HHS Public Access
Author manuscript
J Exp Psychol Gen. Author manuscript; available in PMC 2016 January 14.

Published in final edited form as:
J Exp Psychol Gen. 2009 February ; 138(1): 131–145. doi:10.1037/a0014797.

Don't Look Down: Emotional Arousal Elevates Height Perception

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Abstract

In a series of experiments we found that emotional arousal can influence height perception. In Experiment 1, participants viewed either arousing or non-arousing images before estimating the height of a two-story balcony and the size of a target on the ground below the balcony. People who viewed arousing images overestimated height and target size more than those who viewed non-arousing images. However, in Experiment 2, estimates of horizontal distances were not influenced by emotional arousal. In Experiment 3, we manipulated both valence and arousal cues and observed that arousal, but not valence, moderated height perception. In Experiment 4, participants either up-regulated or down-regulated their emotional experience while viewing emotionally arousing images, and a control group simply viewed the arousing images. Those participants who up-regulated their emotional experience overestimated height more than the control or down-regulated participants. In sum, emotional arousal influences estimates of height and this influence can be moderated by emotion regulation strategies.

Keywords

emotional arousal; arousal and perception; height perception and emotion; emotion regulation

In an expedition in 1677, Father Louis Hennepin became the first European explorer to document the existence of Niagara Falls. Hennepin, viewing the falls from above, estimated the height of the falls to be 600 feet, but the actual height was only 167 feet. Interestingly, he also expressed a fear of the height: "the two brinks are so prodigious high, that it would make one tremble to look steadily upon the water" (Hennepin, 1678). Did arousal associated with a fear of the height influence his estimate of how high the falls were?

Previous research on the perception of height suggests that heights are overestimated more from the top than the bottom (Jackson & Cormack, 2007; Sinai, Ooi, & He, 1998; Stefanucci & Proffitt, in press). This overestimation occurs with a variety of measures (e.g., verbal

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estimates of distance, matching the height to a horizontal extent) and multiple locations, suggesting that this overestimation is robust and reliable. However, the underlying mechanism for this phenomenon remains unclear.

Overestimation of heights from the top is paradoxical given current theories of distance perception. These theories suggest that observers in reduced-cue situations (those in which common cues used to scale distance are unavailable) should underestimate the distance to a target (Gogel, 1965; Philbeck & Loomis, 1997). Philbeck and Loomis (1997) reduced the availability of motion and binocular cues to distance and found that participants in these reduced-cue situations underestimated an extent with both verbal and non-verbal reports of distance. Viewing a height from above is also a reduced-cue situation because normal cues used to scale distances are unavailable to observers when they are not standing on the ground plane. For instance, the use of eye-height, angular elevation, or other secondary depth cues to determine distance is compromised. Why then does standing at the top of a height result in an overestimation of the extent rather than the predicted underestimation?

One possibility is that greater overestimation of heights occurs because of increased anxiety or fear experienced at the top of the height compared to the bottom (Stefanucci & Proffitt, in press; Teachman, Stefanucci, Clerkin, Cody, & Proffitt, 2008). Father Hennepin may have overestimated the height of Niagara Falls because he was afraid. Recent work in clinical psychology suggests that people with phobias may experience a different world than non-phobics. Riskind, Williams, Gessner, Chrosniak, and Cortina (2000) proposed "a global cognitive style involving a tendency to form biased expectations about the temporal and spatial progression of potential threats. The pernicious effects of the *looming maladaptive style* (LMS) can lead individuals to mentally simulate active and dynamic scenarios involving relatively mundane, non-threatening situations" (p. 838). Much of the work on LMS has been questionnaire based, but Riskind, Moore, and Bowley (1995) asked participants to imagine and draw the path that a spider in the room could take if let out of its cage. The participants who were fearful estimated that the spider would move more quickly and would follow a path toward them rather than towards others in the room. Similarly, clinicians have found that people with an extreme fear of heights often report bridges as higher and longer (Rachman & Cuk, 1992). Results from studies that examined these anecdotal patient claims in non-phobic populations are also promising. Stefanucci and Proffitt (in press) found that non-phobic participant's self-ratings of trait- and state-level fear of heights were positively correlated with their estimates of balcony height. In addition, Teachman et al. (2008) found that individuals with a severe fear of heights estimated a balcony to be taller than individuals with a mild fear of heights.

A positive correlation between fear of heights and perceived height suggests that fear may contribute to height overestimation when viewing from the top. Fear includes many components, such as changes in physiological state, cognitive processing, and subjective distress (Barlow, 2002). Proffitt (2006) argues that any of these components could alter the perception of a height if the observer perceives an increase in the costs associated with acting on or around the height (e.g., to minimize danger of falling). As a result, the costs associated with being near the edge of a height are manifested in an overestimation of the extent, and fear evokes a heightened awareness of the apparent danger, which results in an additional increase in perceived height.

In this paper, we will test whether one of the components of fear, arousal, is sufficient to alter perception. Arousal was tested in isolation because there is ample evidence to suggest that arousal could influence perceptions. Zillman (1971) argued that arousal cues, which usually accompany a fear response, are generally non-specific and are easily transferred from one arousing source to another. In addition, the emotional arousal associated with highly arousing emotions, such as fear and excitement, has been found to modulate attention and memory (Adolphs & Damasio, 2001; McGaugh, 2004; Phelps, Ling, & Carrasco, 2006). These findings suggest that emotional arousal can be non-specific and as a result may influence perception as well as attention and memory.

The notion that motivational or affective states can influence perception has a long history. The New Look in Perception movement, which started in the 1940's tested whether factors like motivation and value influenced the perception of size (Bruner & Goodman, 1947; Bruner & Postman, 1947). While the theoretical approach to these studies was interesting, there were methodological problems with the design and execution of the studies that started great debate and ultimately discredited the findings. However, the current studies revisited the notion of the New Look, in that we tested whether arousal influenced the perception of another aspect of the environment: heights.

When an observer is standing at a height there are fewer cues available (as discussed above) with which to estimate the height than are normally available when estimating ground extents. For example, texture gradient, eye-height and horizon information, and other secondary depth cues are unavailable when estimating a height. Therefore, people may use non-visual cues when evaluating or estimating the extent of the height. We suggest that arousal is a cue that people take into account when estimating a height. If people feel aroused AND are standing at a height, then the arousal may be interpreted as being due to the height. This interpretation may be more prevalent for people who have a fear of heights (and have consistently experienced arousal as a symptom of their fear). In addition, arousal may also play a role in people who are not as afraid of heights, because a lack of informative cues about the extent of the height necessitates the use of other information to evaluate the height. In other words, if arousal is present when people view a height, they may attribute the arousal to the height.

According to the arousal-as-importance approach (Storbeck & Clore, 2008), feelings of arousal can serve to intensify evaluations of the situation. In addition, feelings of arousal tend to be non-specific and can easily transfer from one source to another (Zillmann, 1971). Therefore, a critical assumption of the arousal-as-importance approach is that feelings of an irrelevant source can be misattributed and used to assess how one feels about the relevant source being evaluated. Because higher heights are more dangerous, we believe an extra source of arousal should intensify the dangerousness value assigned to the height. Therefore, when individuals assess their feelings while evaluating or judging the height, the extra source of arousal should intensify their feelings of how dangerous the height appears. And if individuals feel the height is more dangerous these feelings should lead to a subsequent overestimation of the height. Furthermore, this overestimation of a height could lead to a cyclical pattern, in which the overestimation of the height serves to increase the arousal, which then could influence future estimates, and so on.

Another possibility is that the arousal was used as information about the height, but the overestimation was a result of reduced attention as Easterbrook (1959) proposed. The arousal could be a dominate cue that observers use to estimate the height, but given that Easterbrook found that arousal can lead to less vigilance, the overestimation of height may occur because of reduced attention to the available cues to distance with which to construct the height estimate. Fewer cues with which to estimate the height would likely lead to a greater bias, and thus, a greater overestimation of height.

Proffitt's approach (the economy of action approach, see Proffitt, 2006) claims that the perception of the environment is influenced by the costs associated with intended actions in those environments. The research presented here is certainly an instance of perception interpreting the world in such a way that reduces the likelihood of action near a height. Because the costs associated with acting on the height are high, the perceptual overestimation is adaptive and serves to protect the observer. In addition, we believe that Proffitt would propose that fear evokes a heightened awareness of the apparent danger, and in so doing, may evoke an additional increase in perceived height. Because fear responses have many symptoms, including arousal, multiple symptoms could increase perceptual estimates of height. The question we address in this paper is whether arousal, which is not related to or caused by a fear reaction, can also increase height estimates.

Experiment 1

This experiment investigated whether induced emotional arousal from a non-height related source can influence height perception. According to Proffitt's approach, only arousal caused by being on a height (e.g., a balcony) should alter perception of that height because it would provide information about the costs or ability associated with acting on the height. However, Zillmann's theory of excitation would predict that arousal from any source, whether height relevant or not, may influence height perception. To evaluate these hypotheses, we manipulated emotional arousal that was not relevant to the balcony used in our experiment by presenting arousing images to non-clinical populations before participants estimated the height.

Method

Participants

Thirty-five (26 female) undergraduates participated to fulfill a course requirement. All participants had normal or corrected-to-normal vision. Mean age was 18.64 years (*SD* = 1.19) and 57% reported race and/or ethnicity as Caucasian, 1% as African American, 11% as Asian, and 1 person did not report their race.

Stimuli & Apparatus

Arousal Task—All pictures were chosen from Lang, Bradley, and Cuthbert's (1999) International Affective Picture System (IAPS). Arousing IAPS pictures were chosen because they reliably elicit emotional arousal (Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley & Lang, 2007). One-hundred and twenty images were selected and divided into four groups of 30 pictures. Each participant saw one set of pictures (A and B were arousing, C and D were non-arousing). All sets contained both positive and negative images, and 27% of the arousing and 10% of the non-arousing pictures had a height-related theme[1]. Pictures were presented using PowerPoint Presentation. The means, standard deviations, and analyses for the images can be found in Table 1.

Perceptual Task—Participants stood on a balcony that measured 8 meters high (see Figure 1). A large blue disk made of core board (45.7 centimeters in diameter) marked the distance to be judged on the ground beneath the balcony.

Anxiety Questionnaires—Participants completed the Acrophobia Questionnaire (Anxiety Subscale; Cohen, 1977) to measure trait-level fear associated with heights *after* performing the perceptual task. This scale measures the degree to which a person has fear-relevant thoughts when thinking about a variety of height environments.

Additionally, a single item, *Height Anxiety*, measured participants' state-level fear associated with the balcony used in this experiment. The question was asked after participants completed the perceptual tasks, while they were still standing on the balcony. The *Height Anxiety* question asked "How anxious are you as you look over the balcony?" on a scale from 0 (completely calm) to 100 (about to have a panic attack). Finally, demographic information was obtained.

Recognition Test—A recognition test of the pictures was given following the perceptual measures. Participants were presented with a picture and then asked to judge whether they had seen it during the learning phase (old) or not (new). However, participants in both groups (we collapsed across the two arousing groups, A and B, and the two non-arousing groups, C and D, of pictures) had very good recognition (> 92%), $p = 0.56$. For the remaining experiments, the same memory cover story was used, but we did not test recognition memory for the images, and thus recognition performance will not be discussed further[2].

[1]Some of the pictures involved heights or height-related themes in both the arousal and control groups, but we were conservative in our characterizations of the pictures. For example, a picture of a mountain from afar was coded as "height-related." However, we did find that the arousing pictures were more often of someone "falling" from a first-person perspective, whereas the neutral pictures did not include this first-person perspective as much.

[2]The lack of differences in the recognition test for this experiment is not surprising given the mixed findings in the literature concerning arousal and memory tested within a day of learning. Some studies show that arousing information is better remembered after a short delay (Blake, Varnhagen, & Parent, 2001; Nielson, Yee, & Erickson, 2005), but other studies often find that emotionally arousing stimuli do not enhance memory and sometimes can impair memory (Dougal & Rotello, 2007; Sharot, Delgado, & Phelps, 2004; Revelle & Loftus, 1992; Walker, 1958; Barros et al., 2002; Bianchin et al., 1999; Schafe & LeDoux, 2000; Christianson, & Mjorndal, 1985; Heuer & Reisberg, 1992; Ochsner, 2000). Furthermore, our participants were almost at ceiling for their recognition of the pictures, which would make it harder to find an effect of arousal. Other studies have found that recognition memory for pictures is outstanding. In an older study by Standing, Conezio, and Haber (1970), participants were presented with 2560 pictures, and a 2-alternative forced-choice test showed that performance exceeded 90% retention.

Procedure

Participants were told that the purpose of the experiment was to test their memory for a series of pictures. To provide a break between the learning and testing phases of the memory task, participants were asked to complete a filler task (judging the height of a balcony). The perceptual task was described as being completely separate from the memory task[3]. Participants were randomly assigned to either the arousing or non-arousing (control) condition.

Arousal Phase—Participants were shown one set of 30 pictures, and all pictures were presented for 3 seconds with a brief delay between pictures.

Perceptual Estimation—Immediately following picture presentation, participants were walked out to the balcony located near the experimental room. All participants viewed the height from the top and stood on the edge of the two-story balcony (with a 0.91m high railing) with the target placed on the ground beneath where the participants stood on the balcony. They estimated the height of the balcony by positioning an experimenter to be the same distance along the balcony as the *top of the railing* was to the target on the ground. The experimenter walked backward while facing the participant and waited for the participant to tell him to stop. Participants were encouraged to look back to the target as often as they liked and to adjust the experimenter in or out until they were satisfied. After estimating the distance to the target, participants estimated the size of the target. Participants were told to match the target diameter to the length of a tape measure, which the experimenter slowly pulled open (numbers facing away from the participant, horizontally) until the participant stopped them.

This indirect measure was chosen because size is a converging measure of perceived height given that apparent size is frequently related to perceived distance (i.e., the size/distance invariance hypothesis; Epstein, 1973). So, size estimates are dependent on perceived distance (and in this case, height), even though participants were likely unaware of this relationship. If a participant saw the height as taller, then they should estimate the target as larger. Also, participants estimated both the balcony height and target size by matching the extent or diameter, which did not rely on memory.

State and Trait Anxiety—The Height Anxiety question was administered while participants stood on the balcony to examine state-level anxiety of heights. Then participants were brought back into the lab where they completed the Acrophobia questionnaire designed to examine trait-level fear of heights.

Testing Phase—After completing the trait-level anxiety measure, participants completed the recognition task.

[3]None of the nineteen subjects questioned believed that the memory task influenced their perception of the balcony height.

Results

The data from four participants (3 in the arousal condition, 1 in the control condition) were not included because the target was removed during the study by an individual unrelated to the experiment. In addition, three participants were removed from the analysis because their height estimates were 2.5 standard deviations above the mean, collapsing across the two sets of pictures, for their respective conditions (1 in the arousal group, and 2 in the control group).

Perceptual Estimates

We found that emotionally-arousing stimuli influenced height perception, such that individuals who viewed arousing pictures (*M* = 13.60m, *SD* = 2.64) overestimated the height of the balcony more than the individuals who viewed non-arousing pictures (*M* = 11.40m, *SD* = 2.95), $F(1, 27) = 4.35$, $p < 0.05$, $\eta_p^2 = 0.14$ (see Figure 2). Participants in the arousal group (*M* = 51.59cm, *SD* = 10.70) also estimated the size of the target to be larger than participants in the control group (*M* = 41.60cm, *SD* = 6.48), $F(1, 27) = 9.21$, $p = 0.005$, $\eta_p^2 =$ 0.26 (see Figure 3). The overestimation of size in the arousal group is important because it suggests that indirect measures of distance are also influenced by the arousal manipulation. Again, size is a converging measure of perceived height given that apparent size is frequently related to perceived distance. This relationship was present in this experiment, participants who saw the height as taller, estimated the target to be larger in both groups of participants. There was a positive correlation between the height and size estimates for the control group, $r(15) = .59$, $p = .02$, and the arousal group, $r(13) = 0.53$, $p = 0.06$[4]. We also tested whether gender influenced the perceptual estimates of size and height. The analyses revealed no effects of gender on height, $F(1, 24) =$, $p = 0.85$, or size, $F(1, 24) = 0.65$, $p =$ 0.43, estimates and no gender x condition interactions, both *F*'s < 1.00, both *p's* > 0.35[5].

Anxiety Measures

First, we examined whether individual differences in height-related trait anxiety and height-related state anxiety correlated with the perception of height. We found that scores on the Acrophobia Questionnaire (AQ) were marginally positively correlated with the perceived height of the balcony, $r(25) = 0.37$, $p = 0.07$. Individuals who had higher trait anxiety were more likely to perceive the balcony to be higher, regardless of their arousal condition. There was also a non-significant trend of a positive correlation between state anxiety and perceived height, $r(26) = 0.31$, $p = 0.11$. This finding supported the notion that when the specific environment in which the observer was located was more anxiety provoking, they reported greater feelings of anxiety (for a complete correlation matrix, see supplemental materials, Table 1). Finally, there were no effects of gender for state-anxiety, $F(1, 24) = 0.97$, $p = 0.34$ or for trait-level anxiety (AQ), $F(1, 24) = 0.01$, $p = 0.92$.

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[4]We recognize that the sample size for these correlations by group may be too small to be reliable (here and throughout). Our conclusions about these correlations are therefore tentative.

[5]We analyzed gender for all of the experiments, but the only experiment that showed an effect of gender was Experiment 2 (on horizontal distance perception, not height perception). Therefore, we reported those analyses in Experiment 2, but do not report gender in any of the other experiments.

In addition to running the ANOVA presented above, we ran an analysis of covariance (ANCOVA) to examine whether individuals' trait anxiety (AQ scores) interacted with the arousal manipulation. This analysis included height estimates as the dependent measure, arousal group as the independent variable, and AQ as a covariate. The analysis revealed a marginal main effect for arousal, $F(1, 24) = 3.55$, $p = 0.07$, $\eta_p^2 = 0.14$, and a marginal main effect for AQ, $F(1, 24) = 3.95$, $p = 0.06$, $\eta_p^2 = 0.16$. However, the interaction between arousal and AQ was not significant, $F(1, 24) = 0.99$, $p = 0.33$. The same analysis was run for the size estimates. A main effect was observed for arousal, $F(1, 24) = 5.46$, $p < 0.05$, $\eta_p^2 = 0.2$, but there were no main effects for AQ and no interaction. These findings suggest that the influence of viewing arousing or non-arousing pictures on height and size estimations were independent of the participants' self-reported trait-level anxiety.

Discussion

Heights were overestimated after viewing arousing images. Specifically, the group that viewed arousing images overestimated both the balcony height and the target size compared to the group that viewed non-arousing images. As stated previously, these overestimations were independent of the trait-level anxiety of the observer. Therefore, the previously found influences of fear on height perception (Stefanucci & Proffitt, in press; Teachman et al., 2008) may be due to an increased level of arousal experienced by fearful observers. Thus, we suggest that arousal can influence lower-level processes, such as perception, in addition to the previously observed effects of arousal on higher-level cognitions like memory, attention, and decision making.

There are two concerns that we could not address with the current experiment. First, were the overestimations observed due to arousal per se? We believe that they were. The pictures were selectively chosen to vary on arousal, and these pictures were effective in prior studies at eliciting an aroused emotional state, such as fear and excitement (Lang et al., 1999, see Bradley & Lang, 2007). Also, recently published studies have used these pictures as reliable elicitors of arousal without obtaining self reports of arousal as a manipulation check (Phelps et al., 2006). Because we did not collect ratings of self-report either it remains unclear whether arousal produced our effect, so we tried to address this issue in Experiments 3 and 4.

Second, why did state-anxiety not differ between the two groups? We believe that participants may have discounted the arousal induced from the pictures when reporting their fear of the balcony height. These discounting effects are not uncommon. For instance, several studies found that arousal intensified evaluative judgments. However, the influence of arousal was only observed when asked about feelings towards the evaluated object, but not when asked to evaluate the object directly (Gorn, Pham, & Sin, 2001; Martin, Thomas, & Strack, 1992). Thus, when our participants were asked to report the anxiety that they felt on the balcony, they may have discounted their arousal from viewing the images. However, because their feelings were not surveyed until after they estimated the height, the induced arousal may have influenced those height reports. There is also the possibility that the single item about state-level anxiety at the height was ineffective at measuring participants' true level of arousal. Rather, the question may have been construed by participants as pertaining to a fear response and they may not have interpreted their arousal as such.

Experiment 2

The results of Experiment 1 suggest that induced emotional arousal unrelated to the balcony could influence the perception of height, lending support to expectations based on Zillman's (1971) rather than Proffitt's (2006) approach. However, as a further test of Proffitt's approach, this experiment examined whether viewing arousing images could influence other perceptions of spatial layout, such as a horizontal distance. Specifically, we were interested in finding whether the effect observed in Experiment 1 was specific to a parameter of spatial layout that often increases arousal, like a height, or whether it would extend to a non-arousing situation, like viewing a ground distance in a hallway. Previous research has shown that other non-optical factors, like the physiological potential of the observer, can influence the perception of horizontal, ground distances (Proffitt, Stefanucci, Banton, & Epstein, 2003; Witt, Proffitt, & Epstein, 2004). Observers who are wearing a heavy backpack, or who have just thrown a heavy ball, perceive distances as farther than observers who are not wearing a pack or who throw a light ball. Therefore, arousal could alter the perception of distances on the ground as well. This experiment was identical to Experiment 1, except individuals were asked to judge horizontal, ground distances rather than a vertical extent.

Method

Participants

Thirty-four (20 female, 3 Ss did not report their gender) undergraduates participated to fulfill a course requirement. All participants had normal or corrected-to-normal vision. Mean age was 19 years (*SD* = 1.6) and 57% reported race and/or ethnicity as Caucasian, 11% as African American, 17% as Asian, 1% reported their race as mixed, and 3 people did not report their race.

Stimuli & Apparatus

Arousal Task—All pictures were the same as those in Experiment 1.

Perceptual Task—Participants stood in a 35 meter hallway and judged three horizontal, ground distances (6.3m, 8.3m, 10.3m) to a large blue disk made of core board (45.7 centimeters in diameter) that was used in the previous height experiment. The disk was displayed vertically (propped up by placing an object behind it) in the hallway so that participants could see the full size of the object from their viewing position.

Anxiety Questionnaires—Only the trait-anxiety scale, the AQ, was administered.

Procedure

Participants were given the same memory cover story as Experiment 1 and then as a between-participants manipulation they were randomly assigned to see either the arousing or non-arousing images. The images were presented in the same manner as in Experiment 1.

After all of the images were presented, participants were moved into the hallway to begin the perceptual task, which was described as being unrelated to the memory task.

Perceptual Estimation—For the distance estimation task, participants were asked to stand at the corner of an 'L' shaped hallway, in which the target was placed in one arm of the L and the distance estimate was given down the other arm of the hallway. They were presented with the one experimental distance (8.3 meters) followed by two distracter distances (6.3 and 10.3 meters). For each trial the participant was asked to face the non-target arm of the hallway with eyes closed while the experimenter set up the target at the appropriate distance. The experimenter walked back to the participants before they turned around and opened their eyes, so the participant did not get any information about how long it took the experimenter to walk to the target. After the target was appropriately placed, and the experimenter had returned to the participant, they were asked to turn around and to judge the distance to the target on the ground by moving an experimenter. The experimenter moved down the other arm of the hallway until the participants judged the experimenter to be the same distance to them as the target was to them (a similar matching procedure to the one used in Experiment 1). They were encouraged to look back and forth as much as they liked and to adjust the experimenter until (s)he was as accurately placed as possible. Between trials, participants were asked to turn away and close their eyes while the next trial distance was placed. The same procedure was repeated for all distance estimations.

After estimating all the distances to the target, the target was returned to the 8.3 m location and participants were asked to estimate the size of the target as in Experiment 1, using the tape measure for the size matching task. Upon completing the perceptual tasks, the participants returned to the experiment room to complete the anxiety questionnaire.

Results

Perceptual Estimates

We found that the arousal manipulation did not influence the perception of horizontal ground distances. A repeated-measures ANOVA was run with distance (6.3m, 8.3m, and 10.3m) as the within-participants factor and arousal as the between-participants factor. There was a significant effect of distance $F(2, 48) = 491.06$, $p < 0.0001$, $\eta_p^2 = 0.95$, but no significant effect for arousal condition, $p = 0.76$. Participants reported greater distances to be farther away (6m: $M = 6.21$, $SD = .59$; 8m: $M = 8.17$, $SD = .64$; 10m: $M = 10.2$, $SD = .63$), but arousal did not influence their distance estimates. Finally, we ran a one-way ANOVA on the size estimate of the target and found that there was no difference in the estimate of the size based on arousal level, $F(1, 33) = 0.19$, $p = 0.67$, see Table 2 for means and standard deviations. There were no correlations between the trait anxiety scores and the estimates of the 6.3m ($r(29) = -0.04$, $p = 0.82$), 8.3m ($r(29) = 0.21$, $p = 0.27$), 10.3m ($r(29) = -0.24$, $p = 0.20$) distances or the size estimate ($r(29) = -0.28$, $p = 0.12$).

Discussion

The results of this experiment suggest that emotional arousal does not influence the perception of horizontal distances in the same manner that it influences height perception, and that viewing the IAPS images does not elicit a general overestimation of all parameters of the environment. We ran a power analysis to determine whether we had enough power to detect an effect for horizontal distances if it were present. Specifically, we used the effect size obtained from Experiment 1, $d = 0.50$, with an alpha level of 0.05, and found that we had 81% power to detect an effect in this experiment (Cohen, 1988). Moreover, these null findings were not surprising given that Proffitt's approach suggests that when no cost is associated with acting in the environment, arousal should not influence perception. Thus, we tentatively suggest that the environment must contain a cost for action in order for experienced arousal, caused by a source unrelated to the perceptual environment, to influence perception. However, we concede that more research is needed to determine whether *any* horizontal distance would be unaffected by manipulations of arousal. If participants were asked to walk a gangplank or reach over a height, then an arousal manipulation may change their perception of the extent of the plank or reach.

We do not know of any prior research that has directly tested the influence of arousal on distance perception. Instead, the research that has been done has shown effects of higher-level cognitive processing, like motivations or cognitive dissonance, on distance perception (Balcetis & Dunning, 2007). We believe that the important finding in this experiment is that simply viewing arousing pictures does not make *every* distance appear farther or larger. This finding provides an important check for general response biases that could follow the viewing of arousing images. If participants intuited our hypothesis, then they would be likely to estimate every parameter of the environment to be larger or farther. This experiment shows that a general cognitive, response bias was probably not the reason for the effect observed in Experiment 1.

Experiment 3

The results of Experiment 1 showed that viewing emotionally arousing images influenced the perception of height and the results of Experiment 2 suggest that this influence may be specific to heights. In this experiment, we tested whether the altered perception of height in Experiment 1 was due specifically to arousal or whether it could be moderated, in part, by valence. Because imagining the costs associated with falling off of a height would presumably be negative in valence, we hypothesized that valence may contribute to an influence of arousal on height perception. Also, testing multiple levels of arousal would begin to reveal the shape of the function that relates arousal to height perception. In the current experiment, we manipulated arousal level (high, medium, or low) and valence (positive vs. negative) to further describe the influence of emotion on height perception.

Method

Participants

Eighty-four (49 female) undergraduates participated to fulfill a course requirement. All participants had normal or corrected-to-normal vision. Mean age was 19 years (*SD* = 1.3) and 63% reported race and/or ethnicity as Caucasian, 11% as African American, 13% as Asian, 1% as Latino, and 3 people did not report their race.

Stimuli & Apparatus

Arousal Task—The picture viewing conditions, height perception task, and questionnaires used were identical to Experiment 1. However, participants also completed a questionnaire about their feelings towards the images. Also, the pictures in this experiment were changed so that they systematically differed in both valence and arousal (the pictures in previous experiments also differed in valence and arousal, but valence was matched across the conditions). Five conditions were selected, positive valence high arousal, positive valence medium arousal, negative valence high arousal, negative valence medium arousal, and neutral valence low arousal (control). Each group of pictures consisted of approximately 30% height-related pictures as in the previous experiments (see Table 1 for slide means and statistical comparisons of valence and arousal across groups). Participants were randomly assigned to one of the five picture conditions.

Arousal Manipulation Check—The manipulation check was administered after the perceptual task. The participant was asked to “describe how you were feeling while viewing the emotional pictures.” They answered this question four times using 6-point Likert scales, each with different endpoints. The first question used a scale with 1 being “not aroused” and 6 being “very aroused,” the second question used a scale ranging from “very unhappy” to “very happy,” the third question ranged from “very unpleasant” to “very pleasant,” and the last question ranged from “very negative” to “very positive.”

Perceptual Task—The same perceptual task was used as in Experiment 1.

Anxiety Questionnaires—The same state and trait anxiety measures were administered as in Experiment 1.

Procedure

The procedure was identical to Experiment 1 except that the recognition test was not given. Participants were told that the purpose of the experiment was to test their memory for a series of pictures. They were shown the pictures for the test and then were led to the balcony where they gave their perceptual estimates and state-level rating of anxiety. Finally, they were brought back to the lab to complete the Acrophobia Questionnaire and to collect demographic data.

Results

One participant was removed because they failed to follow instructions (negative valence, high arousal), another was removed because their size estimate was 3 standard deviations above the mean (positive valence, high arousal), and 4 individuals (2 negative valence, high arousal, 2 control) were removed because their height estimates were 3 standard deviations from the mean.

To determine whether the arousal manipulation was effective, we ran a one-way ANOVA on self-reported arousal and found a significant main effect, $F(4, 75) = 3.95$, $p < 0.01$, $\eta_p^2 = 0.18$. Post-hoc analyses using Fisher’s LSD revealed that the high arousal and medium arousal positive ($p = 0.01$ and 0.06, respectively) and the high arousal and medium arousal negative groups ($p = 0.003$ and 0.001, respectively) all had higher self-reported arousal in comparison to the control group.

In addition, a significant effect was found for self-reported happiness after running a one-way ANOVA, $F(4, 75) = 28.87$, $p < 0.001$, $\eta_p^2 = 0.18$. Post-hoc analyses revealed that the positive high and medium arousal groups, as well as the control groups were happier compared to both the negative high and medium arousal groups (all *ps* < 0.001). Self-reported arousal and self-reported happiness were not correlated, $r(76) = -0.15$, $p = 0.21$ (see supplemental materials for all correlations and Table 2 for all means and standard deviations).

A main effect was observed between the groups for height estimates, $F(4, 77) = 3.22$, $p < 0.05$, $\eta_p^2 = 0.15$. Post-hoc analyses revealed that all groups differed from the control group. The high ($M = 14.4$; $SD = 1.85$: $p < 0.05$) and medium ($M = 13.9$; $SD = 2.33$: $p < 0.01$) negative groups and the high ($M = 13.4$; $SD = 2.51$: $p < 0.05$) and medium ($M = 14.4$; $SD = 3.40$: $p < 0.01$) positive groups all overestimated the balcony height compared to the control ($M = 11.6$; $SD = 1.02$) group. No other differences among the groups were observed. Differences in size estimation also failed to reach significance, $F(4, 77) = 0.58$, $p = 0.68$ (see Table 2 for means and standard deviations). The findings suggest that both positive and negative arousing images influence visually-matched perceptions of height.

Interestingly, after running a one-way ANOVA, we observed a significant main effect for state anxiety while participants were on the balcony, $F(4, 77) = 6.35$, $p < 0.001$, $\eta_p^2 = 0.26$. Post-hoc analyses using Fisher's LSD revealed that the negative valence high arousal group had higher anxiety ratings compared to all of the other groups (all *ps* < 0.01, see Table 2 for means and standard deviations). All other effects were non-significant. Overall, participants in the negative valence high arousal group reported higher state levels of anxiety while on the balcony.

Self-reported feelings of arousal were positively correlated with height estimates, $r(76) = 0.24$, $p < 0.05$, such that individuals who reported higher feelings of arousal while viewing the pictures tended to overestimate height more. No other variables were significantly related to height estimates. Reports of happiness were significantly negatively correlated with reported state anxiety while on the balcony, $r(76) = -0.38$, $p < 0.001$. Participants who reported feeling happier after viewing the images also reported less state-level anxiety while on the balcony. In addition the trait-level anxiety scale for heights (AQ) was significantly positively correlated with both the size estimates, $r(77) = 0.23$, $p < 0.05$, and state-level anxiety, $r(77) = 0.48$, $p < 0.001$.

Because self-reported arousal and self-reported happiness were correlated with height estimates, we ran a multiple regression that included both self-reported arousal and self-reported happiness. The factors were simultaneously entered, the regression equation was: $Y = 12.286 + 0.436(\text{arousal}) - 0.02\ (\text{happiness})$ [Unstandardized coefficients]. The findings showed that self-reported arousal was a significant predictor for height estimates, $t(75) = 2.09$, $p < 0.05$, $\beta = 0.24$, such that higher levels of arousal predicted more overestimation of height. Self-reported happiness did not predict height estimates, $t(75) = -0.09$, $p = 0.93$ $\beta =$

−0.10. The findings showed that self-reported arousal, and not self-reported happiness, predicted overestimation of height estimates.

Discussion

We believe the results of this study suggest that arousal, more than valence, influences height perception. In sum, we observed that both high and medium levels of arousal can influence height perception, but valence manipulations do not have a similar effect on height perception. Admittedly, the manipulations for the 2 arousal conditions (high and medium, collapsing across valence) were not effective. The two high arousal conditions did not differ in arousal ratings from the two moderate arousal conditions. Further research is needed to be able to assess the effects of different levels of arousal on height perception. Or, there may be a certain arousal threshold that needs to be crossed and then any level of arousal will influence perception. This would be an important issue to address in future studies. However, the central purpose of this study was to examine whether the influence of arousal observed in this experiment and Experiment 1 was moderated, in part, by valence. The findings suggest that the effect of arousal on height perception is not mediated by the valence associated with the arousal.

Experiment 4

The results of Experiments 1 and 3 showed that viewing emotionally arousing images influenced the perception of height. Experiment 3 suggested that this effect may be due to the arousal associated with the images, rather than the valence. Therefore, in this experiment, we tested whether encouraging observers to moderate their level of emotional arousal experienced while viewing the images would influence height perception. We manipulated level of arousal by adopting a paradigm from the emotion regulation literature (Ochsner et al., 2004) and applied it to the procedure used in Experiment 1. Specifically, we predicted that by asking participants to up-regulate their emotional experience while viewing emotionally arousing images, their subjective arousal would increase and they would overestimate height more than other groups. On the other hand, if participants could lower the level of subjective arousal, by down-regulating their emotional experience while viewing the pictures, they would overestimate height less than control participants.

Method

Participants

Forty-nine (23 female) undergraduates participated either to fulfill a course requirement or for payment ($7). All participants had normal or corrected-to-normal vision. Mean age was 19 years (*SD* = 2.13) and 59% reported race and/or ethnicity as Caucasian, 14% as African American, 10% as Asian, 1% as Latino, and 1% as Other.

Stimuli & Apparatus

Arousal and Emotion Regulation Task—Only the arousing image sets from Experiment 1 were used in the current experiment. There were three conditions: up-regulation, down-regulation, and control.

Participants were informed that the goal of the study was to memorize the presented pictures. Each participant was then told that they would receive specific instructions to help them remember the pictures. These instructions served as the regulation manipulation and were adapted from Ochsner et al. (2004). The up-regulation group was told to think that they or a loved one was the central person in the picture. The down-regulation group was told to view the picture from a detached, third-person perspective. Ochsner et al. found that giving participants these instructions influenced subjective arousal in the appropriate way; therefore, we anticipated that participants' subjective arousal would be increased in the up-regulation condition and decreased in the down-regulation condition. The control group was simply told to attend to the pictures and to try to remember them.

Perceptual Task—The same perceptual task was used as in Experiment 1.

Anxiety Questionnaires—The same state and trait anxiety measures were administered as in Experiment 1. We also administered an emotion regulation questionnaire that assessed how often individuals used either a reappraisal or a suppression strategy when trying to regulate their emotions (Gross & John, 2003). The scale assesses two factors or strategies typically used to regulate one's emotions. When participants *reappraise* to reduce their emotional consequences and feelings, they cognitively mitigate or redefine their feelings to reduce their level of arousal (see Gross, Richards, & John, 2006). On the other hand, *suppression*, involves inhibiting or avoiding the current emotional state, rather than trying to redefine it cognitively. It is often thought to be a response-focused strategy that is invoked after emotion-related responses have been triggered.

Procedure

The procedure was identical to Experiment 1 with the exception of the memory instructions and the removal of the non-arousing picture condition. Participants were told to study and remember a series of pictures. The memory instructions differed depending on the regulation condition (as described above). Again, the perceptual task was presented as a filler task that was completely separate from the memory task[6]. Participants were randomly assigned to the up- or down-regulation conditions or to the control condition. Upon completion of the perceptual task, participants filled out the trait anxiety measure.

Results

Four individuals were removed from the analysis (1 in the down-regulate condition, and 3 in the control condition): in two cases there were accidentally two targets on the ground, and the other two were removed because of harsh weather conditions.

Perceptual Estimates

The regulation instructions influenced the perceived height of the balcony, $F(2, 42) = 3.91$, $p < 0.05$, $\eta_p^2 = 0.16$ (see Figure 5). Post-hoc comparisons using Fisher's LSD showed that the

[6]The last eight subjects were questioned about the nature of the experiment, and none of the eight subjects believed that the regulation instructions, pictures, and height task were related. We were concerned about participants intuiting our hypothesis, but we did not realize that they were not being asked about the hypothesis until we were almost finished collecting the data.

up-regulation group (M = 15.2; SD = 3.24) estimated the height to be higher than the down-regulation group (M = 13.0; SD = 2.13), $p < 0.05$, and the control group (M = 12.7; SD = 2.45), $p < 0.01$. The down-regulation group and the control group did not differ in their height estimates, $p = 0.71$. There was no significant effect of regulation instruction on the perception of the size of the target, $p = 0.91$ (see Table 2 for means and standard deviations).

Correlational analyses were run to examine whether the height and size estimates were correlated overall, regardless of group membership. These measures were positively correlated, $r(43) = 0.35$, $p < 0.05$. If participants perceived the height to be taller, then they perceived the target to be larger.

Personality Measures

Neither the AQ nor any of the other anxiety measures were correlated with the perceptual estimates in this experiment. However, there were significant correlations found with the reappraisal questionnaire. For the down-regulation condition, we observed a significant positive correlation between the suppression factor of the emotion regulation questionnaire and estimates of balcony height, $r(14) = 0.55$, $p < 0.05$. The more likely individuals were to use a suppression strategy, the higher they tended to perceive the balcony height. For the control group, we observed a negative correlation between the reappraisal factor of the regulation questionnaire and estimates of balcony height, $r(14) = -0.64$, $p < 0.05$. Those who were more likely to engage in a reappraisal strategy when viewing the images estimated the balcony to be shorter. Finally, for the control group we also observed a significant negative correlation, $r(14) = -0.64$, $p < 0.01$, between reappraisal and estimates of target size, such that those who were more likely to use a reappraisal strategy were also more likely to estimate the target to be smaller.

Discussion

Overall, we found that emotion regulation strategies can moderate the overestimation of height. This is an important finding, because it replicates the influence of arousal on height perception, but also shows that this effect can be moderated by different levels of arousal, which would have implications for treatments of anxiety disorders. Furthermore, the results suggest that future studies could more carefully map out the relationship between arousal and height perception by examining how different levels of arousal result in perceptual changes (maybe a threshold has to be crossed to predict a change in perception, or a linear relationship exists between arousal and height estimates).

Admittedly, the down-regulation of emotion did not produce significantly lower estimates compared to the control condition. However, this was not surprising because prior research found that regulation is not always effective for reducing physiological responses in the time specified (see Gross, 2001). Moreover, brain imaging studies using similar regulation strategies also found no differences in brain activation patterns for emotion areas between the control and down-regulation groups (see Urry et al., 2006). Thus, it is possible that participants who were trying to down-regulate their emotional reactions to the images were unsuccessful, particularly given the positive correlation between emotion suppression and height estimates. Individuals in the down-regulation group who were more likely to suppress their emotional feelings were also more likely to overestimate the height of the balcony. These correlational findings suggest that the suppressed arousal may still affect underlying processes outside of the awareness of the participant (see Gross et al., 2006). Therefore, if participants in the down-regulation group were suppressing their reactions, they may have still used arousal to estimate height without experiencing the physiological or cognitive reactions normally associated with the arousal manipulation.

This suppression strategy may have been more prevalent in the down-regulation group than the control group, in which participants may have reappraised their emotions (given the correlational findings) more often. Unlike suppression, which involves inhibiting or avoiding the current emotional state, reappraisal strategies aim to mitigate emotional consequences by cognitively redefining the situation to reduce the emotional consequences or experiences. When participants reappraise during the emotional elicitation, they often reduce their emotional experience and emotional feelings (Gross et al., 2006). Participants in the down-regulation group should have been reappraising given the instructions; however, our correlational data suggest that they may have suppressed more often. Control participants who reappraised, gave shorter estimates of the balcony and smaller estimates for the target size.

Therefore, we were unsure as to whether participants were effectively up- or down-regulating their arousal throughout the task, which could have influenced the results in both conditions. We ran a follow-up study to test for the effectiveness of the regulation task.

Experiment 4b

The results of Experiment 4 showed that emotion regulation strategies influenced the perception of height; however only the up-regulation instructions were influential. After obtaining the results for Experiment 4, we questioned whether the regulation instructions had the intended effect on the participants' arousal levels across the conditions. Therefore, we conducted a follow-up experiment with a new group of participants to examine whether the regulation instructions influenced subjective arousal.

Method

Participants

Forty-three (34 female) undergraduates participated to fulfill a course requirement. All participants had normal or corrected-to-normal vision.

Stimuli & Apparatus

The picture stimuli and memory task instructions were identical to those used in Experiment 4a.

Arousal Manipulation Check

The manipulation check was the same as in Experiment 3.

Procedure

The procedure was identical to Experiment 4a, except instead of completing the perceptual task, participants completed the arousal manipulation check.

Results

A single outlier in the up-regulation condition was removed from the analysis. The regulation instructions influenced the arousal that participants experienced while viewing the images, $F(2, 42) = 5.54$, $p < 0.01$, $\eta_p^2 = 0.22$. As expected, post-hoc comparisons using Fisher's LSD showed that the up-regulation ($M = 4.13$, $SD = 0.64$) felt more aroused than the down-regulation group, ($M = 3.14$, $SD = 0.86$), $p < 0.01$, and the control group, ($M = 3.29$, $SD = 1.07$), $p < 0.05$. The down-regulation group and the control group did not differ in their experienced arousal, $p = 0.67$. The regulation instructions also influenced the participants' happiness levels, $F(2, 42) = 4.85$, $p < 0.01$, $\eta_p^2 = 0.20$. Post-hoc analyses using Fisher's LSD showed that the participants in the up-regulation ($M = 2.67$, $SD = 1.23$) reported feeling less happy than those in the down-regulation ($M = 3.71$, $SD = 0.83$), $p < 0.01$, and the control groups, ($M = 3.64$, $SD = 0.93$), $p < 0.05$. The down-regulation group and the control group did not differ in their happiness ratings, $p = 0.85$.

Discussion

These results suggest that the manipulation in the previous experiment may have been successful at increasing subjective arousal for the up-regulation group compared to the control and down-regulation group, but unsuccessful in lowering subjective arousal for the down-regulation group compared to the control group. If this was the case, then we would expect a difference in the perceptual estimates for only the up-regulation group when compared to the control and down-regulation groups, which is what we found.

General Discussion

These studies suggest that emotional arousal, regardless of its affective value and source, can influence height perception. In four experiments, we showed that 1) overestimation of height results from viewing emotionally-arousing stimuli, 2) emotional arousal may only influence height perception and not other parameters of spatial layout, 3) the valence of the arousal does not seem to further increase height overestimation, and 4) up-regulating subjective arousal does increase height overestimation. The results of Experiment 1 revealed that when participants viewed pictures of emotionally arousing stimuli, they overestimated height, with both direct (visual matching task) and indirect (size matching task) measures of height, more than participants who viewed non-arousing images. Experiment 2 showed that the emotionally arousing stimuli in Experiment 1 had little (if any) influence on the perception of horizontal ground distances. Experiment 3 tested whether the arousal manipulation used in Experiment 1 would interact with valence. Interestingly, arousal, but not valence, influenced height perception. Furthermore, self-reported levels of arousal significantly predicted height overestimation, but self-reported levels of happiness did not. In Experiment 4, we found that height overestimation could be partially moderated by regulating experienced feelings of arousal. Participants who up-regulated their subjective arousal when viewing the images overestimated height more than participants who viewed arousing images with no regulation, or with down-regulation strategies.

Overall, we found that one component of fear – arousal – was sufficient to evoke a greater degree of height overestimation. Previous research has found that arousal influenced non-related task performance in other paradigms. For example, the seminal paper by Yerkes and Dodson (1908) showed that moderate levels of arousal improved learning performance. Another classic study found that men crossing a rickety bridge were more likely to call a female experimenter for a date than men who crossed a stable bridge (Dutton & Aron, 1974). Importantly, they showed that arousal from the bridge could be misattributed as a reaction to the female experimenter to influence subsequent behavior. Finally, a recent perception study observed that emotional arousal from fear faces increased contrast sensitivity, in part by facilitating attention (Phelps et al., 2006). In a similar way, the current study demonstrates that emotional arousal can influence visual processes in other tasks.

We were somewhat surprised that arousal unrelated to heights could produce overestimations of height perception. One reason for our surprise comes from Proffitt’s (2006) predictions that only height-specific arousal should influence perceived height because it would make the observer overestimate the threatening nature of the environment, whereas arousal related to other sources might not. However, we did find that our manipulation of emotional arousal did not influence the perception of horizontal ground distances, lending partial support to Proffitt’s suggestion. The effect of arousal on overestimations of height is consistent, however, with Zillmann’s theory of excitation transfer (1971). He argues that emotional states that elicit arousal symptoms do so in a non-specific manner, permitting the integration of arousal cues of one stimulus with another. In the current study, the arousal associated with the pictures may have been integrated with arousal cues associated with the height of the balcony, resulting in an overestimation of the height. In addition, when arousal was increased by the up-regulation of experienced arousal in Experiment 4, we observed a further increase in the perception of height. However, a similar influence was not present when we examined estimates of ground distances in a hallway. The environment in which observers are located is crucial in determining whether they will incorporate arousal into perceptual estimates or not. We do not claim that horizontal distance would always be immune to the effects of arousal. A horizontal distance across a bridge, for example, might be very different in this regard than the distance down a hallway.

The evidence from our studies suggests that when the observer is in a potentially dangerous environment (like a balcony), arousal cues not relevant to the environment may then be misattributed to the dangerous environment. But when the environment has little danger or no cost associated with it (as in a hallway), arousal cues not relevant to the safe environment are less likely to be attributed to objects in a way that would influence perception. This explanation is consistent with Proffitt’s approach and also to the *affect-as-information* approach first proposed by Schwarz and Clore (1983), (see also Clore, Wyer, Dienes, Gasper, Gohm, & Isbell, 2001; Schwarz & Clore, 2007). The affect-as-information approach explains how feelings guide judgments and cognitive processes. In this view, many judgments and decisions are made as though people ask themselves, “How do I feel about it?”, a process that can influence implicit as well as explicit judgments (Schwarz & Clore, 1988). In addition, whereas the valence dimension of affect conveys information about value, the arousal dimension is believed to convey information about urgency (Clore & Storbeck, 2006). Moreover, feelings of arousal that are not related to the object of the judgment can often be misattributed to that object so that they influence judgments relevant to urgency, as in the case of fear. Thus, we believe that the feelings from the arousing pictures combined with feelings elicited by the height of the balcony to create a greater sense of urgency or anxiety on the balcony. This enhanced experience of arousal should then result in overestimations of height. It is important to note that from this approach arousal should not be attributed to the hallway distance because the hallway has no fear potential and thus the manipulated arousal state is discounted prior to perceptual estimates.

Perception or Bias?

The discussion of the affect-as-information approach leads us to an important question about whether arousal influences early perceptual or later cognitive processes. In other words, does arousal influence how participants *saw* the height, or just how high they *judged* it to be? Throughout this paper we have claimed that our effects are perceptual, but we can not know whether arousal influences perception or judgment when responses involve cognitive processes. The size measure was employed, in part, to provide an indirect measure of height. An effect on such an indirect measure would provide important evidence that the effects of arousal were on perceptual experience rather than on perceptual judgments.

However, we did not obtain consistency between the direct estimate of height (visual matching task) and the indirect estimate of height (size matching task) across all of our studies. In Experiment 1, both the height and size estimates were overestimated more in the arousal condition than the non-aroused condition. In Experiments 3 and 4 arousal manipulations influenced only the visual matching measure and not the size estimates. Moreover, estimates of the size of the target were only sometimes correlated with the height estimates. The question of whether arousal influenced perception or judgment is still open. More evidence is needed to pinpoint the location of our effects. However, the effect of arousal on height estimates was shown to be a robust phenomenon, given that it appeared in three different studies.

Alternative Explanations: Attention and Perceptual Rescaling?

One alternative explanation is that we moderated an attentional process that could feed back to and modify perceptual processes. Many researchers have found that emotional stimuli can capture attention and bias processing (Anderson & Phelps, 2001; Öhman, 2005; Öhman, Flykt, Esteves, 2001; Vuilleumier & Schwartz, 2001). If emotional stimuli are superior at capturing attention, then it is likely that these attentional biases could influence perception. Arousal has also been shown to alter the scope of attention (Easterbrook, 1959), which could have resulted in the overestimation of height observed in the present studies. In the famous “weapon focus” studies conducted by Loftus (1979), witnesses to a crime were more likely to remember the gun than aspects of the criminal holding the gun. In addition, Loftus, Loftus, and Messo (1987) found that when participants viewed an emotional slide, their eye movements were consistent with those produced when a narrowing of attention occurs.

Other evidence also suggests that attention is narrowed to focus on threat-relevant information for individuals who experience anxiety disorders or depression (Mathews, 2006). Moreover, recent evidence from Gable and Harmon-Jones (2008) found that highly arousing positive emotions can also narrow the breadth of attention, which could help to explain the lack of difference between positive and negative arousal groups in Exp. 3. Thus, it could be that the participants in the arousing condition as compared to the neutral condition attended to different sources of information or cues in the environment, which then led to different estimations of the height.

Recent research in cognitive neuroscience has also shown that attention modulates the activity of cells in the visual cortex (for review, see Kastner, 2004). Pessoa and colleagues demonstrated that emotional faces draw attention and as a result are found faster in a display when presented with other non-emotional stimuli (Pessoa, Japee, Sturman, & Ungerleider, 2006). Moreover, rock climbers who experienced more anxiety while climbing were less likely to detect irrelevant flashes of light during a climbing task (Pijpers, Oudejans, Bakker, & Beek, 2006). These findings are in line with recent suggestions of Duncan and Barrett (2007), in which they propose that arousal states tend to amplify aspects of the environment that reach visual awareness. This proposal is consistent with prior theories of arousal and attention in suggesting that arousal can serve to narrow the focus of attention, and consequently enhances the perception of attended objects. Thus, there is solid evidence to suggest that emotional arousal can influence attention and consequently guide visual perception to focus on arousing elements in the environment.

Another possibility is that arousal changed the focus of attention such that high arousal led to a quicker detection of the aversive stimulus (the height) or that the height itself was held in attention for a different amount of time across arousal conditions. Research has shown that arousing stimuli can be processed outside of conscious awareness and focal attention (Christianson, 1992) and that when arousing stimuli are the focus of attention, it may take longer to disengage from them (Fox, Russo, Bowles, & Dutton, 2000). Because attention could be a moderating factor in the effects observed here, assessments of attentional differences in future studies would be both interesting and useful.

The question still remains as to *how* arousal moderated perception. We proposed one mechanism, attention, but further work is needed to test whether attention was truly a moderating factor or not. We now propose a second possible mechanism by which arousal could influence height perception. The arousal could have been interpreted (implicitly or explicitly) as information about the dangerousness of the height, which altered participants' estimates of the extent. In other words, the visual system may have used the bodily cues and sensations associated with the arousal to scale the height. Traditionally, perceptual psychologists have argued that the information available for estimating extents consisted of visual angles and ocular-motor cues only, which is scaled to a unit-less metric (Foley, 1980; Loomis, Da Silva, Philbeck, & Fukusima, 1996). For example, the same unit that scales the size of a room also scales the size of a shoe. In the case of the present studies, we argue that information from arousal was used to determine the metric by which extents would be estimated and scaled. If participants were aroused, their perceptual "ruler" or units were enlarged, which resulted in an increase in their perception of height. This argument for a rescaling of perceptual units in accord with the bodily state of the observer is relatively new, but is supported by other studies that examined the influence of body size and intention to act on reaching and distance perception in near space (Linkenauger, Witt, Stefanucci, Bakdash, & Proffitt, 2008; Witt, Proffitt, & Epstein, 2005).

Conclusions

Emotional arousal has been shown to influence attention, memory, judgment and decision-making, and other high-level cognitive functions. Here, we show that the influence of emotional arousal may extend to lower-level perceptual judgments when the arousal is relevant to the environment being evaluated (a dangerous height rather than a non-dangerous distance). This influence can be moderated by regulating the level of arousal and may also be related to the valence of the arousal. These studies are the first to show an influence of arousal on lower-level processes, such as perception. They have implications both for emotion researchers and perceptual psychologists, as well as clinicians who may be treating height-related phobias or anxieties.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

This research was supported in part by NIH RO1MH075781-01A2 grant, for which the first author serves as a consultant. The authors wish to thank Ashlee Jenkins, Michael Lefebvre, Aliye Mosaad, and Amanda Quinn for their help in collecting the data. We thank Jonathan Bakdash, Gerald Clore, Cedar Riener, and Bethany Teachman for comments on earlier drafts of this manuscript.

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Figure 1.
View of the target on the ground from the balcony used in Experiments 1, 3, and 4.

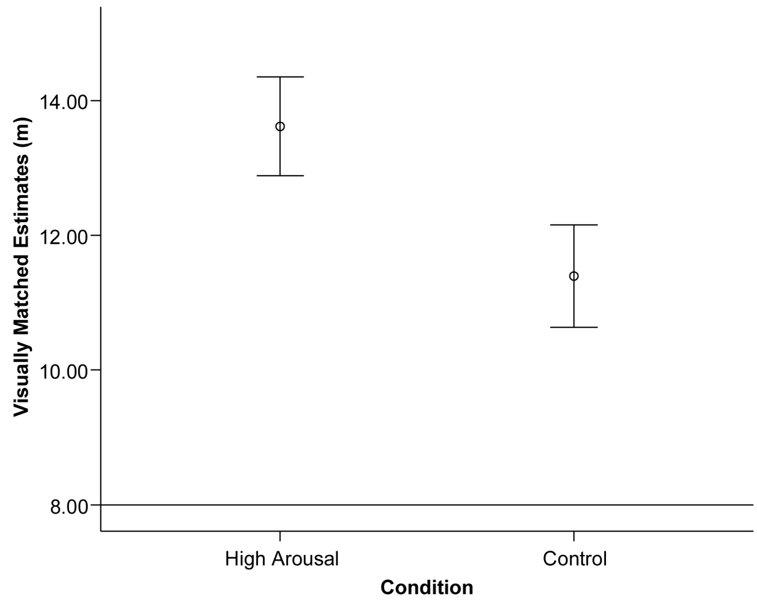

Figure 2.
Participants who viewed arousing images overestimated the height of the balcony more than participants who viewed non-arousing images. (Bars represent one standard error and the line represents the actual height of the balcony in m.)

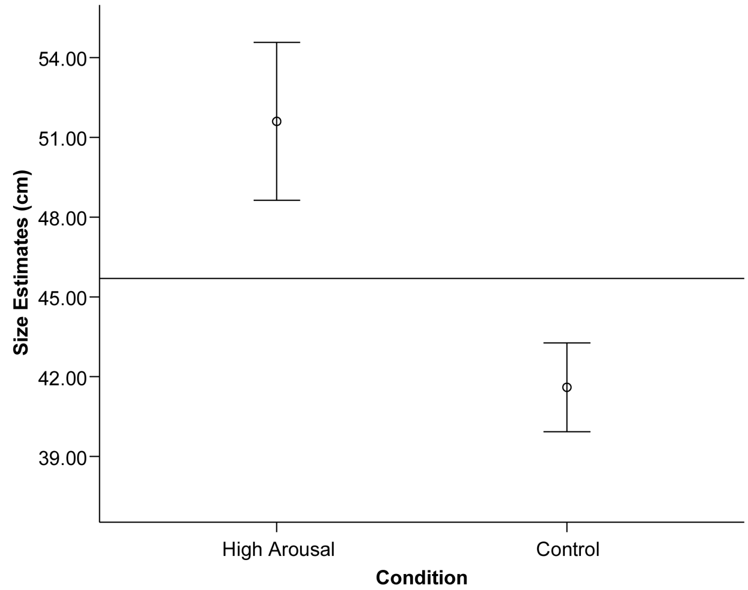

Figure 3.

Participants who viewed arousing images overestimated the size of the target more than participants who viewed non-arousing images. (Bars represent one standard error and the line represents the actual size of the target in cm.)

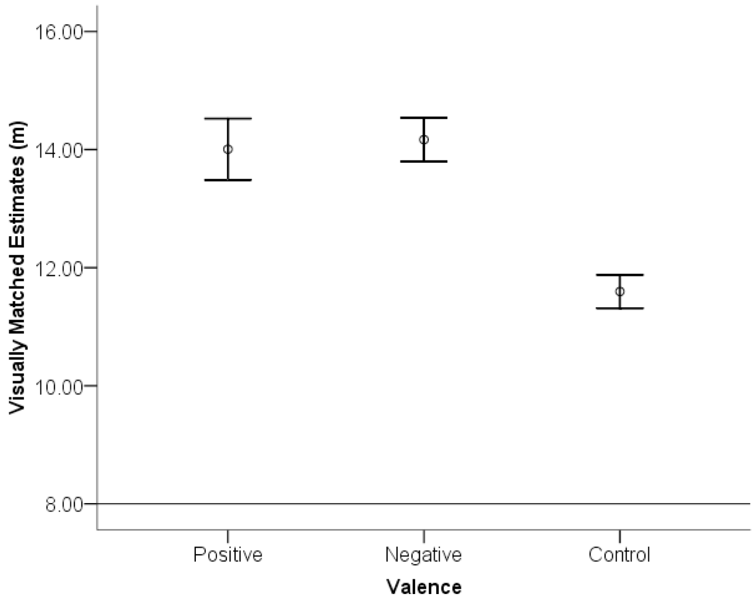

Figure 4.

Participants who viewed arousing images, regardless of their valence, overestimated the height of the balcony more than participants who viewed non-arousing images. PV-HA = Positive valence high arousal, NV-HA = Negative valence high arousal, PV-MA = Positive valence medium arousal, and NV-MA = Negative valence medium arousal. (Bars represent one standard error and the line represents the actual height of the balcony in m.)

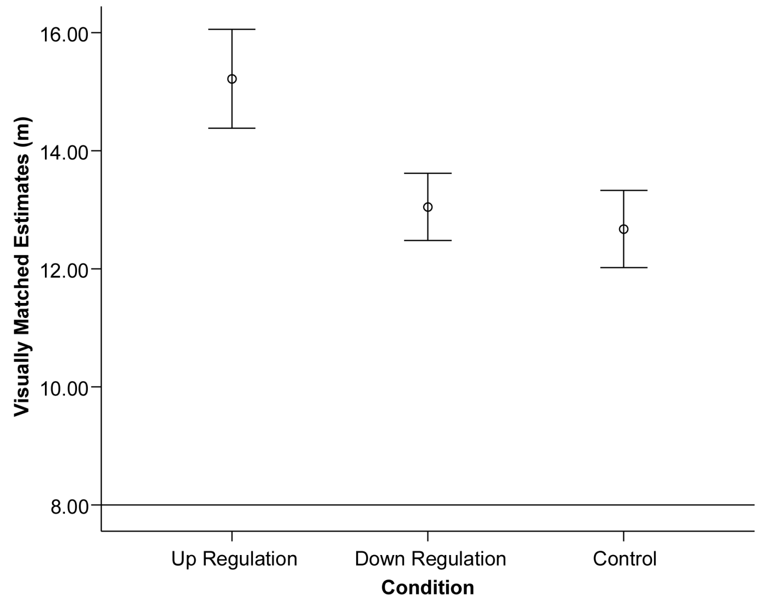

Figure 5.

Participants who up-regulate their arousal overestimated the height of the balcony more than participants who down-regulated or did not regulate their arousal. (Bars represent one standard error and the line represents the actual height of the balcony in m.)

Table 1

Means and standard deviations for slide ratings

Condition	Valence	Arousal	HA-A	HA-B	LA-A	LA-B
Experiment 1, 2, & 4			Valence P-value/Arousal P-value			
High Arousal A	5.6 (1.8)	6.0 (.78)	- / -			
High Arousal B	5.5 (1.8)	6.0 (.78)	.74/.78	- / -		
Low Arousal A	5.6 (1.3)	3.5 (.78)	.91/<.01	.83/<.01	- / -	
Low Arousal B	5.6 (1.2)	3.3 (.93)	.94/<.01	.80/<.01	.97/.32	- / -

Condition	Valence	Arousal	PHA	PMA	NHA	NMA
Experiment 3			Valence P-value/Arousal P-value			
Positive HA	7.0 (.65)	6.1 (.71)	- / -			
Positive MA	7.3 (.52)	4.2 (.74)	.45/<.01	- / -		
Negative HA	3.8 (.95)	6.2 (.65)	<.01/.97	<.01/<.01	- / -	
Negative MA	3.4 (.82)	4.4 (.70)	<.01/<.01	<.01/.54	.22/<.01	- / -
Control	5.7 (.93)	3.1 (.82)	<.01/<.01	<.01/<.01	<.01/<.01	<.01/<.01

Notes. Experiment 4 only used the high arousing images. HA = High Arousal, MA = Medium Arousal, PHA = Positive High Arousal, PMA = Positive Medium Arousal, NHA = Negative High Arousal, NMA = Negative Medium Arousal. Standard deviations are in parentheses. IAPS image numbers used in either Exp. 1, 2, 3, or 4: 1030, 1040, 1051, 1120, 1220, 1240, 1300, 1301, 1302, 1321, 1540, 1590, 1600, 1603, 1604, 1610, 1930, 1931, 2040, 2070, 2100, 2110, 2372, 2383, 2800, 2900, 4599, 4601, 4606, 4608, 4653, 4660, 5000, 5001, 5010, 5030, 5201, 5220, 5470, 5500, 5510, 5621, 5628, 5629, 5660, 5700, 5731, 5750, 5800, 5900, 5950, 5970, 5982, 5991, 6230, 3250, 6260, 6300, 6510, 6570, 6900, 6910, 7000, 7004, 7009, 7010, 7025, 7030, 7034, 7035, 7040, 7050, 7080, 7090, 7095, 7096, 7100, 7130, 7140, 7150, 7175, 7186, 7187, 7190, 7205, 7207, 7211, 7224, 7237, 7238, 7490, 7500, 7545, 7560, 7595, 7640, 7705, 7820, 7830, 8021, 8030, 8031, 8040, 8041, 8080, 8160, 8161, 8180, 8185, 8200, 8250, 8260, 8300, 8340, 8350, 8370, 8400, 8470, 9622.

Table 2

Means and standard deviations for distance, height, size, and anxiety estimates.

Experiment 2					
Condition	Size (cm)	6.3 Distance	8.3 Distance	10.3 Distance	AQ
High Arousal	42.5 (7.2)	6.2 (.64)	8.1 (.51)	10.3 (.63)	43.3 (12.7)
Low Arousal	43.5 (6.7)	6.2 (.55)	8.2 (.76)	10.2 (.65)	50.4 (17.7)

Experiment 3				
Condition	Size (cm)	Self-Arousal	AQ	Anxiety
Positive HA	54.0 (13.1)	3.4 (1.2)	48.6 (19.3)	10.8 (10.5)
Positive MA	51.1 (9.9)	3.1 (1.3)	51.6 (22.7)	6.9 (12.4)
Negative HA	52.7 (9.4)	3.7 (1.5)	63.4 (19.6)	37.9 (28.6)
Negative MA	48.9 (10.7)	4.0 (1.4)	51.7 (21.6)	12.3 (20.6)
Control	50.9 (6.2)	2.2 (1.1)	56.9 (24.5)	16.3 (18.5)

Experiment 4			
Condition	Size (cm)	AQ	Anxiety
Up-Regulation	50.2 (9.2)	50.4 (16.3)	22.7 (24.0)
Down-Regulation	50.3 (12.0)	44.2 (14.7)	22.5 (25.0)
Control	48.9 (7.5)	46.9 (15.1)	17.7 (24.5)

Notes: Standard deviations are in parentheses. HA = High Arousal, MA = Medium Arousal, AQ = Acrophobia Questionnaire, Self-Arousal = self-reported arousal after viewing the images, Anxiety = self-reported anxiety level while over looking the balcony.