valence) x 2 (between: high arousal, low arousal) mixed models ANOVA on *d'* data revealed an interaction between comparison type and arousal, $F(2, 120) = 20.94$, $p < .01$, $\eta^2 = .26$, but no interaction between comparison type and valence, $F(2, 120) = 1.62$, $p > .05$ (see Figure 1). Two separate simple effects ANOVAs were conducted for the high arousal and low arousal groups; as evident in Figure 1, there was a symbolic distance effect in the high arousal groups, $F(2, 62) = 53.09$, $p < .01$, $\eta^2 = .63$, but not in the low arousal groups, $F(2, 62) = .01$, $p > .05$.

To assess whether high arousal amplified the symbolic distance effects found in the control group, we conducted a 3(control, high arousal positive valence, high arousal negative valence) x 3 (proximal, medium, distal) ANOVA; there was a significant group by comparison type interaction, $F(4, 92) = 3.72$, $p < .01$, $\eta^2 = .14$. To assess whether this effect was due to high arousal amplifying distal performance relative to control, and/or attenuating proximal performance relative to control, we conducted two one-way ANOVAs. The first compared distal comparison performance, and found that sensitivity varied significantly across the three groups, $F(2, 48) = 4.2$, $p < .01$, $\eta^2 = .15$; two follow-up comparisons using a Bonferroni correction term ($\alpha = .025$) demonstrated that both groups showed higher sensitivity on distal comparisons relative to the control group for the positive valence group (marginally), $t(31) = 2.01$, $p < .05$, $d = .69$, and the negative valence group: $t(31) = 3.26$, $p < .025$, $d = 1.33$). The second one-way ANOVA compared proximal comparison performance, and found that sensitivity varied only marginally across the three groups, $F(2, 48) = 2.44$, $p < .10$ (nb., medium comparison performance did not vary across the three groups, $F > 1$).

Emotional State Symbolic Distance Effects: Response Time. Response time data are reported for correct trials only (87% of all trials), and outliers were removed (M +/- 2.5SD, accounting for 3.1% of all trials). As with sensitivity data, we conducted 3 (within: proximal, medium, distal) x 2 (between: positive, negative valence) x 2 (between: high arousal, low arousal) mixed models ANOVA on response time data. This analysis revealed an interaction between comparison type and arousal, $F(2, 120) = 7.57$, $p < .01$, $\eta^2 = .11$, but not comparison type and valence, $F(2, 120) = .18$, $p > .05$ (see Figure 2). Two separate simple effects ANOVAs were conducted for the high arousal and low arousal groups; there was a symbolic distance effect in the high arousal groups, $F(2, 60) = 11.16$, $p < .01$, $\eta^2 = .07$, but not in the low arousal groups, $F(2, 60) = .02$, $p > .05$.

To assess whether high arousal changed the symbolic distance effects found in the control group, we conducted a 3(control, high arousal positive valence, high arousal negative valence) x 3 (proximal, medium, distal) ANOVA; there was no group by comparison type interaction, $F(4, 92) = .97$, $p > .05$. Overall, similar magnitude symbolic distance response time effects were found in the control group and both high arousal groups, and no evidence for these effects was found in the low arousal groups.

Discussion

People study maps to learn about the overall layout of an environment, identify the location of a particular landmark, or to find a route from one place to another. The mental images resulting from map study, spatial description reading, and navigation are often deemed analogical, categorical, and metric in nature (Chabanne, Péruch, Denis, & Thinus-Blanc, 2004; Denis, 2008; Denis & Cocude, 1989, 1992; Denis & Zimmer, 1992; Iachini & Giusberti, 2004; Noordzij & Postma, 2005; Péruch, Chabanne, Nesa, Thinus-Blanc, & Denis, 2006; Trojano, Grossi, Linden, Formisano, Goebel, Cirillo, et al., 2002). One result of these characteristics is the commonly replicated symbolic distance effect (Moyer, 1973; Moyer & Bayer, 1976). Here we have demonstrated that this effect, in both accuracy and response times, can be elicited using a canonical landmark relationship task that varies interlandmark distance. Relative to far landmark interrelationship judgments, close judgments are relatively cognitive demanding, necessitating a higher level of specificity and local knowledge in the images stored during map study. As the metric distance between compared landmarks increases, so does the ease with which participants can judge their relative canonical locations. This is a common trademark of the symbolic distance effect, and replicates with both accuracy (in this case sensitivity) and response times.

We demonstrate that the accuracy and response time advantages seen with distal relative to proximal landmark judgments can be modulated by the emotional state of the individual during map study. With high arousal states, a broader attentional focus during map study can strengthen the representation of distal spatial relationships and amplify conventional symbolic distance effects. In the present study, this effect persisted for both positive and negative valence. In contrast, we found some evidence that low arousal can reduce or even eliminate the symbolic distance effect by encouraging a local item-specific processing of landmark information. Further evidence came from the free recall task, where we found an indication that high arousal states led to the use of a relatively global spatial framework to guide retrieval. We thus provide some evidence that arousal (but not valence), such as being in a state of relative alertness or somnolence, can play a role in the development and subsequent use of spatial memory. We

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propose that the analog representations developed from map study are shaped during the construction of spatial memories, and the nature of mental images can be biased towards local relative to global spatial relationships. The present procedure allowed us to assess these differences through an adaptation of the traditional symbolic distance task (i.e., Denis, 2008). It appears to be the case that more global configural details about the larger interlandmark structure of an environment are relatively well-established in representations resulting from high arousal states. This advantage, however, appears to come partially at the expense of relatively local interlandmark information, such as the fine canonical details pertaining to close building relationships. Low arousal states, however, diminished the symbolic distance effect and led to rather equivalent performance for relatively close versus far trials, suggesting a rather balanced representation but poor performance with distal comparisons relative to both control and high arousal states. The symbolic distance effect is a rather robust and reliable phenomenon and has been replicated across a wide variety of experimental paradigms; the fact that low arousal diminished this effect may point to the malleability of spatial attention and/or memory.

As in some recent work (Corson & Verrier, 2007), performance did not change on either of the present tasks as a function of valence. As such we find no direct support for the levels-of-focus hypothesis (i.e., Clore et al., 2001). Rather, we propose that high arousal (whether associated with positive or negative valence) leads to more accurate and retrievable memories of global relative to local information (see also Fiedler & Stroehm, 1986). There was also evidence that high arousal led to poorer performance on tasks requiring the application of local spatial relationships. We believe our results support a growing body of literature suggesting that high arousal states promote global processing of neutral stimuli (i.e., Corson & Verrier, 2007; Vasterling et al., 2004). Indeed it could be the case that emotional arousal states direct visual attention towards relatively global elements of neutral scenes (Adolphs, Tranel, & Buchanan, 2005), much in contrast to the finding of local attentional focus when participants are presented with arousing scenes (Loftus, 1979). Indeed some have proposed that avoidance-related emotional states such as fear and sadness lead to local as opposed to global focus, and approach-related emotional states such as happiness and serenity do the opposite (Basso et al., 1996; Derryberry & Reed, 1998; Derryberry & Tucker, 1994; Gasper & Clore, 2002). The present results do not directly support these findings but rather suggest that future work consider the potentially important role of arousal state, and whether the task-related stimuli are valenced or neutral, in modulating global versus local effects.

Some work suggests that increased attention towards global elements of a scene during high arousal states may be adaptive; that is, they may increase chances for survival when seeking resolution to a high arousal state (Mather, 2007; Mendl, 1999). A state of increased arousal may cause participants to actively seek a source of the arousal; indeed some work finds broad and erratic saccadic eye movements across multiple areas of a scene during high arousal states (i.e., Janelle, 2002). In the case of presenting participants with arousing stimuli the result of such a mechanism is rather straight-forward (e.g., identification of a weapon; Loftus, Loftus, & Messo, 1987); with emotionally neutral stimuli, however, this search process may be prolonged and rather ill-fated. The result of this process, however, appears to be increased knowledge of relatively large-scale information about, in this case, an environment. Future work should assess this possibility using eye movements during map study in emotional state induction paradigms.

We also note that, in support of existing work, overall memory performance during recall and statement verification did not vary as a function of emotional state (Corson & Verrier, 2007;

Storbeck & Clore, 2005); only when that performance was parsed into global and local components did the effects of arousal become evident.

It is well-established that knowing relative landmark positions is critical for finding paths to destinations in both small- and large-scale environments (Denis, Michon, & Tom, 2007; Foo et al., 2005; Loomis et al., 1999; Tom & Denis, 2004). The present data show that arousal might influence knowledge of landmark positioning and consequently carry implications for human navigation in the face of complex contextual influences. The present findings can thus inform the design of contextually-aware navigation devices: high arousal states might enhance global spatial memory, but perhaps at the cost of local spatial memory, and to the extent that spatial memory is influenced by the emotional states characterizing its acquisition, technologies can be adapted to account for such influences. For instance, high arousal states as measured through neurophysiological indicators can trigger the visual cueing of local landmark interrelationships while a person performs map study; with low arousal states the opposite might prove beneficial, with cueing of relatively global relations.

Given the relatively mild form of the present emotional induction procedure, the impact of our manipulation suggests that effects of arousal on spatial memory may be even more pronounced in the real world. In contrast to the IAPS images, the events and images participants are exposed to in daily life are dynamic and continuous, comprised of known and unknown persons, can last for extended durations, and carry high self-relevance and have large and sometimes devastating consequences. Future work should consider relatively naturalistic emotional state induction effects on spatial memory.

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Table 1. IAPS image ratings for valence and arousal, for each of the four conditions.

	IAPS Rating			
	Valence		Arousal	
Condition	M	SE	M	SE
Positive Valence, High Arousal	7.38	.13	6.19	.04
Positive Valence, Low Arousal	7.37	.03	3.76	.08
Negative Valence, High Arousal	3.76	.04	6.22	.08
Negative Valence, Low Arousal	3.77	.10	3.70	.08

Table 2. Composite mood and arousal scores for the five experimental conditions. Parenthetical notes detail the directionality of ratings differences. Confirmatory independent-samples t-tests compare each group's mood and arousal scores to those of the control group.

	Composite Score	
Condition & Measure	*M*	*SE*
Positive Valence, High Arousal (n = 16; 9 female)		
Valence (happy > sad)	.80	.09*
Arousal (energetic > calm)	.08	.06*
Positive Valence, Low Arousal (n = 16; 8 female)		
Valence (happy > sad)	.84	.06**
Arousal (calm > energetic)	-.73	.04**
Negative Valence, High Arousal (n = 16; 7 female)		
Valence (sad > happy)	-.28	.10**
Arousal (energetic > calm)	.15	.10*
Negative Valence, Low Arousal (n = 16; 8 female)		
Valence (sad > happy)	-.22	.08**
Arousal (calm > energetic)	-.77	.07**
Control (n = 17; 9 female)		
Valence (happy > sad)	.46	.13
Arousal (calm > energetic)	-.26	.12

Confirmatory analyses: t-test $df = 31$ * $p < .05$ ** $p < .01$

Table 3a. Means and standard errors representing proportion recalled for landmarks and street names in the four state induction groups and the control group.

	Proportion Recalled			
	Landmarks		Streets	
Condition	*M*	*SE*	*M*	*SE*
Control	.84	.04	.86	.05
Positive Valence, High Arousal	.81	.05	.85	.06
Positive Valence, Low Arousal	.79	.05	.82	.05
Negative Valence, High Arousal	.81	.04	.87	.05
Negative Valence, Low Arousal	.80	.04	.86	.04

Table 3b. Means and standard errors representing the average distance between successively recalled landmarks in the four state induction groups and the control group.

	Distance on Map (inches)	
Condition	*M*	*SE*
Control	2.08	.04
Positive Valence, High Arousal	2.41	.08
Positive Valence, Low Arousal	1.94	.12
Negative Valence, High Arousal	2.37	.06
Negative Valence, Low Arousal	1.95	.11

Table 3c. Means and standard errors representing two verbal free recall scoring procedures: orthographic similarity and phonological similarity, for the four state induction groups and the control group.

Measure & Condition	*M*	*SE*
Orthographic Similarity (Dice's Coefficient), one-way ANOVA, F(4, 80) = .319, p > .05		
Control	.025	.01
Positive Valence, High Arousal	.025	.01
Positive Valence, Low Arousal	.031	.01
Negative Valence, High Arousal	.029	.01
Negative Valence, Low Arousal	.027	.01
Phonological Similarity (ALINE Scores), one-way ANOVA, F(4, 80) = .882, p > .05		
Control	55.36	2.25
Positive Valence, High Arousal	51.42	2.41
Positive Valence, Low Arousal	57.37	2.39
Negative Valence, High Arousal	54.13	2.92
Negative Valence, Low Arousal	55.52	2.87

Table 4. Mean hit and false alarm rates, and sensitivity (*d'*), for the statement verification task, for the five groups and distal versus proximal comparison types. Results are presented for independent-samples t-tests comparing each group to the control group (four within short, medium, and long).

	Proximal		Medium		Distal	
Condition	M	SE	M	SE	M	SE
Control						
Hit Rate	.86	.02	.89	.02	.91	.01
False Alarm Rate	.12	.02	.13	.02	.13	.02
Sensitivity (*d'*)	2.06	.09	2.20	.15	2.60	.08
Positive Valence, High Arousal						
Hit Rate	.82	.02	.85	.02	.95	.02*
False Alarm Rate	.13	.02	.12	.02	.12	.02
Sensitivity (*d'*)	1.84	.11	2.17	.18	2.85	.09*
Positive Valence, Low Arousal						
Hit Rate	.91	.01*	.86	.03	.88	.02
False Alarm Rate	.14	.02	.15	.02	.12	.02
Sensitivity (*d'*)	2.25	.20	2.18	.11	2.16	.10**
Negative Valence, High Arousal						
Hit Rate	.84	.03	.87	.03	.93	.02
False Alarm Rate	.12	.02	.14	.02	.13	.02
Sensitivity (*d'*)	1.74	.13*	2.50	.14*	2.94	.05*
Negative Valence, Low Arousal						
Hit Rate	.83	.02	.81	.02*	.84	.02**

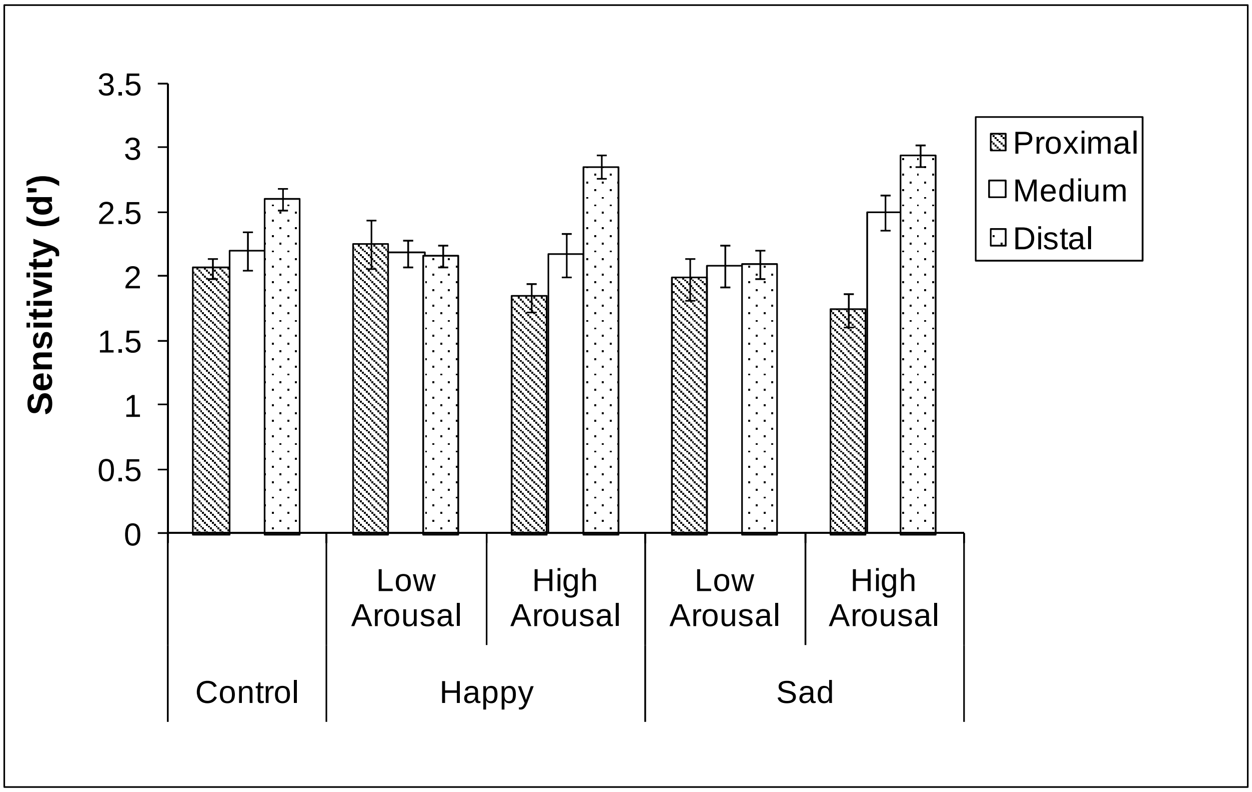
False Alarm Rate	.13	.02	.11	.02	.10	.02
Sensitivity (*d’*)	1.98	.16	2.08	.16	2.09	.11**

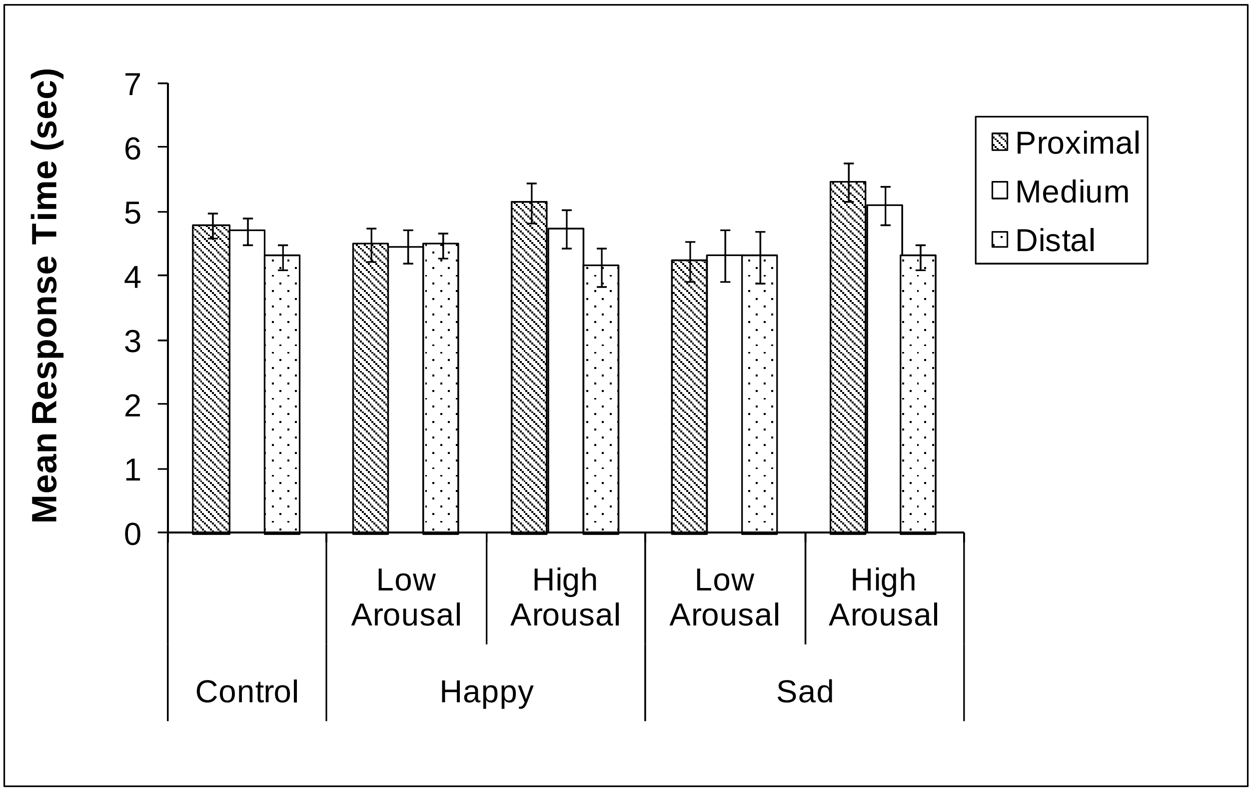
Analyses: **t-test *df* = 31** ** $p < .01$ * $p < .05$

Figure Captions

Figure 1. Mean sensitivity (d’) to proximal, medium and distal comparisons for each of the five participant groups. Error bars represent standard error of the mean.

Figure 2. Mean response times (in seconds) to proximal, medium and distal comparisons for each of the five participant groups. Error bars represent standard error of the mean.


Sensitivity (d')
3.5
3
2.5
2
1.5
1
0.5
0
Proximal
Medium
Distal
Control
Low Arousal
High Arousal
Happy
Low Arousal
High Arousal
Sad


Mean Response Time (sec)
7
6
5
4
3
2
1
0
▨ Proximal
☐ Medium
⊡ Distal
Low Arousal
High Arousal
Low Arousal
High Arousal
Control
Happy
Sad

2