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CURRENT DIRECTIONS IN PSYCHOLOGICAL SCIENCE

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Emotional Attention

Uncovering the Mechanisms of Affective Biases in Perception

Patrik Vuilleumier[1,2] and Yang-Ming Huang[3]

[1]Department of Neuroscience & Clinic of Neurology, University Medical Center, University of Geneva; [2]Swiss National Center for Affective Sciences, University of Geneva; and [3]Department of Psychological and Brain Sciences, Indiana University

ABSTRACT—*The emotional significance of sensory events may influence attention in a reflexive manner, but these effects vary across paradigms and participants. Recent research indicates that specific circuits in the brain may serve to amplify neural responses to emotional stimuli, a modulation similar to attentional effects usually driven by endogenous goals. However, this modulation involves distinct sources in emotional systems such as the amygdala, and may thus operate partly independent of top-down control by attentional systems in frontoparietal cortices. It remains to be clarified to what degree these emotional effects are influenced by specific perceptual and emotional dimensions, automaticity and attentional resources, task goals or expectations, and individual personality traits.*

KEYWORDS—*emotion; attention; awareness; top-down control; automaticity; personality; affective neuroscience*

Some see the world with gloomy shades, while others see it through rose-colored glasses. But how is it possible that emotion may govern our senses? Past philosophers and scientists (such as Descartes or Zajonc) have often considered that perception and cognition are separate from emotion processing. However, increasing evidence from both psychology and neuroscience now clearly indicates that emotion and cognition do not operate entirely separately but reciprocally influence each other. Although it may come as no surprise that what we look at can determine what emotions we will experience, a much more fascinating finding from recent research is that, conversely, emotional reactions may influence what we perceive from the external world.

Here, we review current knowledge concerning the mechanisms by which emotional processes may interact with attention and awareness. This issue was initially pioneered by behavioral work on cognitive biases associated with affective disorders, and it has lately received increasing interest from a neurobiological perspective. The latter research suggests that our brain is endowed with specific mechanisms to regulate the allocation of attention as a function of the emotional significance of sensory stimuli, an ability with obvious adaptive advantages. However, we are just beginning to uncover such effects and their underlying neural circuits (Vuilleumier, 2005). Much remains to be learned about the exact processes or representations that are engaged by different components of emotion and attention interactions, including factors that can promote or constrain their cross-talk in different conditions, the extent of automaticity or voluntary control, the nature of emotional appraisals, and the role of individual variability. Our review will briefly highlight current data and questions on these issues.

EMOTIONAL GUIDANCE OF ATTENTION

Behavioral studies have shown that emotional information may "capture" attention in various tasks, including visual search, spatial cueing (i.e., spatial orienting to a target preceded by emotional information at the same location), or attentional blink (i.e., transient lapses in detecting a second target rapidly following a first one), and for various stimulus categories such as faces, words, animals (e.g., spiders), or sounds. Such effects are generally taken to indicate a privileged access to awareness for emotionally significant stimuli, relative to neutral stimuli, when attentional resources are limited in space or time. However, the influence of emotion on attention may vary with the nature of the task and the relevance of emotional information. For example, attention is drawn faster to emotional items than to neutral items when these constitute the targets to be searched (Frischen, Eastwood, & Smilek, 2008). When no active search is required (i.e., emotional stimuli are task irrelevant), a delayed disengagement may be observed instead of (or in addition to) faster orienting. Emotion might therefore exert distinct influences on attention components related to target selection and distractor

Address correspondence to Patrik Vuilleumier, Laboratory for Neurology and Imaging of Cognition, University Medical Center, CMU Dept. of Neuroscience, Bat A, 7th Floor, Room 7008, 1 rue Michel-Servet, CH-1211, Geneva, Switzerland; e-mail: patrik.vuilleumier@unige.ch.

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inhibition, although the underlying mechanisms remain unresolved.

Some emotional effects are also carried over to the processing of an upcoming (neutral) stimulus. For example, a brief task-irrelevant emotional face may improve perception of a subsequent target when there is no spatial overlap between these events (Phelps, Ling, & Carrasco, 2006) but may also speed up orienting to a target at the same location and delay orienting to other locations (Pourtois, Thut, Grave de Peralta, Michel, & Vuilleumier, 2005).

Most of these effects were originally reported for negative stimuli (snakes, fearful or angry faces) and accordingly have been considered to promote adaptive behavior in response to potential threats. Similar effects have been described for positive stimuli in some attentional tasks, although results seem more variable and may depend on the arousal value or on more complex affective dimensions of stimuli, such as personal relevance. For instance, Brosch, Sander, Pourtois, & Scherer (2008) observed enhanced attentional orienting toward baby faces, which constitute highly arousing positive stimuli and convey no threat. Other findings suggest that positive emotions may broaden the breadth of attention (Rowe, Hirsh, & Anderson, 2007) and thus promote exploration of new information, while negative emotions primarily act to focus attention and cognition on specific actions or stimuli (Fredrickson & Branigan, 2005). Future research needs to better disentangle these different influences of emotion on attention, as well as to clarify the critical affective dimensions that are responsible for such effects and identify which mechanisms are common (or distinct) across different kinds of emotions.

DEDICATED BRAIN CIRCUITS FOR EMOTIONAL ATTENTION

Our understanding of emotional effects on attention has been greatly advanced by studies that pinpointed specific brain mechanisms for not only emotional but also attentional processes. At the neural level, selective attention operates by increasing sensory responses, through modulatory influences imposed on early cortical pathways by frontal and parietal areas (Pessoa & Ungerleider, 2004; Vuilleumier & Driver, 2007). Both neurophysiology in monkeys and neuroimaging in humans indicate that the activation evoked by a given stimulus is reduced when concurrent stimuli are present, but that it can be restored to an optimal level by directing attention to the stimulus so as to bias neural responses in its favor relative to the concurrent distracters.

Remarkably, emotion signals can produce a similar enhancement of cortical processing for affectively relevant stimuli. For instance, emotional faces produce greater activation than do neutral faces in the "face area" within the visual cortex (Vuilleumier, 2005), whereas emotional voices activate the "voice area" in the auditory cortex more than do neutral voices (Grandjean et al., 2005). Thus, emotion processing can strengthen the representation of relevant stimuli and boost their competitive weight relative to distractors, which may account for their greater attentional salience in behavioral studies.

One potential mechanism for these effects might involve emotional influences on frontoparietal attention networks, which could then bias activity in sensory cortices (Fig. 1). Neuroimaging results show increased parietal activation in response to emotional stimuli or during spatial-orienting tasks when neutral targets are preceded by emotional cues (Armony & Dolan, 2002). This activation in the parietal cortex is selective for the location of emotional cues (leading to reduced responses to targets only in parietal areas contralateral to the preceding emotional stimulus) and might provide a neural substrate for the classic modulation of spatial orienting to neutral stimuli when these are subsequent to emotional stimuli at the same or different positions (Pourtois, Schwartz, Seghier, Lazeyras, & Vuilleumier, 2006). However, enhanced sensory responses to emotional stimuli themselves do not seem to depend on frontoparietal attention systems. Patients with deficits in spatial attention due to parietal damage (i.e., neglect syndrome) still show an advantage for the detection of emotional relative to neutral stimuli, together with increased activation in the visual cortex, even when emotional stimuli appear on the "neglected" side of space, where patients usually fail to direct attention (Vuilleumier, 2005).

Another source of emotional influences on sensory processing is the amygdala (Fig. 1), a subcortical nucleus in the anterior medial temporal lobe that is known to mediate fear processing and to perform other affective and social functions (Phelps & LeDoux, 2005). The amygdala has reciprocal connections with sensory cortical areas, which convey not only feedforward inputs to the amygdala but also feedback projections to the cortex. A role of amygdala feedback is demonstrated by functional magnetic resonance imaging results showing that, unlike healthy controls, patients with amygdala damage no longer show any differential increase to fearful versus neutral faces in visual areas (Vuilleumier, Richardson, Armony, Driver, & Dolan, 2004). In this study, participants saw faces paired with houses and had to focus attention on one stimulus category only, while face expression was either fearful or neutral but always task irrelevant. In amygdala-damaged patients, activation in the fusiform cortex to faces was normally enhanced when attention was directed to faces rather than houses, but it was unaffected by the emotional expression of faces. By contrast, patients with lesions affecting the hippocampus but sparing the amygdala showed normal increases to fearful faces, not only when focusing attention on faces but also when focusing on the concurrent houses. Moreover, unlike controls, amygdala-damaged patients show no attention advantage for emotional over neutral stimuli (Phelps & LeDoux, 2005).

The existence of distinct modulatory influences of emotion and attention on sensory processing suggests that these systems may operate partly independently of each other to produce

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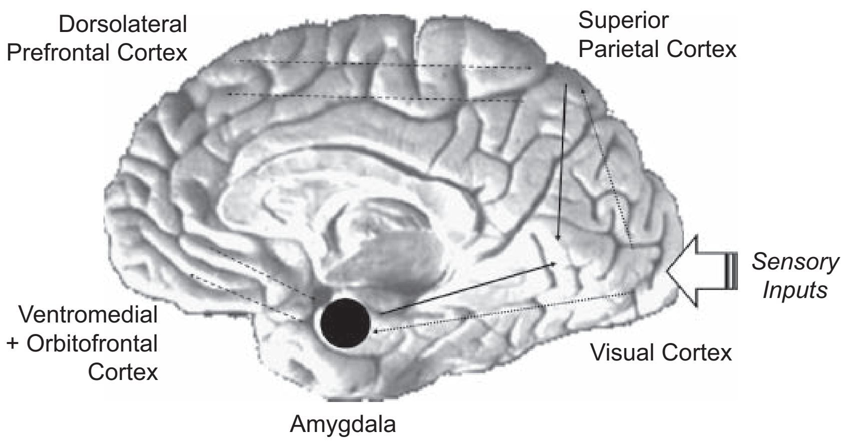

Fig. 1. Illustration of distinct brain pathways for enhancing perception of behaviorally relevant stimuli. Mechanisms of voluntary attention are mediated by top-down signals from the parietal cortex on the sensory cortex, in cooperation with dorsolateral frontal regions involved in executive control. By contrast, mechanisms of emotional attention are mediated by modulatory influences from the amygdala on the same sensory areas, in cooperation with ventromedial frontal regions involved in emotion regulation. Both systems are likely to interact through the reciprocal relations of dorsolateral and ventromedial frontal cortices.

different and additive effects on perception and awareness. Indeed, neuroimaging studies indicate that although both emotional and neutral stimuli produce weaker activation when they are unattended than when they are attended, responses are still amplified to emotional relative to neutral stimuli even without selective attention (Vuilleumier, 2005). This persistent modulation might produce a reflexive form of "emotional attention" that is dependent on amygdala signals and distinct from more voluntary components of attention mediated by fronto-parietal networks.

However, emotion and attention may not always produce parallel or additive effects; they may also act in an interactive manner for some brain areas and/or some task conditions. Although in many conditions amygdala activation may arise prior to attention or awareness and thus serve to guide attention to emotionally salient information, the degree of automaticity of emotional processing remains debated (Pessoa & Ungerleider, 2004), and the possible factors influencing amygdala responsiveness are still unclear (see below). In addition, amygdala activation and increased cortical responses may arise for not only threat-related but also positive and arousing stimuli, although it is unknown whether the amygdala is uniquely responsible for different effects of emotion on attention and subserves similar influences for different types of emotions.

WHICH FACTORS MODULATE EMOTIONAL ATTENTION?

A number of uncertainties and controversies still persist concerning the mechanisms or pathways by which emotional information may affect attention and, conversely, the extent or conditions of attentional influences on emotion processing, both behaviorally and neurally. Here we briefly review a few important issues that future research needs to address.

Top-Down Control of Emotional Processing

Although emotion can drive attention independently of conscious goals, such effects are not necessarily immune to modulation by other processes. Some results (Pessoa & Ungerleider, 2004) suggest that emotional distractors do not activate the amygdala or capture attention more than do neutral distractors when processing resources are fully engaged by another task. However, resource availability may not act in an all-or-none manner. For instance, neural responses to emotional stimuli are prolonged (beyond 500 milliseconds) when attentional resources are sufficient but briefer (less than 200 milliseconds) when attentional resources are limited (Eimer & Holmes, 2007), suggesting at least two distinct stages during which emotional processing can be differentially modulated. Therefore, emotional responses in the amygdala might persist in conditions when cortical responses are weak but still present (Vuilleumier, 2005) and may act to amplify these weak perceptual inputs in order to lower their threshold for awareness. But when emotional signals are too weak or too brief, they may fail to trigger any differential response without sufficient attention.

Furthermore, the degree of automaticity and inattention in emotional processing should be more clearly distinguished (Moors & De Houwer, 2006). Some effects might be automatic, in that they can arise without or even against conscious control, yet still require sufficient resources (Okon-Singer, Tzelgov, & Henik, 2007). Conversely, perceptual processing can be unconscious but not automatic, as shown for effects of expectation on priming. Behavioral and neuroimaging data suggest that emotional influences on attention are modified by task goals or

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processing strategy (Most, Chun, Johnson, & Kiehl, 2006). Thus, in a rapid sequence of pictures, emotional items capture more attention and induce more misses for subsequent targets only if the latter are not uniquely defined. But when participants always expect the same target, emotional interference is abolished and the amygdala does not activate.

Task goals can also modulate emotional effects during visual search (Hahn & Gronlund, 2007). Search is faster for angry targets than it is for happy targets when participants must detect a specific expression or any discrepant expression among neutral faces (so-called threat superiority), but a single angry target among distractors does not impair the detection of a happy target more than vice versa. This suggests that negative stimuli guide attention with a higher priority in the absence of a unique goal; whereas such advantage depends on both top-down and bottom-up factors otherwise.

Differences in the preparedness for responding to particular stimuli might thus modify the impact of emotion on attention. Efficient "preattentive" processing and involuntary capture might reflect a default mode, perhaps due to the high relevance of emotional stimuli, but such readiness could be enhanced or suppressed depending on contextual or individual factors. For instance, poor top-down control might facilitate automatic effects, whereas weak goal-setting might prevent appropriate emotional processing. Such interactions might result from modulations of perceptual and/or emotional processes by prefrontal areas responsible for goal setting, monitoring, and emotion regulation. Ventromedial prefrontal and anterior cingulate regions are well positioned to modulate amygdala responses, including the gain of feedback signals on sensory pathways; but they also interact with cognitive processes in the dorsolateral prefrontal cortex. Future research should better dissect these different components of automaticity in emotional attention.

Perceptual Saliency and Emotional Meaning

The exact perceptual and emotional dimensions that need to be extracted to trigger attentional capture remain unclear. Enhanced attention might result from particular perceptual features of stimuli rather than from their emotional significance itself. For example, Purkis and Lipp (2007) studied spider or snake experts and nonexperts and found that both experts and nonexperts showed more efficient search for snake and spider targets; but only nonexperts had negative biases for snakes and spiders in an implicit priming task, in which snake or spider pictures were followed by positive/negative judgments for common words. Hence, stimuli do not need to be evaluated as negative to capture attention. Moreover, simple visual features from emotional stimuli (e.g., wide-open eyes or sharp-edged objects) may be sufficient to activate the amygdala (Bar & Neta, 2007; Whalen et al., 2004).

Nevertheless, a role for affective processes is suggested by greater emotional biases in attention in people with affective disorders such as anxiety, phobia, or depression. Accordingly, only individuals with high anxiety scores may show a differential activation in the amygdala to fear stimuli presented outside the focus of attention (Bishop, 2008). Furthermore, attentional biases can be obtained after fear conditioning while physical features of the stimuli are actually not distinctive (Armony & Dolan, 2002). Activation of emotional associations may also depend on the degree of semantic processing (Huang, Baddeley, & Young, 2008). However, more work is necessary to determine the exact perceptual and emotional dimensions that activate the amygdala prior to full attention.

CONCLUSIONS AND FUTURE DIRECTIONS

Recent cognitive neuroscience approaches have provided new insights into the brain mechanisms by which affective signals can regulate perception and attention. However, much remains to be understood in terms of the nature of emotional information that is necessary to capture attention (bottom-up processes), as well as in terms of the functional dynamics of factors that may either facilitate or constrain such effects (top-down processes). Beyond questions on how resource availability might modulate emotional processing, it is essential to clarify what information is processed when attentional resources are limited; how different components of attention (such as orienting, disengaging, or shifting) are modulated; and how specific emotional mechanisms are, in comparison with more traditional attentional processes. Future research should also determine whether (and how) affective biases can modulate the selection of higher-level representations such as memories, thoughts, or actions, possibly via similar signals from the amygdala or involving other brain regions associated with emotion and motivation processes (such as the striatum for reward). Finally, it remains to be determined whether different emotions have similar effects based on some common dimension mediated by the amygdala (such as arousal or self-relevance) or whether they instead produce distinct influences on attention based on specific emotional signals. Ultimately, this work may also yield useful new measures to assess clinical conditions associated with abnormal emotional processing.

Recommended Reading

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