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Follow your heart: Emotion adaptively influences perception

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Abstract

The current review introduces a new program of research that suggests the perception of spatial layout is influenced by emotions. Though perceptual systems are often described as closed and insulated, this review presents research suggesting that a variety of induced emotions (e.g., fear, disgust, sadness) can produce changes in vision and audition. Thus, the perceptual system may be highly interconnected, allowing emotional information to influence perceptions that, in turn, influence cognition. The body of work presented here also suggests that emotion-based changes in perception help us solve particular adaptive problems because emotion does not change all perceptions of the world. Taking the adaptive significance of emotion into account allows us to make predictions about when and how emotion influences perception.

Traditional models of perception have focused on how we represent the geometry and three-dimensional properties of the environment, such as the distance from an observer to an object. The visual system uses environmental cues as well as the inherent physiology of the observer (e.g., depth cues arising from the anatomy of the eyes) to determine what is in the environment and how to act. Most vision researchers have been interested in how the visual system detects and then stores visual information such as edges for object identification. Another area of interest is whether top-down processes that use assumptions, biases, and knowledge intrinsic to the observer can influence the recognition of a previously encountered object.

In this review, we argue that a different top-down process than is normally discussed – emotion – influences perception. Researchers have dubbed our perspective “embodied perception” (Proffitt, 2006) because it claims that states or capabilities of the body can alter perception. We also place our work in a larger theoretical framework, which emphasizes the adaptive function of emotion-perception relationships. From this framework we also offer suggestions for future investigations.

We will focus our discussion on perception of the spatial layout of the environment (e.g., distance to objects, balcony height, or steepness of hills). To support our claim that emotion influences perception, we discuss recent discoveries showing that fear, disgust, social support, and sadness influence the perception of spatial layout. Moreover, we provide the first evidence that emotion-perception relationships are not limited to vision by extending our investigation of emotional influences on perception to audition. Finally, we outline our future plans for testing the underlying systems or mechanisms involved in the influence of emotion on perception.

Cognition Influences Perception

Prior research has examined the influence of context, memory, knowledge, and intention (often termed top-down processes) on perception. These processes are described as being task-driven processes rather than stimulus-driven and are thought to be under voluntary control. Constructs such as attention and executive functions actively select perceptual information and therefore could be considered top-down processes. These processes may be accompanied by subjective feelings of selection as well.

Effects of top-down processes have been shown for object and space perception. For example, when viewing moving objects that are ambiguous in their motion, object memories can influence the direction at which objects appear to move (McBeath, Morikawa, & Kaiser, 1992). Also, the rate at which one can detect an object varies with knowledge about the object (Purcell & Stewart, 1991) and recognition of an object can influence its perceived depth (Peterson, 1994). More recent work has shown that the intention to act can influence space perception. Witt, Proffitt, and Epstein (2005) asked participants to hold a long baton and estimate the distance to an object just out of reach, finding that distances appeared closer to participants holding the baton compared to participants whose reach was not extended. This change in perceived distance only occurred when participants intended to use the baton suggesting that the intention to act rescales space perception for that action.

Recent research shows that emotion and motivation influence face perception (Halberstadt, Winkelman, Niedenthal, & Dalle, 2009), visual illusions (Balcetis & Dunning, 2006) and low-level perceptual processes such as contrast detection (Phelps, Ling, & Carrasco, 2006). This body of research led to our hypothesis that emotion should influence the perception of spatial layout. Emotion could actively select for perceptual information or change the intentions of the observer, as have other top-down processes.

Perception or Response Bias?

However, a common problem in perception research involves determining whether overt perceptual judgments are based on underlying perceptual representations or cognitive interpretations of those representations. Pastore (1949) refuted many of the early results showing influences of motivation and intention on perception by showing the effects were actually response biases rather than perceptual biases. This argument endures, even in the context of the results we present showing an influence of emotion on perception (Durgin et al., 2009; Woods, Philbeck, & Danoff, 2009). It is possible that emotion could bias the formation of the perceptual representation, or it could alter cognitive judgments resulting from the perceptual representation. Unfortunately, determining whether emotion biases perception or a post-perceptual response is difficult given the limits of our understanding of early perceptual processing. Furthermore, our experiments are primarily behavioral, so emotion could alter participants' responses rather than their perceptions and we would not be able to detect such a difference given all participants must respond in some way. In other words, participants may intuit the hypotheses of our experiments and change their responses while having the same perceptual experience or their perceptual experiences could differ and produce different responses. However, in all studies we strived to control for this potential explanation by measuring perception indirectly when possible (such as asking participants to report size, a measure indirectly related to perceived distance) and by using converging measures. To allay concerns, we present the findings of our experiments in light of this potential criticism for each of our reviewed experiments.

Emotion influences Space Perception

Our research questions whether emotion influences space perception. However, we are also interested in answering why emotions would influence the perception of spatial layout. The answer to this question may lie in the adaptive function of emotions. The following sections will (1) discuss the role of emotions as superordinate systems, (2) emphasize the adaptive function of particular emotions, (3) integrate these ideas into our findings, and (4) explain how these ideas may inform the direction of future work.

The Role of Emotion

One view of the human mind advocates that it contains an array of functional systems optimized to process information that was essential to solving recurring adaptive problems (see, Tooby & Cosmides, 1992; Barrett & Kurzban, 2006). For example, humans have systems for identifying kin (Lieberman, Tooby, & Cosmides, 2007), recognizing faces (Kanwisher, 2000), detecting and tracking coalition partners (Kurzban, Tooby & Cosmides, 2001), and gauging inclusion in social groups (Kirkpatrick, Waugh, Valencia, & Webster, 2002). It is important to note that our view of functional systems is different from Fodor's (1983) concept of a module (see for review, Barrett & Kurzban, 2006). The most important distinction is that we *do not* view functional systems as working in isolation, and we believe that our research supports this position. Rather, an array of systems is present and these systems work together when interpreting and discovering spatial layout. In our view, this array of systems could also be considered top-down processes, per our description of those processes in the previous section.

Coordinating the activity of these functional systems may be problematic if different systems produce conflicting outputs or motivations (e.g., foraging versus avoiding predators). As a solution to this problem, emotions may coordinate and even override the computations being performed by competing functional systems (Tooby & Cosmides, 2008). In terms of perception, emotions may inform judgments of environmental features when conflicting information is present (known as the "affect as information" hypothesis, Clore, 2009; Clore & Huntsinger, 2009; Storbeck & Clore, 2008; Zadra & Clore, in press). Although emotions may coordinate the activity of many other functional systems, making predictions about specific perceptual changes requires an understanding of the adaptive function of each emotion.

Functional Specialization of Emotions and their Role in Altering Perception

Identifying the functional significance of an emotion may take years of research and observation as it requires pinpointing the recurring adaptive problems that it helped solve. Fortunately, the functional significance of some emotions has already been identified. Although we acknowledge these identifications as working hypotheses, we extend these ideas to perception, ultimately enhancing our understanding of both emotions and perception. Here, we discuss the currently viewed functional significance of fear, disgust, and sadness, and demonstrate how these functions explain the findings of our work as well as making specific predictions for future investigations.

Fear—Fear has been well documented as an evolutionary strategy designed to protect an organism from threats, such as predators (Ohman, 2009) and falling off of cliffs (see Marks & Nesse, 1994; Nesse, 1990). As a superordinate system fear systematically changes physiology, including accelerated heart rate and increased skin conductance (Levenson, 1992). In addition, fear enhances attention to threatening stimuli in visual searches (Ohman, Flykt, & Esteves, 2001) and even alters body posture (Wallbott, 1998). If the adaptive function of fear is to protect an organism from threat, then we expect perceptual cues

relevant to threats, such as predator detection (auditory cues) and avoiding dangerous terrain (heights and steep hills), to be influenced by fear, but perceptual cues irrelevant to these adaptive problems to remain unchanged.

From subjective experience, and as Alfred Hitchcock's 1958 film *Vertigo* readily attests, fear can be a salient emotion when perceiving heights. While the contra-zoom shot featured in *Vertigo* may not be an entirely accurate depiction of acrophobia, people fearful of heights do perceive heights as taller than those unafraid (Jackson, 2009; Stefanucci & Proffitt, 2009). In general, heights are overestimated 60% when viewed from the top and 30% when viewed from below (Stefanucci & Proffitt, 2009). In a non-clinical sample, we found a positive correlation between estimates of height and two measures of fear of heights: a trait-level measure called the Acrophobia Questionnaire (Cohen, 1977) and a state-level measure called the Subjective Units of Distress Scale (SUDS), which is gathered by asking participants their anxiety level (0 not at all to 100 panic level). Higher fear was related to an increase in height overestimation when viewing from both the top and the bottom.

We expanded this finding by showing that participants who were identified as high in height fear judged a height to be taller than low fear participants when viewing from the top (Teachman, Stefanucci, Clerkin, Cody, & Proffitt, 2008). Moreover, increased overestimation in the high fear group was uniquely predicted by fear even when controlling for cognitive biases present in the high fear group. Furthering that research, we asked both high fear and low fear groups to estimate heights while visualizing falling from that height (Clerkin, Cody, Stefanucci, Proffitt, & Teachman, 2009). The visualization of falling was meant to simulate a dangerous action at that height. While both groups overestimated the visualization height compared to a non-visualization control height, the high fear group overestimated the heights even more than the low fear group. Thus, there was an interaction between fear group status and imagery, such that the high fear group showed a particularly high overestimation when imagining falling.

Fear also influences the perception of slant (Stefanucci, Proffitt, Clore, & Parekh, 2008). At the top of a steep 7° slope, participants estimated the degree of slant while standing either on a skateboard (fearful condition) or on a stationary box (control condition) (see Figure 1a). While standing on the skateboard, participants perceived the slope as steeper than when standing on the box. Explicit estimates of the slant showed this difference; an action-oriented measure (adjusting a palmboard with an unseen hand) did not (see Figure 1b). Though the explicit perception of slant increased, participants were still able to act appropriately as evidenced by the palmboard data. This discrepancy between the explicit estimates of slant and the action-oriented measure is driven by two distinct streams of visual processing, the ventral and the dorsal streams (Milner & Goodale, 1995). The ventral stream is responsible for explicit awareness of percepts, whereas the dorsal stream unconsciously guides action. Overestimation of slant with the explicit estimates is useful in making decisions or plans for action, but a more accurate visual guidance of action is important for the visual system to appropriately place a foot when stepping on the hill (for more discussion of this distinction for slant estimates, see Proffitt et al., 1995).

Does fear influence audition? Others have suggested that fear may influence audition in an attempt to detect the presence of predators (Tooby & Cosmides, 2008). Also, nearly everyone has been startled by an unexpected loud sound (see any horror movie for examples), so we hypothesized that fear would increase the perceived loudness of sounds as a means of determining the distance to the source of the sound (Siegel & Stefanucci, in press). Participants wrote about a neutral or frightening experience to induce a neutral or fearful mood. Participants then rated the duration and loudness of short neutral tones. Both groups rated the duration of the tones as the same, but the fear group rated the sounds as

significantly louder than the neutral group. This suggests that the effect of fear on perception is not limited to vision, and supports our hypothesis that fear influences threat-relevant perceptions.

Overall, our data suggest that fear can influence visual and auditory space perception and we argue these results are not solely due to response biases. In all of the height studies, fearful people estimated heights as taller than unafraid people with both a direct estimate of the height (visual matching task) and an indirect measure of the distance (size estimate; see Stefanucci & Proffitt, 2009; Teachman et al., 2008). If a height is judged as taller, size estimates of targets on the ground should be larger to adhere to the size-distance invariance hypothesis (Epstein, 1973; Gilinsky, 1951). Given the difficulty involved in determining the relationship between distance and size, it is unlikely that participants would have figured out that the target should be estimated as larger to be consistent in their responses across measures. Because participants also overestimated the size of the target at the height, the indirect measure of distance perception, we argue that the effects of emotion on perception are not due solely to cognitive or response biases. Furthermore, in the skateboard and slant experiment as well as the audition experiment, some perceptual estimates were influenced by fear, but some were not. If participants suspected that fear should increase estimates of slant or perceptions of auditory stimuli, then we would predict overestimations of slant or increased perceptions of stimulus intensity with all dependent measures. Because they did not, we have reason to believe our results are not solely due to response biases.

In sum, our findings show that fear influences the perception of heights, especially for heights in which a fall could cause serious injury. In addition, fear influences the perception of slopes, discouraging a descent down hazardous slants. In terms of auditory perception, we have evidence that fear influences the perceived amplitude, but not duration of sounds. Others have shown that fear influences the perceived size of objects (van Ulzen et al., 2007). Participants who were shown circles that contained affectively loaded stimuli (pictures from the IAPS library) judged the circles to be larger when filled with negative images (spiders) compared to positive images (flowers). By considering the adaptive function of fear, we predict that fear should raise the salience of perceptual cues that detect biological motion, threat-like shapes (e.g., snakes), and the location of sounds in future studies.

Disgust—Over evolutionary time (and in every kindergarten classroom), humans encountered pathogens that posed a threat to survival and reproduction (Tybur, Lieberman, & Griskevicius, 2009; Tooby, 1982). As such, humans have evolved an intricate and flexible immune system to defend themselves from pathogens (Solomon, Berg, & Martin, 2005). As an additional defense strategy, humans may have adapted disgust to generate behavioral and physiological responses discouraging contact with pathogens (Rozin & Fallon, 1987; Susskind et al., 2008; Tybur et al., 2009). In fact, women show heightened disgust sensitivity during their first trimester of pregnancy, a time when the immune system is often the most suppressed (Fessler, Eng, & Navarrete, 2005). Humans are not just disgusted by objects from which the pathogens originate, but by any object that comes in contact with the “disgusting” object. This is often referred to as contamination, and has been shown to exist in children as young as 36 months old (Siegal & Share, 1990).

Though other research has shown that desire can make objects appear closer (Balcetis & Dunning, 2010), we wondered whether disgust could similarly influence the perception of objects in near space (within arm’s reach and slightly beyond, see Cutting & Vishton, 1995). Two competing hypotheses were tested; participants could perceive distances to disgusting objects as farther in response to motivational tendencies to distance oneself from contamination, or they could perceive disgusting objects as too close, causing them to place more distance between themselves and the objects. We believed the latter to be more in line

with evolutionary predictions, though either could have been supported. While sitting, participants estimated distances to clean tools (neutral condition) or slimy tools (disgusting condition) (Stefanucci, McCardell, Siegel, & Walker, 2011). Disgusted participants were less likely to grasp the tool by its handle and more likely to perceive the disgusting tools as closer with both a reaching task and a distance estimation task. However, we were concerned that the disgusting tools were simply more difficult to grasp, which could have caused the change in perceived distance to the tools, similar to Linkenauger et al. (2009). To clarify, we had participants view disgusting or neutral images from the International Affective Picture System (IAPS, Lang, Bradley, & Cuthbert, 1999) to elicit those feelings. Clean tools appeared closer after seeing disgusting images compared to neutral images. Regardless of the source of the disgusted feelings, disgust seems to alter the perception of objects that are close to the body, possibly encouraging one to stay farther away in order to ultimately avoid contact with pathogens. Considering the adaptive function of disgust, we predict that disgust may compress not only perceived distances between the observer and an object, but the perceived space surrounding the entire object and any benign object that may be close by reflecting perceived contamination. Preliminary data support our notion (Gagnon, McCardell, Furhman, & Stefanucci, 2011); future work will directly test this hypothesis.

Sadness—The human experience of sadness is typically an undesirable one, but from the point of view of natural selection, sadness may be a strategy used to reduce the expenditure of energy and resources (Nesse, 1991). Modifying this view, Keller and Nesse (2005) have shown that specific precipitating events may trigger slightly different aspects of sadness (e.g., social isolation leads to more crying, while a failure to accomplish a goal leads to more fatigue and pessimism).

We manipulated sadness to determine its influence on the perception of slant (Riener, Stefanucci, Proffitt, & Clore, in press) because we believed that depressed individuals may literally see the world as harder to navigate. Participants listened to happy or sad music and made estimates of the slant of hills from the bottom. Sad participants explicitly overestimated the slant compared to happy participants. Consistent with previous research, action-oriented estimates (adjusting a palmboard) were the same across conditions. Moreover, we replicated these findings using a different manipulation of emotion – writing about a happy or sad life event. Sad participants saw the slopes as steeper than happy participants, but action-oriented measures did not show overestimation. Seeing the hill as steeper when sad serves to discourage taking on tasks that involve more energy (e.g., climbing a hill), but does not put the observer in danger by altering non-conscious perceptions used to plan actions.

It is worth taking into account Keller and Nesse's (2005) findings and manipulating specific sadness-precipitating factors with the expectation that this may lead to different influences on perception. For example, losing a race over an unknown distance may make that distance appear farther than it actually is, but breaking up with a romantic partner may not. In contrast, social exclusion may alter the perception of slants when participants are to engage in a team activity relevant to ascending the slant, while failing a chemistry exam may not.

Social Support—In contrast to social exclusion, social support is a psychological resource that could increase positive affect (e.g., boosting morale) and buffer against negative reactions such as stress (Thoits, 1986). Although not technically an emotion, we examined the influence of social support (a psychosocial resource) on the perception of slant (Schnall, Harber, Stefanucci, & Proffitt, 2008) with the prediction that feelings of support may literally “lighten one's load.” Participants explicitly judged the slant of hills while wearing a backpack and estimated slopes as significantly steeper when alone than with a friend. In a

second study, participants estimated slants while doing an imagery task, either thinking about a friend or thinking about a neutral or disliked person. Participants judged slopes as steeper when thinking about a neutral or disliked person. Being with a friend may have created a cooperative scenario that made the slope appear shallower because the participant could “share the load” with the friend. Although we did not directly measure emotion in these experiments, it is possible that social support evoked a positive emotion. Future investigations will directly test positive emotion to verify whether these effects are driven by emotion or social support as a psychosocial resource.

Mechanisms Underlying Emotion-Perception Relationships

Arousal

Emotions like fear and disgust include both physiological and cognitive reactions in the body. Given this, our lab has started determining whether one component of the emotional response underlies the effect on perceived layout. Specifically, we focused on understanding the role of arousal in space perception because of the variety of physiological changes occurring during arousal such as increases in heart rate, blood pressure, and pupil dilation (see Barlow, 2002). Because both emotions and physiological potential may influence perceived spatial layout (Proffitt, 2006), we hypothesized that feelings of arousal could underlie the effects of emotion on perception.

Investigating the influence of elevated arousal on the perception of heights, we manipulated arousal by showing participants non-height related arousing or non-arousing IAPS images (Stefanucci & Storbeck, 2009). After viewing these images for a hypothetical memory test, participants estimated the height of a balcony (see Figure 2a). Participants who saw arousing images overestimated heights compared to those who saw neutral images, despite no belief that the pictures were related to the height estimation task (see Figure 2b). This effect was not due to the valence of the IAPS images, because a second study showed that both positive and negative arousing images produced similar overestimations. In a third study, participants viewed arousing or neutral images before estimating a safe, horizontal distance in a hallway, but did not estimate the distances differently. In the final study, we asked participants to regulate their level of arousal, which resulted in a difference in height estimates. The results showed that feelings of arousal (whether positive or negative) influence the perception of dangerous environments but not safe ones, suggesting that arousal may be a sufficient cue for altering perception.

In addition to height and distance, we have also examined the effect of arousal on size perception (Geuss, Stefanucci, de Benedictis-Kessner, & Stevens, 2010). Participants viewed balance beams (potentially dangerous environmental objects) and made estimates of the width of the beams while standing on a balanced or unbalanced commercially available exercise board (see Figure 3a). While unbalanced, participants estimated widths as narrower than when balanced. In further experiments, participants jogged in place, or counted backward by sevens, or viewed arousing images to increase arousal. Across several manipulations, aroused participants judged the beams as narrower compared to when they were not aroused (see Figure 3b for jogging results).

The findings that arousal can influence space perception suggest that dimensional aspects of emotion may be sufficient to affect perception, in addition to discrete emotions. However, we found that arousal does not generally produce changes in space perception in Stefanucci and Storbeck (2009). Those participants who were aroused judged heights to be taller, but did not exhibit overestimations of horizontal, ground distances. More research is needed to discern whether dimensions of emotion are as influential as discrete emotions, but given the difficulties and individual differences involved in measuring dimensional vs. discrete

emotional experiences (Barrett, 1998), we feel that this will take time to pursue thoroughly in future research.

Attention

Arousal (and emotion, more generally) alters the scope of attention (Easterbrook, 1959), which could lead to perceptual biases. Therefore, we will further investigate whether attention moderates the effect of emotion on perception, or if the effects are solely due to a narrowing of attention. Work in other domains, such as memory, has already shown a relationship between emotion and attention. For example, Loftus, Loftus, and Messo (1987) found participants who viewed an emotional slide showed eye movements that were consistent with those produced when a narrowing of attention occurs. Clinical research also suggests a focusing of attention occurs in those who have anxiety disorders or depression (Mathews, 2006). Gable and Harmon-Jones (2008) found that highly arousing positive emotions also focus or narrow attention, which could explain the lack of difference in height overestimation between positive and negative arousal groups in Stefanucci and Storbeck (2009). Finally, Duncan and Barrett (2007) claim the affective state of an observer may modulate or select those aspects of the environment that reach awareness in that individual. Taken together, this evidence suggests that emotion may lead participants to attend to different sources of information or cues in the environment, which could then produce changes in their estimates of the layout of the environment. However, the causal chain may be bidirectional, in which case emotions, perceptions, and attention work in concert as a larger system to coordinate behavior in adaptive ways.

Future Directions

In addition to testing for systems that underlie the effect of emotion on perception, we also plan to extend our findings to other emotional and motivational states by applying evolutionary theory to generate our hypotheses. For example, anger is often discouraged in contemporary society, but everyone experiences anger at some point in their life (like the last time you were in the line at the DMV). This has prompted some researchers to study why humans possess such a quality in the first place. Sell, Tooby, and Cosmides (2009) provide evidence that anger is an evolved adaptation designed to resolve interpersonal conflicts in the best interest of the angry individual. For example, if an acquaintance has been “borrowing” money from you, and has failed to hold their promise of paying you back, you are likely to become angry with them. Demonstrating to this person that you are angry signals that you may either inflict cost (e.g., physical harm) or withhold benefits (e.g., stop giving them more money) unless they pay you back.

If expressions of anger show others that you are considering inflicting costs, then it is possible that an angry individual perceives more action capabilities in their environment (e.g., distances look shorter, tools look closer, etc.). Another prediction may be that the target of anger may perceive the angry individual to be closer, larger, or taller encouraging them to avoid a physical altercation. More subtly, it is possible that the target of anger may perceive an increase in the angry individual’s action space, reflecting the idea that they may be more capable (or willing) of traversing their environment.

Other Emotions and Motivations

Humans have a variety of distinct emotions that are universally displayed and recognized (Ekman, Sorenson, & Friesen, 1969). Although most research on emotions has been limited to emotions that involve unique facial expressions, we believe that there are many more fundamental emotions than just the “basic” emotions. For example, jealousy may not produce a distinct universally recognizable facial expression, but we believe it has the

potential to alter perceptions, similar to fear or sadness. Hunger, although typically considered a bodily state, may influence perception in a similar fashion to emotions or fatigue (hence the phrase “your eyes are bigger than your stomach”). For example, Changizi and Hall (2001) showed that thirst modulates the perception of transparency, such that dehydrated individuals are biased to see more surfaces as transparent, which is a property of water. Recent work by Balci et al. and colleagues has also shown effects of motivational state on perception (Balci et al. & Dunning, 2006; 2007; 2010). However, in contrast to our claim that arousal influences threat-relevant perceptions, they found motivational influences on perception were not due to arousal, suggesting motivation may affect perception through different systems (Balci et al. & Dunning, 2007). Physiological and psychological states (like motivations), while not traditionally considered emotions, may still influence perception.

Conclusions

The embodied perception approach argues that perceptual representations are grounded in the capabilities and experiences of the body. The work in our laboratory and others suggests that emotion should be added to the list of bodily states that can moderate perceptual representations. This research can be applied to many settings, from treatments for clinical populations with emotion dysregulation disorders to the design of human interfaces. Further, it weaves seemingly disparate fields of study: research on emotion and perception of the environment. However, the adaptive significance of individual emotional states should be taken into account when making hypotheses about emotion-based changes in perception. Perception is not an encapsulated process; it works in conjunction with many other processes in the brain to ensure safety from cliffs, pathogens, and lava-filled pits.

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References

- Balci et al. E, Dunning D. Wishful seeing: More desired objects are seen as closer. *Psychological Science*. 2010; 21:147–152. [PubMed: 20424036]
- Balci et al. E, Dunning D. Cognitive dissonance and the perception of natural environments. *Psychological Science*. 2007; 18:917–921. [PubMed: 17894610]
- Balci et al. E, Dunning D. See what you want to see: Motivational influences on visual perception. *Journal of Personality and Social Psychology*. 2006; 91:612–625. [PubMed: 17014288]
- Barlow, DH. *Anxiety and its disorders: The nature and treatment of anxiety and panic*. 2nd ed.. New York: Guilford Press; 2002.
- Barrett HC, Kurzban R. Modularity in cognition: Framing the debate. *Psychological Review*. 2006; 113:628–647. [PubMed: 16802884]
- Barrett LF. Discrete emotions or dimensions? The role of valence focus and arousal focus. *Cognition and Emotion*. 1998; 12:579–599.
- Bhalla M, Proffitt DR. Visual-motor recalibration in geographical slant perception. *Journal of Experimental Psychology: Human Perception and Performance*. 1999; 25(4):1–21.
- Changizi MA, Hall WG. Thirst modulates a perception. *Perception*. 2001; 30:1489–1497. [PubMed: 11817755]
- Clerkin EM, Cody MW, Stefanucci JK, Proffitt DR, Teachman BA. Imagery and fear influence height perception. *Journal of Anxiety Disorders*. 2009; 23:381–386. [PubMed: 19162437]
- Clore, GL. Affect-as-information model. In: Sander, D.; Scherer, K., editors. *The Oxford Companion to Emotion and the Affective Sciences*. Oxford: Oxford University Press; 2009. p. 10-11.
- Clore GL, Huntsinger JR. How the object of affect guides its impact. *Emotion Review*. 2009; 1:39–54.

- Cohen DC. Comparison of self-report and behavioral procedures for assessing acrophobia. *Behavior Therapy*. 1977; 8:17–23.
- Cutting, JE.; Vishton, PM. Perceiving layout and knowing distances: The integration, relative potency, and contextual use of different information about depth. In: Epstein, W.; Rogers, SJ., editors. *Perception of space and motion. Handbook of perception and cognition*. 2nd. San Diego, CA: Academic Press; 1995. p. 69-117.
- Duncan S, Barrett LF. The role of the amygdala in visual awareness. *Trends in Cognitive Sciences*. 2007; 11:190–192. [PubMed: 17360224]
- Durgin FH, Baird JA, Greenburg M, Russell R, Shaughnessy K, Waymouth S. Who is being deceived? The experimental demands of wearing a backpack. *Psychonomic Bulletin & Review*. 2009; 16:964–969. [PubMed: 19815806]
- Easterbrook J. The effect of emotion on cue utilization and the organization of behavior. *Psychological Review*. 1959; 66:183–201. [PubMed: 13658305]
- Ekman P, Sorenson RE, Friesen WV. Pan-cultural elements in facial displays of emotion. *Science*. 1969; 4:86–88. [PubMed: 5773719]
- Epstein W. The process of “taking into account” in visual perception. *Perception*. 1973; 2:267–285. [PubMed: 4794124]
- Fessler DMT, Eng SJ, Navarrete CD. Elevated disgust sensitivity in the first trimester of pregnancy: Evidence supporting the compensatory prophylaxis hypothesis. *Evolution and Human Behavior*. 2005; 26:344–351.
- Fodor, JA. *Modularity of mind*. Massachusetts Institute of Technology: MIT Press; 1983.
- Gable P, Harmon-Jones E. Approach-motivated positive affect reduces breadth of attention. *Psychological Science*. 2008; 19:476–482. [PubMed: 18466409]
- Gagnon, K.; McCardell, M.; Furhman, S.; Stefanucci, J. Mapping the perceived extent of contamination; Presented at the annual Society for Personality and Social Psychology Evolutionary Pre-conference; San Antonio, TX. 2011.
- Gilinsky A. Perceived size and distance in visual space. *Psychological Review*. 1951; 58:460–482. [PubMed: 14900306]
- Geuss MN, Stefanucci JK, de Benedictis-Kessner J, Stevens NR. A balancing act: Physical balance, through arousal, influences size perception. *Attention, Perception, & Psychophysics*. 2010; 72:1890–1902.
- Halberstadt J, Winkelman P, Niedenthal PM, Dalle N. Emotional conception: How embodied emotion concepts guide perception and facial action. *Psychological Science*. 2009; 20:1254–1261. [PubMed: 19732387]
- Kanwisher N. Domain specificity in face perception. *Nature Neuroscience*. 2000; 3:759–763.
- Keller MC, Nesse RM. Is low mood an adaptation? Evidence for subtypes with symptoms that match precipitants. *Journal of Affective Disorders*. 2005; 86:27–35. [PubMed: 15820268]
- Kirkpatrick LA, Waugh CE, Valencia A, Webster GD. The functional domain-specificity of self-esteem and the differential prediction of aggression. *Journal of Personality and Social Psychology*. 2002; 82:756–767. [PubMed: 12003475]
- Kurzban R, Tooby J, Cosmides L. Can race be erased?: Coalitional computation and social categorization. *Proceedings of the National Academy of Sciences*. 2001; 98:15287–15392.
- Lang, P.; Bradley, M.; Cuthbert, B. *International affective picture system (IAPS): Technical manual and affective ratings*. Gainesville, FL: The Center for Research in Psychophysiology, University of Florida; 1999.
- Levenson RW. Autonomic nervous system differences among emotions. *Psychological Science*. 1992; 3:23–27.
- Lieberman D, Tooby J, Cosmides L. The architecture of human kin detection. *Nature*. 2007; 44:727–731. [PubMed: 17301784]
- Linkenauger SA, Witt JK, Stefanucci JK, Bakdash JZ, Proffitt DR. Effects of handedness and reachability on perceived distance. *Journal of Experimental Psychology: Human Perception and Performance*. 2009; 35:1649–1660. [PubMed: 19968426]

- Loftus EF, Loftus GR, Messo J. Some facts about “weapon focus.”. *Law and Human Behavior*. 1987; 11:55–62.
- Marks IM, Nesse RM. Fear and fitness: An evolutionary analysis of anxiety disorder. *Ethology and Sociobiology*. 1994; 15:247–261.
- Mathews, A. Anxiety and the encoding of emotional information. In: Uttl, B.; Singenthaler, A.; Ohta, N., editors. *Memory and emotion: Interdisciplinary perspectives*. Malden, MA: Blackwell; 2006. p. 37–58.
- McBeath MC, Morikowa K, Kaiser M. Perceptual bias for forward-facing motion. *Psychological Science*. 1992; 3:362–367.
- Milner, AD.; Goodale, MA. *The visual brain in action*. Oxford: Oxford University Press; 1995.
- Nesse RM. Evolutionary explanations of emotions. *Human Nature*. 1990; 1:261–289.
- Nesse RM. What good is feeling bad? The evolutionary utility of psychic pain. *The Sciences*. 1991:30–37.
- Ohman A. Of snakes and faces: An evolutionary perspective on the psychology of fear. *Scandinavian Journal of Psychology*. 2009; 50:543–552. [PubMed: 19930253]
- Ohman A, Flykt A, Esteves F. Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology*. 2001; 130:466–478. [PubMed: 11561921]
- Olofsson J, Nordin S, Sequeira H, Polich J. Affective picture processing: An integrative review of ERP findings. *Biological Psychology*. 2008; 75:101–108. [PubMed: 17275979]
- Pessoa L, Japee S, Sturman D, Ungerleider LG. Target visibility and visual awareness modulate amygdala responses to fearful faces. *Cerebral Cortex*. 2006; 16:366–375. [PubMed: 15930371]
- Peterson MA. Shape recognition can and does occur before figure-ground organization. *Current Directions in Psychological Science*. 1994; 3:105–111.
- Phelps E, Ling S, Carrasco M. Emotion facilitates perception and potentiates the perceptual benefits of attention. *Psychological Science*. 2006; 17:292–299. [PubMed: 16623685]
- Proffitt DR, Bhalla M, Gossweiler R, Midgett J. Perceiving geographical slant. *Psychonomic Bulletin & Review*. 1995; 2:409–428.
- Purcell DG, Stewart AL. The object-detection effect: configuration enhances perception. *Perception & Psychophysics*. 1991; 50:215–224. [PubMed: 1754362]
- Riener CR, Stefanucci JK, Proffitt DR, Clore GL. An effect of mood on geographical slant perception. *Cognition & Emotion*. (in press).
- Rozin P, Fallon AE. A perspective on disgust. *Psychological Review*. 1987; 94:23–41. [PubMed: 3823304]
- Schnall S, Harber KD, Stefanucci JK, Proffitt DR. Social support and the perception of geographical slant. *Journal of Experimental Social Psychology*. 2008; 44:1246–1255.
- Sell A, Tooby J, Cosmides L. Formidability and the logic of human anger. *Proceedings of the National Academy of Sciences*. 2009; 106:15073–15078.
- Siegal M, Share DL. Contamination sensitivity in young children. *Developmental Psychology*. 1990; 26:455–458.
- Siegel EH, Stefanucci JK. A little bit louder now: Negative affect increases perceived loudness. *Emotion*. (in press).
- Solomon, EP.; Berg, LR.; Martin, DW. *Biology*. Belmont, CA: Brooks/Cole-Thompson Learning; 2005.
- Stefanucci JK, McCardell MJ, Siegel EH, Walker PM. Too close for comfort: Disgust affects distance perception. 2010 Manuscript in preparation.
- Stefanucci JK, Proffitt DR. The roles of altitude and fear in the perception of heights. *Journal of Experimental Psychology: Human Perception and Performance*. 2009; 35:424–438. [PubMed: 19331498]
- Stefanucci JK, Proffitt DR, Clore GL, Parekh N. Skating down a steeper slope: Fear influences the perception of geographical slant. *Perception*. 2008; 37:321–323. [PubMed: 18414594]
- Stefanucci JK, Storbeck J. Don’t look down: Emotional arousal elevates height perception. *Journal of Experimental Psychology: General*. 2009; 138:131–145. [PubMed: 19203173]

- Storbeck J, Clore GL. Affective arousal as information: How affective arousal influences judgments, learning, and memory. *Social and Personality Psychology Compass*. 2008; 2:1824–1843.
- Susskind JM, Lee DH, Cusi A, Feiman R, Wojtek G, Anderson AK. Expressing fear enhances sensory acquisition. *Nature Neuroscience*. 2008; 11:843–850.
- Teachman BA, Stefanucci JK, Clerkin EM, Cody MW, Proffitt DR. A new mode of fear expression: Perceptual bias in height fear. *Emotion*. 2008; 8:296–301. [PubMed: 18410203]
- Thoits PA. Social support as coping assistance. *Journal of Consulting and Clinical Psychology*. 1986; 54:416–423. [PubMed: 3745593]
- Tooby J. Pathogens, polymorphism, and the evolution of sex. *Journal of Theoretical Biology*. 1982; 97:557–576. [PubMed: 7154682]
- Tooby, J.; Cosmides, L. The psychological foundations of culture. In: Barkow, J.; Cosmides, L.; Tooby, J., editors. *The adapted mind: Evolutionary psychology and the generation of culture*. New York: Oxford University Press; 1992. p. 24p. 97-106.
- Tooby, J.; Cosmides, L. The evolutionary psychology of the emotions and their relationship to internal regulatory variables. In: Lewis, M.; Haviland-Jones, JM.; Barrett, LF., editors. *Handbook of emotions*. 3rd Ed.. NY: Guilford; 2008. p. 114-137.
- Tybur JM, Lieberman D, Griskevicius V. Microbes, mating, and morality: Individual differences in three functional domains of disgust. *Journal of Personality and Social Psychology*. 2009; 97:103–122. [PubMed: 19586243]
- van Ulzen NR, Semin GR, Oudejans RRD, Beek PJ. Affective stimulus properties influence size perception and the Ebbinghaus illusion. *Psychological Research*. 2008; 72:304–310. [PubMed: 17410379]
- Wallbott HG. Bodily expression of emotion. *European Journal of Social Psychology*. 1998; 28:879–896.
- Woods AJ, Philbeck JW, Danoff JV. The various perceptions of distance: An alternative view of how effort affects distance judgments. *Journal of Experimental Psychology: Human Perception and Performance*. 2009; 35:1104–1117. [PubMed: 19653752]
- Zadra JR, Clore GL. *Emotion and perception: The role of affective information*. Wiley Interdisciplinary Reviews: Cognitive Science.

Figure 1. Stimulus and results from Stefanucci, Proffitt, Clore, & Parekh (2008)

a) A participant standing on the skateboard at the hill. b) Mean slant estimates (verbal, visual, and haptic) for the neutral (control) and fear conditions. Bars represent ± 1 standard error.

Figure 2. Stimulus and results from Stefanucci & Storbeck (2009)

a) A participant standing at the top of the balcony. b) Mean height estimates for the high arousal and control conditions. Bars represent ± 1 standard error.

Figure 3.

a) A participant standing on the balance board in Geuss, Stefanucci, de-Benedictis Kessner & Stevens (2010). b) Mean size estimates for the beams viewed in the balanced, unbalanced (pictured at left) and jogging conditions. Bars represent ± 1 standard error.