1. Introduction

2. Method

Participants & Design

Forty Tufts University undergraduates participated for monetary compensation. In a five-session repeated-measures study, each participant experienced each of the five emotional state conditions (happy, sad, fear, calm, neutral/control) in counterbalanced order using a partial Latin square design.

Materials

Emotional State Induction. We chose to use an autobiographical recall technique adapted from prior research that has been demonstrated as both effective and reliable at inducing various affective states (Baker & Guttfreund,1993; Brewer, Doughtie & Lubin,1980; Bless, Clore, Schwarz, Golisano, Rabe & Wölk, 1996; Bodenhausen, Kramer, Süsser, 1994; Jallais & Corson, 2008; Jallais & Gilet, 2009; Krauth-Gruber & Ric, 2000).

Manipulation Check. To assess the effectiveness of our emotional state induction technique we developed an adjective-rating questionnaire (ARQ) adapted from the brief mood introspection scale (BMIS; Mayer & Gaschke, 1988) and positive and negative affect schedule – expanded (PANAS-X; Watson & Clark, 1991). The questionnaire contained 26 adjectives, each rated on a 4-point scale ranging from 1(*definitely do not feel*) to 4(*definitely feel*).

Campus Maps. Five college campus maps were adapted for use in this study, corresponding to Grinnell College, Occidental College, Trinity College, Beloit College, and St. Olaf's College. Each map is 1280 x 1024 in size and includes 14 labeled buildings, 6 labeled roads and a compass rose (north-up). Each map has similar landmark densities in central and peripheral areas, and the five maps have similar overall spatial densities for landmarks (M = 3671 pixels/inch^2, SD = 19.2) and roads (M = 3814 pixels/inch^2, SD = 23.7).

Memory Tests. Two memory tests were adopted from previous work (Brunyé et al., 2009), a verbal free recall task and spatial statement verification task. Free recall was done on plain white paper. The spatial statement verification task included 56 trials for each of the 5 maps, each probing for canonical (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). No single landmark to landmark relationships 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; distal: M = 3.78, SD = .39; **$t(54)$ = x.xx, p < .05),** St Olaf's (proximal: M = 1.1, SD = .24; distal: M = 3.84, SD = .52; **$t(54)$ = x.xx, p < .05**), and Occidental (proximal: M = 1.21, SD = .34; distal: M = 4.05, SD = .53; **$t(54)$ = x.xx, p < .05),** Trinity (proximal: M = 1.39, SD = .51; distal: M = 2.97, SD = .58; **$t(54)$ = 10.80, p < .01),** and Beloit (proximal: M = 1.280, SD = .52; distal: M = 2.77, SD = .61; **$t(54)$ = x.xx, p < .05).**

-- Calculate t values

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

Emotional State Induction & Manipulation Checks. Each participant visited the laboratory for a total of 5 visits, each separated by at least 24 hours. After consenting to participate in the study, participants were introduced to the SensoMotoric Instruments' eyetracker used for the experiment. Their physical positioning (chair/desk/monitor/chin-rest) was adjusted so that the eyetracker could recognize the participant's right eye with minimal final adjustments. The gross adjustment was be done in the beginning of the procedure so that minimal time elapsed between emotion induction and map study. After adjustment, participants completed the ARQ, were randomly assigned to one of the five emotion groups (happy, angry, fear, calm, and neutral/control), and began autobiographical recall. During recall, each participant was asked to write for 15 minutes about a personal experience relating to the emotion specific to their group; they were be asked to relive the experience in 'their mind's eye' and write in as much detail as possible (i.e., Ford, Tamir, Brunyé, Shirer, Mahoney, & Taylor, in review).

Eye Tracking. Following emotion induction, participants were again asked to complete the ARQ, and then began the eyetracking portion of the study. We calibrated the eyetracker to participants' right eye using a 13-point calibration method, repeated until the error between two fixations at any point was less than 0.5º. Once calibration was finished, participants were presented with one of the five campus maps and instructed to memorize everything they could about the environment. The order of campus maps and assignment of maps to each emotion condition was counterbalanced using a Latin square.

Testing. After studying the map for 3 minutes participants were moved to a different computer to do the test phase of this experiment. First, participants were given a blank sheet of paper and asked to recall all buildings and street names they could remember in a period of 5 minutes. Participants then started the spatial statement verification task. Each spatial statement was presented one at a time centered on the computer monitor, and participants were asked to respond to each trial be pressing TRUE or FALSE (using the keys C and M, respectively), as quickly as possible without compromising accuracy.

3. Results

3.1. Mood manipulation checks

The pre- and post-induction BMIS were scored for pleasantness and arousal using the method of subtractive scoring. The orthogonal, bipolar nature of valance and arousal allowed us to create separate indices for each based on reverse-scoring techniques (Revell & Loftus, 1992). Participant scores were individually averaged for adjectives labeled as positive or negative valance and high or low arousal (Mayer & Gaschke, 1988; Brunyé, Mahoney, Augustyn, Taylor, 2009). Two separate 2x2 ANOVAs were conducted excluding the neutral conditions to find overall pleasantness and arousal ratings. Overall pleasantness scores displayed a main effect positive versus negative mood (see Fig. 1). Overall arousal scores demonstrated a main effect of arousal (see Fig. 2). Because the neutral condition is hovering around zero for both conditions, we see that neutral mood manipulation was successful. Thus there was no reason to consider it in any further analysis. Pre- and post-induction analysis demonstrated an effect of positive vs. negative mood and also high vs. low arousal. Post-induction scores were also analyzed and a main effect in pleasantness and arousal was seen through this method as well. We also see that there is an interaction between arousal and valence is nonexistent, though participants under high arousal were also slightly positive as well.

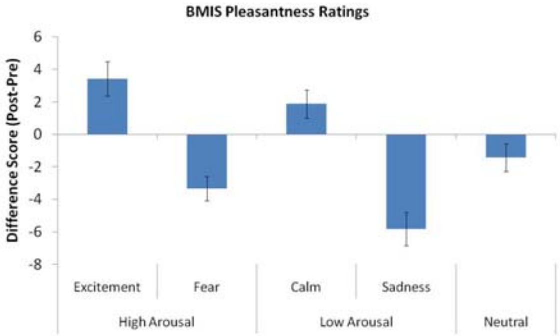

Fig. 1. BMIS pleasantness ratings for the five experimental conditions. Error bars represent standard error of the mean.

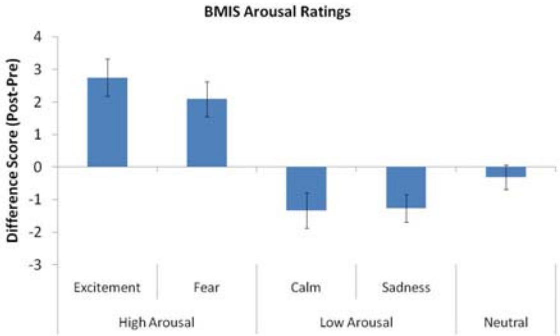

Fig. 2. BMIS arousal ratings for the five experimental conditions. Error bars represent standard error of the mean.

3.2. Free recall

The free recall tasks demonstrated participant memory for landmarks and streets on each given map.

< ***analysis*** >

3.3. Spatial statement verification

The spatial statement verification task allowed us to compare participant sensitivity to proximal versus distal landmarks under the effect of arousal and mood. The task was scored according to response time for both arousal and valance groups with respect to proximal, medial, distal comparison types.

For the spatial statement verification analysis, a within-subjects 2x2x3 ANOVA and within-subjects paired t-test were performed to test the existence of a symbolic distance effect in response times. These tests were conducted on arousal (between: high, low), valence (between: positive, negative), and distance of comparisons (within: proximal, medial, distal). Outlier data points were removed from further analysis (*M* +/- 2.5 SD), which were the participants that responded too quickly or took too long in responding to the verification questions. The results showed an interaction between arousal and the distance of comparisons where participants under high arousal were able to more quickly recognize landmark relationships over distal distances, *F*(2,46) = 4.185, $p < .05$. This demonstrated a classic symbolic distance effect. Furthermore, there was no interaction between mood and the distance of comparison types, *F*(2,46) = .807, $p > .05$. In all analyses the control neutral condition was not included.

Paired t-tests revealed significant differences in mean response times between proximal and distal comparisons in the high arousal states of excitement, *t*(23) = __, p = 0.004, and fear, *t*(23) = __, p = 0.048, and also in the neutral condition, *t*(23) = __, p = 0.039 (see Fig. 3).

***** need to fill in t-test values***

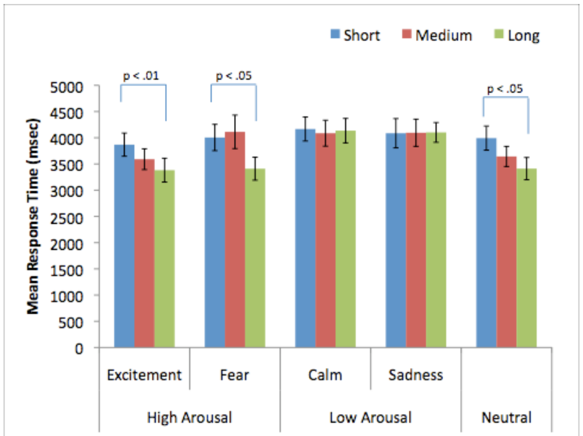

Fig. 3. Mean response times (in milliseconds) to proximal, medium, and distal comparisons for each of the five participant groups. Error bars represent standard error of the mean.

3.4. Eyetracking data

Eyetracking data was used to provide more insight into the mechanisms with which humans organize spatial information in different emotional states. The data was used to help understand whether higher-order goals modulate overt visual attention during map study or if goal-congruent spatial memories are the result of memory organization alone (Brunyé & Taylor, 2009). Eye movement was analyzed as a function of valence and arousal.

In assessing the data, we examined the saccade amplitude between landmark fixations and also their overall central versus peripheral attention allocation. This measure allowed us to determine whether participants had a global or local focus of attention on the environment. These measures were averaged over all fixations, and a 2x2 ANOVA was conducted excluding the neutral condition to find overall saccade lengths for arousal and valence. The results showed a main effect of arousal, *F*(1,22) = 14.241, $p < .001$, no effect of valence, *F*(1,22) = .072, $p > .05$. This proved that it is arousal and not mood that caused participants to get tunnel vision, or a local focus of attention when examining spatial data. Furthermore, the ANOVA found no interaction between the two factors, *F*(1,22) = .987, $p > .05$.

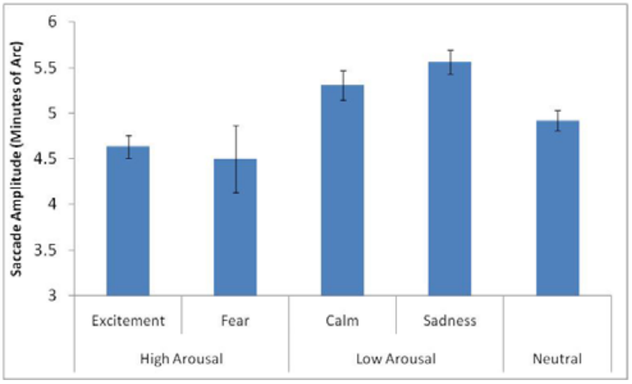

Fig. 4. Saccade amplitude (minutes of arc) in valence states of excitement, fear, calm, sadness, and high or low arousal states, with a neutral control condition for each of the five participant groups. Error bars represent standard error of the mean.

4. Discussion

When studying spatial data, emotional state has been shown to influence how people gather and interpret spatial information (Tucker, 1981; Loftus & Burns, 1982; Gasper & Clore, 2002). Specifically, these studies have shown influences on spatial memory by the two constituents of emotion: valence and arousal. The current research brings together previous work to demonstrate the primary role of arousal in spatial memory. When comparing the effect of both valence and arousal on neutral stimuli, our results have shown a classic replication of the symbolic distance effect, where the ability to recognize landmark relationships is easier when the respective landmarks are farther apart than if they are closer together (Moyer, 1973). People under a high state of arousal do have tunnel vision and narrowed focus of attention, even when the stimuli being viewed are completely neutral. Furthermore, we have been able to support previous work demonstrating the absence of valence as an effect upon spatial memory (Brunyé, Mahoney, Augustyn, & Taylor, 2009; Corson & Verrier, 2007).

The use of an eyetracker is a novel addition to this study that provides more insight into the mental and physical mechanisms by which spatial information is stored in memory. The lack of information on people's eye movements when gathering spatial information has led researchers to question whether spatial information acquisition is a function of data gathered by eye movement, data encoded through organizational schemas in memory, or both. We were able to examine eye movement using our eyetracker data and also examine informational acquisition based on our spatial statement verification results to find that both eye movement and mental encoding are involved in the creation of spatial memory.

The data gathered clearly demonstrated that people under a high state of arousal have localized attention, shown in the form of smaller overall saccade amplitude, under conditions of high arousal. While this finding would indicate that eye movement does play a role in spatial encoding of memory, it is interesting to find contradicting results in the statement verification task results. The statement verification tasks found that participants under high arousal demonstrated a quicker response time for distal comparison statements during the statement verification task. Though, according to the eye movement data, participants under high arousal clearly had tunnel vision, they were still quicker to respond to distal comparisons than proximal and medial ones during statement verification. Perhaps the tunnel vision of participants gave them more insight into the general locations of each landmark, thus while allowing them to distinguish that certain landmarks were within a certain area, it would become more difficult for them to ascertain the relative locations of these landmarks. It would then be easier for them to group landmarks according to areas of location, and thus determine distal relationships more quickly that proximal ones. While this is one hypothesis, further work must be done to understand the relationship between eye movement and data encoding and whether an interaction exists between the two.

The present data demonstrates the effect of arousal upon mood and the contradiction between eye movement and data encoding. The relationship found between arousal and eye movement has implications for the design of visual interfaces, especially involving neutral kinds of stimuli such as navigational map data. Workers of various professions under states of high stress or excitement are privy to the same kind of tunnel vision, regardless of mood. The present findings can inform design decisions on the importance of localization of pertinent data and the importance of arousal upon spatial memory. For instance, a high arousal state would cause a military soldier to localize his or her attention to specific areas of a map, though according to our study, this soldier might then become stronger in determining distal spatial relationships. Future work should consider the mechanisms and relationship between eye movement and spatial encoding of memory.

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