The regulation of vision: How motivation and emotion shape what we see

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A thoughtful introductory psychology student could be excused for wondering why their course textbook might include chapters on sensation and perception. After all, aren't these functions things that the *eyes* do (in the case of vision)? What does perception have to do with the *mind* – and with the motivations and personalities that define us? The answer is, quite a lot. Even the limited amount of information available to our senses during a passing glance is enough to overflow our capacity for awareness, and thus the contents of awareness are largely driven by what our mind prioritizes, either because of our explicit goals or because of some reflexive attraction.

The idea that our perception of the external world can be shaped by our internal motivations and emotions has held appeal through much of the history of psychological thought, particularly among those inclined to view aspects of the mind as interconnected even at the earliest information-processing stages. In a classic study from the "New Look" movement of the 1940s and 1950s – a loosely knit effort among psychologists to reveal contributions of emotion, knowledge, personality, and motivation to perception – researchers found that when children were asked to adjust the size of a patch of light so that it matched the size of either various nearby coins or size-matched cardboard disks, their errors were greater when estimating the sizes of coins than cardboard disks, a pattern particularly evident among the poorer than more wealthy children (Bruner & Goodman, 1947). They concluded that perception is influenced by the value accorded to aspects of the environment, and they argued that motivational factors need to be taken into account in order to understand perception in the real world. In the wake of that rallying cry, a body of research emerged to suggest that many of our perceptual judgments – for example, about the physical distance to an object or the perceived difficulty of traversing a terrain – are influenced by our motivations and emotions (e.g., Balcetis & Dunning, 2010; see also Alter & Balcetis, 2011; Cole, Balcetis, & Duning, 2013; Cole, Balcetis, & Zhang, 2013).

Such influences are striking, but it has become evident that our motivations and emotions affect not just our perceptual *judgments* about what we see, but our very ability to see the people and objects that cross our path in the first place. Despite deeply held intuitions that seeing is simply a matter of pointing one's eyes in the right direction, conscious perception emerges via complex processes that involve input from high-level cognitive mechanisms, including attention, anticipation, and emotion. Perhaps no experiment of the past 50 years illustrates the central role of such high-level processes in perception than the now-famous "gorilla experiment" (Simons & Chabris, 1999), in which participants watched a videotape of 3 players in white shirts and 3 players in black shirts pass a basketball among themselves. Participants counted the number of passes made by one of the two teams and, as a result of their concentration on the task, were oblivious to the fact that – partway through the video – a person in a full-body gorilla outfit casually strolled through the middle of the scene, stopping to turn and pound its chest at the viewer before walking out of frame. In short, because participants' attention was preoccupied by the pass-counting task, people failed to notice it despite looking directly at it, a phenomenon known as *inattentional blindness*.

But what does it mean to "attend" to something? At the most general level, "attention" refers to a family of mechanisms that converge to prioritize processing of some aspects of our experience over others. Importantly, what we attend to is not always under our strict control. *Endogenous* shifts of attention refer to those instances when we actively choose to focus on something that interests us, but in some cases attention can seem to shift without our volition. This distraction can be stimulus-driven, or *exogenous*: features that are particularly unique in the environment and stimuli that seem to appear abruptly via a sudden onset have proven to be particularly powerful attentional magnets (Theeuwes, 1991, 1994; Yantis & Jonides, 1984), as are emotional stimuli, which attract attention more robustly than do non-emotional stimuli (e.g., Anderson, 2005; Anderson & Phelps, 2001; Öhman et al., 2001; Vuilleumier &

Huang, 2009). Framed in terms of motivational states, attention can be guided by our goals (on the basis of what might be considered "explicit" motivation), or attention can shift reflexively, often because of our emotional responses to things. (This might be called "implicit" motivation, given the link between emotion and approach-withdrawal action tendencies; e.g,. Carver, 2006; Harmon-Jones, 2003). Given that what we attend to determines what we become aware of, this suggests that our goals and emotions have the power to shape literally what we see.

Goals

A common metaphor for attention is that of a "spotlight" that we move around the visual environment to illuminate whatever falls within it (e.g., Posner, 1980). And certainly we are able to shift attention from one spot to another voluntarily, just as spatial attention is sometimes captured reflexively (e.g., Yantis & Jonides, 1984). Note, though, that this metaphor emphasizes attention in space ("spatial attention"). People also have the ability to tune their attention for certain features (i.e., establish a feature-based "attentional set"). Consider, for example, the famous children's book series *Where's Waldo*, where readers need to find the protagonist within densely packed scenes of people and places; because readers know that Waldo always wears red stripes, they might establish an attentional set for that color, leading all red items in the scene to become salient. When people seek or prepare to respond to specific visual features, strong interconnections between prefrontal cortical areas and visual areas such as the inferior temporal cortex allow attentional set to modulate stimulus-linked responsiveness in the latter regions (Desimone & Duncan, 1995). When preparing to respond to a target, IT neurons optimally responsive to the target's properties demonstrate elevated activity even in the delay period before the target appears (Chelazzi, Miller, Duncan, & Desimone, 1993).

Contrary to possible notions that attention to positions in space and to features reflect simply different manifestations of the same selection mechanism, evidence suggests that they have different consequences for visual awareness. For example, in a computerized analogue of the gorilla experiment, my colleagues and I developed a dynamic rectangular display in which a set of black shapes and a set of white shapes moved around a display, occasionally coming into contact with a horizontal line that bisected the display (Most, Simons, Scholl, & Chabris, 2000). Participants counted the number of times that one of these sets of shapes touched the line on each of several trials, and on a critical trial a unique gray shape entered the display from the right, traveled slowly on a horizontal path, and exited to the left. Crucially, the shape's horizontal path ran either along the line or at varying distances away from it. Although participants were more likely to notice the unexpected object the closer it appeared to the line – which was presumably the focus of spatial attention – this influence on noticing rate was rather modest. In fact, fewer than half of the participants noticed the unexpected object when its path overlapped completely with the horizontal line. Perhaps even more striking evidence for the modest role of spatial attention in shaping awareness comes from experiments that have combined inattentional blindness tasks with eye-tracking. In a version of the gorilla study, for instance, people who saw and who failed to see the gorilla did not differ in the number of times they looked directly at it (Memmert, 2006). In both cases, the crucial factor was that the critical item was unexpected; when a person has no expectation that an object will appear, the proximity of its appearance to the locus of spatial attention has minimal impact on awareness.

In contrast, the tuning of attention for particular properties appears to have profound consequences for conscious perception. For example, in a variation of the computerized task described above, four black and four white items moved through a computerized display and participants kept track of either the black or white shapes during each of several trials, counting the number of times that their target set of shapes bounced off the display edges. On a critical trial, a new, unexpected object entered the display and remained visible for about 5 seconds. When the unexpected object was white, 94% of those tracking white items noticed it, but no one tracking black items did. When the unexpected object was black this pattern reversed, and when it was gray noticing rates were intermediate (Most et al., 2001). In other words, the more similar the unexpected object was to the targets' features, and the less similar it was to the distractors' features, the more likely it was to be seen. In addition to being able to tune attention for features, people can establish attentional sets for semantic category (Brand, 1971; Potter, 1975). Research suggests that such abstract attentional tuning also can influence the likelihood that brief periods of inattentional blindness will occur. For example, in one experiment, participants saw 1-second displays, each containing two pictures of animals and two pictures of furniture. In a between-subjects manipulation they were asked to identify the stimuli from one of the categories or the other on each trial. On a critical trial, letters spelling out the name of a piece of furniture (e.g., ''table'') or the name of a type of animal (e.g., ''cat'') appeared among the pictures, and participants were more likely to notice the word when it belonged to the same category as the pictures they were attending (Koivisto & Revonsuo, 2007). In another, dynamic-display experiment, a set of digits and a set of letters moved around the screen and participants counted the bounces made by either the digits or letters. On a critical trial, the letter 'E' or its mirror reverse – a block letter '3' – unexpectedly traveled across the display. Despite the fact that they shared nearly all features, people were more likely to notice the 'E' when tracking the letters than when tracking the numbers, and they were more likely to notice the '3' when tracking the numbers than when tracking the letters (Most, 2013).

The real-world consequences of people's ability to tune their attention based on what they think will be important in a scene has also been tested in virtual reality scenarios. For example, in one experiment, participants "drove" through a virtual cityscape and at each intersection they encountered a road sign with blue and gold arrows pointing in different directions (Most & Astur, 2007). Half of the participants were instructed to follow the yellow arrow at each intersection and half were instructed to follow the blue arrow. At a critical intersection, an oncoming motorcycle veered into the driver's path and came to a stop (thus, establishing an attentional set for either yellow or blue). Crucially, the color of the motorcycle was either blue or yellow, so that it either matched or did not match the driver's attentional set (all combinations were counterbalanced). The results were striking: when the color of the motorcycle matched drivers' attentional set, only 7% of participants collided with it (Most & Astur, 2007; see Figure 7). In contrast, when the motorcycle did not match drivers' attentional set, collision rate skyrocketed to 38%. In contrast, when unexpected object only varied in how far it appeared from the attended items, and not in the degree to which it shared features with the attended items, visual awareness was affected to a much smaller degree (Most, Simons, Scholl, & Chabris, 2000). In short, as my colleagues and I have stated elsewhere, to a large degree "what you see is what you set" (Most et al., 2005): people have a tendency to see what they have tuned themselves to see and to miss other things. We often enter places and situations with an *a priori* idea in mind of the people and objects we expect to be important, and such goal-related attentional preparation can heavily influence what we become aware of.

Emotions

Because most aspects of the environment resonate with emotional meaning, understanding perception in the real world necessitates understanding how it is impacted by emotion. Given their power to grab attention, combined with the impoverished nature of perception in the absence of attention, one might predict that encounters with emotional stimuli have the potential to "blind" people to other things in the environment. And indeed, this does seem to be the case. For example, my colleagues and I discovered that the rapid presentation of an emotional picture could impair people's ability to see subsequent targets, an effect we labeled *emotion-induced blindness*. On each trial, participants viewed a rapid serial sequence of upright landscape photos (presented at a rate of 100-ms/item) and within each stream searched for a single target (a landscape photo rotated 90-degrees clockwise or counterclockwise). When an emotional distractor (e.g., a picture of violence or medical trauma) appeared in the stream just before the target, people spontaneously experienced a brief period of functional "blindness": for about half a second, people became unable to perceive the target that they were searching for even though it appeared right in front of their eyes. This pattern appears to reflect a disruption of conscious perception rather than disrupted maintenance of information in visual working memory, as the size of the effect is comparable regardless of whether participants respond immediately or withhold their response for a brief delay (Kennedy and Most, 2012). Furthermore, this effect seems to stem from the arousal induced by the emotional stimuli, not by the valence (positive vs. negative) of the stimuli themselves: in one set of studies, we included a set of erotic pictures as critical distractors – which both men and women tend to rate as emotionally arousing and emotionally positive (Bradley et al., 2001) – and these caused at least as much emotion-induced blindness as did the emotionally aversive distractors (Most et al., 2007). In fact, when participants were offered up to $90 for high target accuracy, their performance in the negative condition improved slightly but no such improvement occurred following the erotic distractors.

In a recent extension of our emotion-induced blindness research, people monitored two simultaneous streams for the target and the emotional distractor appeared in either the same or opposite stream as the target. The results of this experiment were surprising: rather than inducing an across-the-board impairment in target perception, emotional distractors primarily disrupted perception primarily at their location, leaving target perception elsewhere in the visual field intact (Most & Wang, 2011). There are a number of reasons why this – and emotion-induced blindness generally – is surprising, both when considered in the context of the attention-emotion and mental health literatures and when considered in the context of the visual cognition literature.

One reason that emotion-induced blindness itself is surprising is because decades of research on attention-emotion interactions suggest that emotional stimuli have an *enhancing* effect on perception. For example, it is commonly found that emotional stimuli attract and hold spatial attention, thereby *facilitating* perception of subsequent targets appearing at their location (e.g., Fox, Russo, Bowles, & Dutton, 2001; Jiang et al., 2006; MacLeod, Mathews, & Tata, 1986; Mogg & Bradley, 1999; Van Damme et al., 2008). This has usually been demonstrated through changes in response time: for example, when an emotional stimulus appears in one of two possible target locations, people respond faster to a subsequent target at that location than in the opposite location. The widely accepted explanation for this effect is that because emotional stimuli capture spatial attention, people are able to process targets appearing at that location without having to "reorient" attention, a time-consuming process that leads to longer response times when the target appears elsewhere. Individual differences in the tendency to orient spatial attention to the location of an emotional stimulus have been used to inform information-processing models of emotional disorders (e.g., Mathews & Mackintosh, 1998; Mogg & Bradley, 1998; Williams et al., 1997), with related research exploring whether such attentional biases play a causal role in emotional disorders (Mathews & MacLeod, 2002).

Note, however, that the theoretical and empirical endeavours within this literature rely heavily on indexes of *spatial* attention shifts, and there are at least two important limitations to this approach. First, as noted above, the ability to move attention around in space is only one of a family of attention mechanisms that allow us to sample, select, and prioritize information within our environments. Second, increasing evidence suggests a dissociation between indices of spatial attention shifts and conscious awareness: that is, it is possible to shift spatial attention to a location without becoming aware of stimuli at that location (Kentridge, Heywood, & Weiskrantz, 1999, 2004; Lambert, Naikar, McLachlan, & Aitken, 1999; McCormick, 1997; Woodman & Luck, 2003). Thus, studies that focus on individual differences in orienting to the location of an emotional stimulus (or disengaging from that location; Fox, Russo, Bowles, & Dutton, 2001) may be limited in the degree to which their insights can inform understanding and treatment of emotional disorders, which are often characterized by heightened awareness of emotionally negative information at the expense of competing emotionally positive or non-emotional aspects of the environment.

The spatially localized nature of emotion-induced blindness is also surprising within the context of the broader visual cognition literature. In fact, it can't be accounted for by contemporary understanding of the most closely related phenomenon, known as the *attentional blink (AB)*. The AB is a robust failure of conscious perception that reveals the temporal limitations of attention: participants typically view rapid streams of alphanumeric characters and attempt to report two targets embedded within each stream. When the two targets appear close together in the stream (e.g., appear within 600-ms of each other), people can generally report the first but not the second. When more time separates these targets, people can report both (Raymond, Shapiro, & Arnell, 1992). Note that on its surface, this pattern is similar to emotion-induced blindness, with the only difference being that people only need to report one target in the latter, with the emotional distractor spontaneously capturing attention. However, decades of research on the AB have suggested that it reflects perceptual disruption at a late, relatively central stage of processing, such as limitations in the ability to consolidate targets into visual working memory (Chun & Potter, 1995; for alternative accounts that also implicate late-stage or central resources, see Di Lollo et al., 2005; Nieuwenhuis et al., 2005; Shapiro, Raymond, & Arnell, 1994). The implication of such central bottleneck accounts is that the perceptual disruption should occur across the visual field, and indeed, direct evidence suggests that this is the case (Lunau & Olivers, 2010; Shih, 2000). Thus, the spatially localized nature of emotion-induced blindness suggests mechanisms other than those that drive the AB and that may be unique to emotion's impact on perception.

My students and I recently proposed a novel framework positing a "dual-route" impact of emotion on perception (e.g., Most & Wang, 2011; see also Wang, Kennedy, & Most, 2012). The underlying hypothesis was that emotional stimuli do attract spatial attention to their location, but they at the same time compete with other representations that might be linked to an overlapping point in time and space. This is consistent with notions that rapidly, sequentially presented stimuli can give rise to neural responses that in themselves overlap in time (even though the stimuli themselves do not), and that when such temporally overlapping representations activate spatially overlapping receptive fields in the visual system these representations compete in a "winner takes all" fashion (Keysers & Perrett, 2002). According to this account, emotion-induced blindness occurs because this competition is biased by people's tendency to spontaneously prioritize emotional stimuli. One key finding that supports this account is the following: we found that when targets and emotional distractors were both embedded in the middle of a rapid stream (as is the case in most emotion-induced blindness experiments), emotion-induced blindness was limited to the location of the distractor. However, when the target was the last item appearing in its stream, this pattern reversed: in this case, target perception was *better* at the location of the emotional distractor, consistent with patterns found elsewhere in the attention-emotion literature. This evidence suggests that when the target is the last item in its stream and is not "masked" by subsequent items, its persistence in iconic memory renders it relatively immune to suppression by the emotional distractor. In this case, it is the more common pattern reflective of *spatial* shifts of attention to the location of an emotional distractor that emerges (i.e., with benefits for target processing at the distractor's location).

Competition between top-down goals and the reflexive draw of emotions

If emotion-induced blindness arises due to competition between targets and emotional distractors, then it may be possible for certain strategies and task manipulations to strengthen people's tendency to prioritize emotional distractors, thereby reducing the degree to which emotional stimuli disrupt perception. By the same token, certain contexts or emotional states might bias the competition even more in favor of emotional distractors, thereby increasing emotion-induced blindness. In fact, both of these appear to be the case. For example, in one experiment participants were informed in some blocks that their target could be a rotated picture of either (a) a building or (b) a landscape with no building, and in the remaining blocks they were informed that their rotated target would always be a picture of a building (Most et al., 2005, Experiment 2). The latter case – labeled the "SPECIFIC ATTENTIONAL SET" condition – enabled participants to establish a more concrete attentional template of what their target would look like, and the results revealed that emotion-induced blindness decreased in this condition, at least among participants who had scored low in a measure associated with trait anxiety. This instruction did not reduce emotion-induced blindness among participants who had scored high in the anxiety-related measure, however, perhaps because for them the bias to prioritize emotional stimuli was more difficult to overcome.

In a complementary study, temporary anxiety inductions had the reverse effect, exacerbating the disruptive impact of negative emotional distractors on target perception (Most et al., 2010). In this study, male-female romantic couples came to the lab, and the two members of each couple sat at computers next to each (with a curtain drawn between them). At the start of the session, a female experimenter stood where both participants could see her and assigned the emotion-induced blindness task to the female participant. The male partner's task, she explained, was to rate the attractiveness of landscapes as the appeared one at a time on his computer screen. The experimenter then left but returned about 10 minutes later to explain that the male partner's task would now change to rating the attractiveness of pictures of single women, many of whom were students at the university. At the end of the experiment, the female partner received a prompt asking her to rate how uneasy she was about the fact that her partner was rating the attractiveness of other women. In two separate experiments, there was a strong correlation between the female partners' reports of unease and the degree of emotion-induced blindness that they experienced during the time that their partner was engaged in this task. Perhaps most strikingly, women who reported themselves as being high uneasy and those who reported no sense of unease only differed in their target perception performance following emotionally negative distractors, not following neutral distractors or when there were no distractors. Thus, it seems that being in an anxious state may indeed lead people to weight emotionally negative distractors more heavily in the competition for perceptual dominance. Together, such findings are consistent with suggestions that attention-emotion interactions often depend on the resolution of competition between goal-oriented executive control and reactivity to emotional stimuli, and that individual differences are likely to emerge when these two sources of attentional bias are pitted against each other (e.g., Mathews & Mackintosh, 1998).

Conclusion

Although it may often seem as if the field of perception research lies disconnected from other areas of field, such as social- and clinical- psychology, the finding seem to suggest that conscious perception, at least, is robustly shaped by the internal states and motivations that often are the focus of these related sub-disciplines. Because *conscious* perception itself emerges from a complex coordination of mechanisms, an open question is how early in visual processing such internal states exert their regulatory effects. A number of theorists have argued compellingly that early vision is impenetrable by high-level processes such as motivation and emotion (e.g,. Pylyshyn, 1999), and this may yet be the case. The evidence seems clear, though, that when it comes to what we perceptually *experience*, the mind's eye often sees with the person's heart.

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