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IMAGE AND EMOTION: FROM OUTCOMES TO BRAIN BEHAVIOR

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Image and Emotion: From Outcomes to Brain Behavior

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Abstract

Aim: A systematic review of neuroscience articles on the emotional states of fear, anxiety, and pain to understand how emotional response is linked to the visual characteristics of an image at the level of brain behavior.

Background: A number of outcome studies link exposure to visual images (with nature content) to improvements in stress, anxiety, and pain perception. However, an understanding of the underlying perceptual mechanisms has been lacking. In this article, neuroscience studies that use visual images to induce fear, anxiety, or pain are reviewed to gain an understanding of how the brain processes visual images in this context and to explore whether this processing can be linked to specific visual characteristics.

Conclusions: The amygdala was identified as one of the key regions of the brain involved in the processing of fear, anxiety, and pain (induced by visual images). Other key areas included the thalamus, insula, and hippocampus. Characteristics of visual images such as the emotional dimension (valence/arousal), subject matter (familiarity, ambiguity, novelty, realism, and facial expressions), and form (sharp and curved contours) were identified as key factors influencing emotional processing. The broad structural properties of an image and overall content were found to have a more pivotal role in the emotional response than the specific details of an image. Insights on specific visual properties were translated to recommendations for what should be incorporated—and avoided—in healthcare environments.

Key Words: *Visual image, healthcare art, emotion, neuroscience, health*

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Background: Impact of Visual Images on Health

A compelling body of evidence in place today argues for the role of nature images in visual art to improve the patient experience of healthcare through reduced stress, anxiety, and pain perception, and improved perception of quality of care (Hathorn & Nanda, 2008; Nanda, 2011; Ulrich, 2009).

A significant amount of evidence on the impact of visual images (through different media) has focused on stress reduction from viewing nature images (Coss, 1990; Parsons, Tassinary, Ulrich, Hebl, & Grossman-Alexander, 1998; Ulrich, 1991; Ulrich, Lunden, & Eltinge, 1993). Stress has a strong physiological component and is manifested in increased heart rate, blood pressure, and skin conductance (Ulrich, 1992). Research shows that even short-term visual contact with nature can be restorative.

According to Korpela, Klemettila, and Hietanen (2002), positive changes in physiological activity that occur within 4 to 40 minutes are called *restoration*, and the environments that induce these changes are called *restorative environments*. For example, physiological data collected by measuring skin conductance, muscle tension, and pulse transit time from subjects who watched photographic simulations of natural settings showed faster recovery than subjects who viewed simulated urban settings (Ulrich et al., 1991). There were similar findings for heart rate measurements collected in a dental clinic; patients experienced lower stress on days that a large mural depicting a natural scene was hung on the waiting room wall versus days when the wall was left blank (Heerwagen, 1990). In another study, patients on gurneys viewing ceiling-mounted scenes of nature and/or water had systolic blood pressure levels 10 to15 points lower than patients exposed to either aesthetically pleasing "arousing" pictures or a control condition of no picture (Coss, 1990).

A precognitive, rapid assessment of the environment based on certain gross elements of an image is at the core of human survivial, with some properties of visual images eliciting an affective response even when they are insufficient for basic cognitive judgments like recognition.

Many of the studies investigating the impact of positive distractions on health outcomes have addressed short-term exposure to visual images in simulated experiments (such as Tse, Ng, Chung, & Wong, 2002; Ulrich, 1991; Vincent, Battisto, Grimes, & McCubbin, 2010). Whereas the studies in real-life settings are typically in high-stress areas such as before, during, or after a painful or stressful procedure (e.g., Coss, 1990; Diette, Lechtzin, Haponik, Devrotes, & Rubin, 2003; Ulrich et al., 1993). All of these studies suggest that the response to images can be quick, but few theories explain this rapid response. In the following section, some of the prominent theories within the environmental psychology literature that could explain this response are discussed.

Visual Properties and Underlying Theories

Ulrich (2009) shares two theories supporting the impact of nonthreatening nature scenes on improved physiological and psychological outcomes. The first is the *evolutionary theory* or *biophilia theory*, which holds that millions of years of evolution have left humans genetically prone to respond positively to nature settings that fostered well-being and survival for early humans. As outlined in Appleton's (1975) evolutionary theory, specific attributes of landscapes that dictate aesthetic preference concern *prospect* (opportunity/vantage point) and *refuge* (safety/shelter)—both essential for survival. The second theory Ulrich identifies is the *emotional congruence theory*, the notion that emotional states bias human perception of environmental stimuli in ways that are congruent or match feelings (Ulrich, 2009).

Zajonc (1980) argued that a precognitive, rapid assessment of the environment based on certain gross elements of an image is at the core of human survival, with some properties of visual images eliciting an affective response even when they are insufficient for basic cognitive judgments like recognition. This led Ulrich (1983) to outline a psychoevolutionary framework that argues that affect precedes cognition (and therefore aesthetic preference). Based on Zajonc's work, Ulrich proposed a *theory of preferenda*, outlining gross visual properties that could elicit an affective response, including (1) gross configurational or structural aspects of settings; (2) gross depth properties that require little inference; and (3) general classes of environmental content (e.g., water, vegetation, and mountains). Specific properties outlined by Ulrich based on preference studies include focality (degree to which a scene contains an area that attracts the observer's attention), depth of field, ground surface texture (ground surfaces in the natural environment and the different textures, patterns, and elements that help discern depth in a scene), deflected vistas (when a line of sight is deflected or curved, which implies that new landscape information is just beyond the visual bounds), and lack of threat and tension.

Parsons (1991) proposed that any encounter with an environment engages two affective analyses. The first is immediate and subcortical, based on simple stimulus information that is presented to hard-wired environmental feature detectors and mediated by the amygdala. The second is more deliberate, involves neocortical processing and the comparison of incoming information with stored information (possibly including the communication of the comparison outcome to the amygdala for evaluation), and is mediated by the hippocampus. Parsons' work is one of the earliest to address the need to understand affective responses to environmental stimuli at the level of brain behavior.

Although various studies have established a correlation between viewing images and experiencing an emotional or physiological state, it is unclear what perceptual mechanisms explain the varied responses to an image. Little is known about which specific properties of an image evoke specific emotional responses. This paper conducts a systematic literature review to help answer some of these questions from a design practitioner's perspective by tapping into the most fundamental measure of human perception: brain behavior.

Scope of Review

According to the Society for Neuroscience (2011), neuroscience is the study of the nervous system including the brain, spinal cord, and networks of neurons throughout the body. The central nervous system is made up of the brain and the spinal cord. A branch of neuroscience known as *cognitive neuroscience* studies functions such as perception and memory in animals and humans. In humans, noninvasive brain scan techniques are used to understand the route of neural processing. These include fMRI (functional magnetic resonance imaging to measure neural activity by changes in the blood-oxygen-level-dependence [BOLD] signal), EEG (electroencephalography: a measure of the electrical activity generated by the brain) or MEG (magnetoencephalography: a measure of the magnetic fields produced by electrical activity in the brain), and PET (positron emission tomography). Of these technologies, fMRI provides high-spatial-resolution images of brain activation as good as 1 mm without the bias toward the cortical surface of EEG or MEG, and with a much better time resolution than other techniques such as PET.

In this study the authors focused on the fMRI studies to gain an understanding of the "neural address" of specific emotional responses via a systematic review of the neuroscience literature linking emotional response and visual properties. In a typical fMRI, experiment subjects are asked to lie still in the scanner and their heads are usually restrained with soft pads to prevent movement. During this time, visual stimuli are delivered to the subjects by using a mirror, and brain activity is monitored. The setup required for an fMRI study limits its application in real-life situations, such as in hospital ICUs or waiting rooms. All studies reviewed were conducted in lab settings, using visual images to induce emotional states.

According to the American Psychological Association, emotion is "a complex pattern of changes, including physiological arousal, feelings, cognitive processes, and behavioral reactions, made in response to a situation perceived to be personally significant" (Frijda, 2000, p. 208). Emotion is a complex subject defined by numerous theoretical constructs. What comes first—the thought, behavior, or physiological arousal associated with emotion—remains unclear, and different theories offer different frameworks to explain the cause and effect.

One prominent theory is the James-Lang theory, which proposes that an event causes physiological arousal first and then this arousal is interpreted (Lange & James, 1922). Only after the arousal is interpreted is emotion experienced. In another theory, by contrast, Lazarus (1982) proposes that a thought must come before any emotion or physiological arousal. The causality of emotion is beyond the scope of this review. Because it is such a huge topic, to limit the scope the authors focused on feelings directly relevant to the patient experience in the hospital. According to Gordon, Sheppard, and Anaf (2010), it is common to "feel" fear, anxiety, and pain in a hospital setting. Although these emotions are certainly not an exhaustive list of what a patient can experience in a healthcare setting, they helped create a road map for how to navigate the neuroscience literature.

Accordingly, key word searches using *emotional state* (fear/pain/anxiety), *fMRI*, and *visual* were conducted in PubMed (an online database for biomedical literature). Initial responses revealed that although hundreds of articles used visual stimuli to study brain responses to emotional states or the neural underpinnings of different emotional states, very few of them addressed specific properties of the image that could explain the results. This review concentrated on the studies that clearly identified the properties of the visual stimuli. Overview articles on emotional processing, visual processing, and specific emotional states were used to establish the context.

Before the literature review, specific inclusion and exclusion criteria were identified. Inclusion criteria were (1) published, full-text, English-language journal articles; (2) for experiments, visual stimuli; and (3) for review articles, relevance to visual stimuli or overall emotional context and papers published after 2001. Exclusion criteria included (1) studies involving patients with specific neurological disorders and/or lesions and/or other damage to the brain; (2) studies involving patients diagnosed with specific psychological disorders (e.g., for fear studies, with phobia; for anxiety, studies of post-traumatic sress disorder); (3) studies with pediatric or geriatric populations; and (4) studies that tested the roles of certain chemical substances.

After an initial screening using inclusion and exclusion criteria, articles were reviewed in terms of study purpose. The focus of this review was to match brain response to the visual properties of stimuli as they pertained to specific emotional states, and to provide an adequate context for the response. The abstract and methodology of each article were then reviewed to evaluate whether a clear link had been made between the visual property and the emotion measured by brain response. The reference list from each of these articles was reviewed to identify other articles of potential interest. The same inclusion and exclusion criteria, along with screening toward the purpose of the study, were used. Twenty-three articles were identified, which included experiments, meta-analyses, and review articles. Table 1 lists the short-listed articles iden-

Table 1. Overview of Articles Reviewed

Article		Type of Study		Emotion			Visual Stimuli; *Visual Property*
No.	*Reference*	*Experiment*	*Review*	*Fear*	*Anxiety*	*Pain*	
1	Irwin et al., 1996	X		X			Facial expressions and scenes; *valence*
2	Whalen et al., 1998	X		X			Facial expression; *valence*
3	Whalen, 1998		X	X			N/A
4	Whalen et al., 2001	X		X			Facial expression; *valence*
5	Phan et al., 2002		X	X			N/A
6	Glascher & Adolphs, 2003	X		X			Scenes, animals, people, objects; *arousal*
6	Vuilleumier et al., 2003	X		X			Facial expression; *spatial frequency*
7	Simmons et al., 2004	X		X	X	X	Aversive images; *valence*
8	Ongur et al., 2005	X					Pentagon or ellipsoid shapes; *novelty*
9	Sengupta & Kumar, 2005		X			X	N/A
10	Britton et al., 2006	X		X			Facial expressions, evocative scenes; *valence, arousal*
11	Nitschke et al., 2006	X		X	X	X	Aversive images; *valence*
12	Gu & Han, 2007	X				X	Pictures or cartoons of hands; *reality*
13	Bar & Neta, 2007	X		X			Objects, patterns; *contour, spatial frequency*
14	Cheng, 2007	X				X	Painful events; N/A
15	Ogino et al., 2007	X		X		X	Painful events; N/A
16	Saarela et al., 2007	X				X	Faces of chronic pain patients; N/A
17	Anders et al., 2008	X		X			Humans or animals pictures; *valence, arousal*
18	Chiao et al., 2008	X		X			Facial expressions; *valence*
19	Kober, 2008		X	X			N/A
20	Onoda et al., 2008	X			X		Positive and negative pictures; *valence*
21	Roy et al., 2009	X				X	Positive and negative pictures; *valence*
22	Weierich et al., 2010	X					Pictures with different arousal and valence; *novelty*

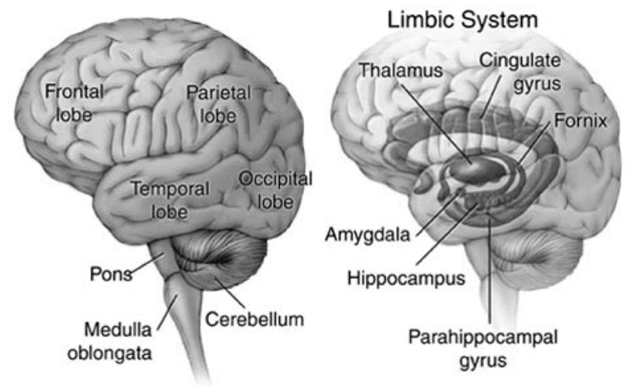

Figure 1: Anatomy of the brain. LEFT: A side view of the outside of the brain, showing the major lobes and brain stem structures. RIGHT: A side view showing the location of the limbic system inside the brain. The insula is not visible in this figure; it is located in the cerebral cortex, folded deep between the temporal and frontal lobes. See Table 2 for descriptions of the amygdala, insula, thalamus, and hippocampus. A full description of brain areas is available at http://www.ahaf.org/alzheimers/about/understanding/anatomy-of-the-brain.html

Source: The medical illustration is provided courtesy of Alzheimer's Disease Research, a program of the American Health Assistance Foundation. © 2011.

tified, along with the type of study, specific emotions involved, and visual stimuli used.

The Neural Underpinnings of Emotional Processing

A key article identified early in the literature review was a comprehensive meta-analysis of studies on the functional neuroanatomy of emotion. Phan, Wager, Taylor, and Liberzon (2002) reviewed 43 PET and 12 fMRI studies spanning 1993 to 2000 to determine whether common or segregated patterns of activation existed across various emotional tasks. The authors analyzed activation results from the short-listed studies and grouped them as follows: (1) regions associated with individual emotions (fear, sadness, disgust, anger, and happiness); (2) regions associated with the induction method, which refers to the kind of stimuli used to induce the emotion including visual, auditory, autobiographical recall/imagery; and (3) regions associated with the presence and absence of cognitive demand. Then the authors grouped together conditions in which the emotional task had no explicitly cognitive component (such as passive listening or viewing) to isolate the impact of the cognitive component on emotional tasks.

To bring the various studies to a common platform, the authors divided the brain into 20 overlapping regions and characterized each region by its responsiveness across the preceding categories. A key finding of this important study was that no specific brain region is consistently activated across individual emotions and induction methods. However, it was determined that the medial prefrontal cortex (the anterior part of the frontal lobe [see Figure 1]), known to interface between cognitive and emotional systems, was commonly activated across emotional tasks. This is supported by another meta-analysis of neuroimaging studies on emotional processing (Kober, 2008). Phan et al. (2002) also found that fear induction had a strong association with the amygdala (which is widely supported in the literature and is discussed further in the following sections).

Relevant to this study, the authors found that emotionally evocative visual stimuli activated parts of the occipital/visual cortex. In itself this is not surprising because visual stimuli should trigger a response in the visual processing center of the brain, but the studies evaluated controlled for simple sensory processing. The authors concluded that the modulation of the occipital/visual cortex might be driven by (a) the processing of emotionally loaded content, or (b) an interaction between visual perception and emotional processing. Phan et al. (2002) explain this anatomically by pointing out that projections from limbic regions like the amygdala extend to all the processing steps in the visual system, including the visual cortex. In a way, the limbic regions act as a relay center for the emotional salience of visual information (see Figure 1).

Fear and Anxiety

The amygdala is part of the limbic system, which receives information from all sensory modalities and is also connected to various cortical and lower-brain centers, including the insula, which enables it to cause rapid changes in the brain and regulate physiological responses such as heart rate or blood pressure (Davidson & Irwin, 1999). These physiological responses are typical of the "stress response" that has been discussed in the background section, which is used as a metric to determine the efficacy of viewing visual images. A key role of the amygdala is the processing of fear (Irwin et al., 1996; Whalen et al., 1998; Whalen et al., 2001).

According to Fellous, Armony, and LeDoux (2002) fearful stimuli (learned or innate) can be processed through two main routes: the fast route and the slow route. The fast route involves the thalamo-amygdala pathway, which responds best to simple stimulus features (such as a tone); the slow route involves the thalamo-cortical-amygdala pathway, which carries more complex features (such as context). Both processes occur simultaneously. Response to fear can also be thought of in terms of expression and experience. The expression of fear as emotion is manifested in physiological responses such as blood pressure, freezing, and hormonal change, and it is mediated by the outputs of the amygdala to lower-brain centers (insula, hypothalamus), whereas the experience of fear is a feeling, a conscious higher-level recognition of being *scared*, involving the frontal and sensory cortices (Nanda, Pati, & McCurry, 2009).

A key insight into the mechanism of fear comes from how it is connected to previous memories of stressful experiences. According to Sapolsky (2003), severe stress can harm the hippocampus, preventing the consolidation of a conscious, explicit memory of an event. At the same time, the implicit memory machinery of the amygdala could be enhanced. In subsequent events, the amygdala may respond to preconscious information, but conscious awareness or memory may not follow, resulting in the experience of a free-floating anxiety. For example, a specific image or a particular tone of voice might cause anxiety (because of a prior stressful or harmful event), but people cannot "place" it and do not remember why.

Similarly, elements of the healthcare environment associated with stress on one occasion are likely to trigger the same response preconsciously during a later visit. In healthcare settings, fear and anxiety are common among patients and caregivers. Anxiety may be the more prevalent emotion, driven by the anticipation of painful procedures or serious diagnoses. The link between fear and anxiety is critical to understanding the impact of visual images. In a hospital setting where patients must come back, a stressful setting could initiate a chain reaction of fear and anxiety responses that can compound this response on subsequent visits.

Anticipation

Anticipation is a critical component of affective processing in general and of anxiety in particular. Researchers suggest that the anticipation of emotional events is critical for individual survival and cognitive control of emotions (Herwig et al., 2007). Nitschke, Sarinopoulos, Mackiewicz, Schaefer, and Davidson (2006) found that several key regions of the brain, including the amygdala and the hippocampus, become activated when a subject is anticipating aversive photographs like mutilated bodies or attack scenes. They propose that the amygdala is associated with the formation of emotional memories, whereas the hippocampus helps the brain form long-term recollections. They indicated that the anticipation of a difficult situation probably starts up an "arousal or fear circuitry" in the brain, which in turn helps to reinforce old memories (Nitschke et al., 2006).

Visual stimuli can trigger this emotional response. Onoda et al. (2008) suggest that a neural network including the anterior cingulate cortex (ACC), prefrontal cortex, insula, and amygdala is involved in the anticipation of negative images. The authors indicated that the anterior brain regions of the network might provide top-down modulation to perceptual processing areas during certain negative anticipation.

In another fMRI study, Simmons, Matthews, Stein, and Paulus (2004) found that a network including the anterior insula and parahippocampal cortex was activated when anticipating aversive emotional stimuli like photographs of spiders and snakes. The anterior insula has been shown to play an important role in the anticipation of physical pain (Ploghaus et al., 1999). Thus, their study provides evidence that anticipation of emotionally aversive stimuli involves brain structures that are involved in the anticipation of physically painful stimuli. In fact, it makes the case that looking at something that we find emotionally aversive can be perceptually comparable to physical pain.

Pain

Pain is distinct from fear and anxiety in that it is a sensation with a strong subjective and emotional component (Fields, 1999; Ogino et al., 2007). In a review of the emerging evidence from neuropsychological and empirical studies, Sengupta and Kumar (2005) provide a comprehensive insight into the neuroanatomic basis of the perception of pain. Pain can act as a stressor, which affects a patient's emotional state. Conversely, a patient's emotional state can influence the perception of pain. Roy, Piche, Chen, Peretz, and Rainville

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Table 2. Key Brain Areas Identified in the Emotional Processing of Visual Stimuli

Brain Area	Role
Amygdala	An almond-shaped cluster located in the medial temporal lobe. Critical to fear-related emotional processing or stimulus salience.
Insula	Located in the cerebral cortex between the temporal and frontal lobes. Regulates physiological responses such as heart rate and blood pressure and produces an emotional context for convergent (sensory) information. Also plays a role in the experience of pain and the emotions of anger, fear, disgust, and happiness.
Thalamus	Located between the cerebral cortex and the midbrain. Acts as a relay between the subcortical areas and the cerebral cortex.
Hippocampus	Located in the medial temporal lobe. Stores and retrieves conscious memories; processes sets of stimuli to establish context.

(2009) found that study participants subjected to electric shocks reported stronger pain while viewing unpleasant pictures than while looking at pleasant pictures.

In another imaging study using photographs of faces in pain, researchers found that subjective pain ratings and pain-related activation of the ACC were higher in the sad emotional context compared to happy and neutral contexts (Yoshino et al., 2010).

Empathy plays a key role in pain perception. A study using photographs of faces in pain showed that viewing pictures of others in pain triggers a "mirroring system," with a remarkable overlap between areas of the brain activated when a subject undergoes painful sensory stimulation and when he or she observes others in pain (Saarela et al., 2007). In a study comparing responses to images of painful events with images evoking emotions of fear and rest, Ogino et al. (2007) identified an overlap between the regions activated for pain and fear (The ACC and the amygdala). As discussed previously, the ACC has a role in anticipation, which links it to anxiety. Interestingly, research shows that stress and anxiety cause a release of adrenaline, which can lead to increased muscle contraction and that could be the source of pain (Atkinson & Hilgard, 2000). The reciprocal relationship between fear, anxiety, and pain is an important insight in the context of healthcare.

In the next section the connection between specific components of the visual image and the neural response that defines emotional processing, based on the literature that was identified in this review, are discussed. Please see Table 2 for a description of the key brain areas identified and Figure 1 for the illustration.

Image Content and Neural Response

Emotional Dimensions of Valence and Arousal

Components of the visual stimuli used were carefully identified and classified during the literature

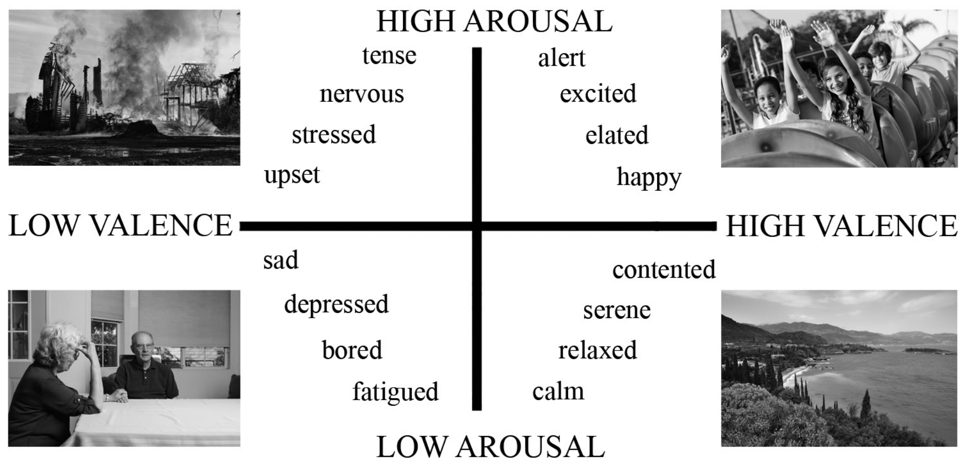

Figure 2. Example of images based on the dimensions of valence and arousal. The horizontal axis represents the valence dimension (pleasant—unpleasant), and the vertical axis represents the arousal dimension (exciting—non-exciting). Based on diagram by Colibazzi et al. (2010), where authors argue that valence and arousal are not mutually exclusive but simply different conceptual frameworks. IAPS images were selected based on their valence and arousal ratings in the IAPS technical report (Lang, Bradley, & Cuthbert, 2008). Comparable examples were found from stock imagery and are included in the figure above.

review. A key discovery during the review was the availability of a database of images called the International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert, 2008), which provides access to more than 1,000 images that have been rated based on a series of experiments along the following emotional dimensions: *valence* (ranging from pleasant or positive to unpleasant or negative); *arousal* (ranging from calming or soothing to exciting or agitating); and *dominance* (ranging from large-figure to small-figure). These include pictures depicting mutilations, snakes, insects, attack scenes, accidents, contamination, illness, loss, pollution, puppies, babies, and landscape scenes, among others that are often used to induce emotional states.

Britton, Taylor, Sudheimer, and Liberzon (2006) state that the IAPS serves as a common emotional probe, depicting emotion-laden scenes to induce affective states for fMRI studies. Mikels and colleagues (2005) provide insight into the different uses of the IAPS images and their impact on physiological outcomes such as heart rate and facial electromyographic activity. Figure 2 presents a conceptual framework for how emotions can be organized along the dimensions of valence and arousal (based on the model developed by Colibazzi et al., 2010). Sample images are included based on images from the IAPS Technical Report (Lang, Bradley, & Cuthbert, 2008). Because of copyright issues, the original IAPS images could not be used. Instead, the authors have identified

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IAPS images with valence and arousal values representative of each quadrant (high valence, high arousal; high valence, low arousal; low valence, high arousal; and low valence, low arousal), and found similar images to illustrate the different emotional dimensions.

The use of IAPS images has been particularly common in fMRI studies investigating the mechanism of fear using images with low valence (unpleasant) and high arousal (exciting) properties. However, for many of these studies, it has been difficult to dissociate brain circuits involved in the processing of valence and arousal. The distinction is important because studies show that valence and arousal have different physiological manifestations (see Table 1). According to Mikels et al. (2005), physiological outcomes such as heart rate and facial electromyographic activity (or movement of facial muscles) differ between negative and positive valence, whereas outcomes like skin conductance increase with arousal. The latter has been reinforced by an fMRI study by Glascher and Adolphs (2003), which correlates amygdala activation and skin conductance response (SCR) in reaction to arousing images to amygdala activation. Heart rate and skin conductance have been used as measures for stress responses to visual images in previous work by various researchers (for overview of articles, see Ulrich, 2009).

Anders, Eippert, Weiskopf, and Veit (2008) dissociated stimulus valence and stimulus-related arousal and confirmed that the amygdala was sensitive to stimulus valence even when arousal was controlled for. Their paper provides insight into the processes by which the amygdala derives emotional meaning. They also found that increased amygdala activity in response to emotional pictures of humans and animals was better explained by valence than by arousal, and that the amygdala was sensitive to the valence of emotional stimuli even when it was equated for arousal. The amygdala responded to both negative and positive stimuli, and this response did not increase with arousal.

In contrast, thalamic and cortical activity increased with arousal. SCRs were also collected and were greater for arousing stimuli. Glascher and Adolphs (2003) show that in fact the right and left amygdala have different roles in the processing of arousing images: the left amygdala decodes the information presented by a visual stimulus, and the right provides a global level of autonomic activation triggered "automatically" by any arousing stimulus. This is in line with the role of the amygdala in the primal fight-or-flight response. Although determining the exact neural networks at work during the processing of unpleasant or pleasant images (valence) or exciting or non-exciting images (arousal) is beyond the scope of this work, it is important to understand that although these two factors can overlap, they function independently.

Familiarity and Novelty

In addition to valence and arousal, *novelty* is a critical stimulus dimension for amygdala engagement. Weierich, Wright, Negreira, Dickerson, and Barrett (2010) conducted an fMRI study that examined the contributions of novelty, valence, and arousal to amygdala activation. The study showed that in comparison to negative (vs. positive) and high (vs. low) arousal stimuli, the amygdala had higher peak responses and a longer period of activation to novel (vs. familiar) stimuli. They also found that novelty could be dissociated from valence and arousal and have independent affective significance. On a behavioral level, the authors found a strong relationship between novelty and arousal, demonstrating that subjects found novel images more arousing, which would, in turn, also have an impact on the amygdala. Because amygdala activation links to fear and anxiety, the novelty of stimuli should be considered carefully in settings where people might be vulnerable.

In another study, Ongur et al. (2005) found significantly greater activation of the right hippocampus when subjects were discriminating previously seen stimuli as opposed to novel pairs of visual stimuli. This result indicates that the hippocampus also plays an important role in recognizing relationships with previously seen stimuli, but not with novel stimuli. The activation of the hippocampus is relevant to the retrieval of previous memories and the creation of context. Failure to retrieve memories and create a context links to the notion of free-floating anxiety discussed previously.

Culture

Some research shows that *culture* can also play a role in emotional response to visual images. Chiao et al. (2008) used fMRI to measure amygdala response to a fearful, neutral, happy, or angry expression in two distinct cultures: Japanese and Caucasian. The authors found that the fear response (measured by amygdala activation) increased when fear was detected in members of one's own culture relative to other cultural groups. Chiao et al. (2008) cited significant behavioral studies on how recognition of emotional expressions is greater for one's own culture. This is an interesting insight for multicultural societies such as the United States. The role of culture may relate to the response to familiar vs. novel stimuli.

Realism

Although the authors did not find many articles that addressed the issue of style (for more information on issues of style, the field of neuroaesthetics must be studied), they did find that the level of realism in an image contributed to emotional response. For example, neural activity associated with empathy for pain was found to be higher in response to realistic pictures compared to cartoons (Gu & Han, 2007). In the previous section, the role of empathy was discussed in the work of Saarela et al. (2007), which showed that a pain response can be triggered by empathy when seeing others in pain. The issue of realism also connects with familiarity and novelty. Abstracted images may be more novel than realistic images viewed in a person's day-to-day life. This review did not locate any articles that compared abstraction to realism in the context of fear, anxiety, and pain.

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Neural activity associated with empathy for pain was found to be higher in response to realistic pictures compared to cartoons.

Facial Expression

Another key property of visual content identified in the literature was the presence of *direct or indirect information.* Irwin et al. (1996) found that fearful stimuli like pictures of snakes, spiders, or medical procedures (direct threat) can cause the emotion of fear, but so can fearful expressions on other people's faces (indirect threat). Studies of expressive faces and IAPS pictures suggest that similar regions are involved in processing both types of emotional stimuli. In a review of some of the early neuroimaging studies on the role of the amygdala, Whalen (1998) discusses the finding that viewing a fearful face induces more fear than viewing an angry face.

This seems counterintuitive because looking at someone's angry face can be construed as a direct threat. Whalen proposed that fearful faces convey the threat more *ambiguously* than angry faces by signaling the presence of threat or danger without identifying the source of the threat, whereas angry faces signal a more direct and immediate negative consequence. Thus, Whalen argues that, because fearful faces require more information about a probable threat than angry faces, they induce greater activation of the amygdala. To quote Whalen, "A system that modulates vigilance will be preferentially activated by a stimulus that requires additional information to be understood" (Whalen, 1998, p. 181). This hypothesis was tested in a neuroimaging study conducted by Whalen et al. (2001), which found that the responses in the amygdala were more pronounced for fearful faces than for angry faces.

Rapid Extraction of Information

Independent of the issues of subject matter, style, or expression is the issue of how quickly information can be extracted from an image. This is key to the notion of a "quick evaluative system" that defines emotional processing as discussed in the previous section. This literature review revealed two key components of the rapid extraction of information: context and spatial frequency.

Visual objects in the environment tend to appear in specific and typical contexts and seem out of place beyond these contexts. Bar and Aminoff (2003) demonstrated that the cortical regions activated when people recognize visual objects that are highly associated with a certain context (e.g., a hardhat) compared to those not associated with any context in particular (e.g., a fly). Their findings indicate that part of the cortical region surrounding the hippocampus (the parahippocampal cortex) and a region in the retrosplenial cortex together comprise a system that mediates contextual processing. They base their research on an earlier work by Carr, McCauley, Sperber, and Parmelee (1982), which argues that semantic meaning about context is extracted from input at an early stage, possibly even before perceptual processing is complete.

According to Bar (2004), the swift extraction of contextual meaning from an image is mediated by global cues conveyed by the low spatial frequencies of an image. Bar explains that different spatial frequencies convey different information about the appearance of a stimulus. High spatial frequencies (HSFs) represent abrupt spatial changes in an image, such as edges, and they generally correspond to configural information and fine detail. Low spatial frequencies (LSFs), on the other hand, represent global information about shape, such as general orientation and proportion. Every image contains both types of frequencies, which can be obtained by the two-dimensional Fourier transform (Bone, Bachor, & Sandeman, 1986).

Vuilleumier, Armony, Driver, and Dolan (2003) investigated whether high and low spatial frequency are processed by distinct neural channels. They decomposed fearful face stimuli into their HSF and LSF components. The results indicated that amygdala responses to fearful expressions were greater for LSF faces than for HSF faces. LSF cues support perception of face configuration but lack information for detailed identification and are rapidly extracted; on the other hand, visual recognition mechanisms are attuned to encode HSF information.

Contour

Proof of the role of elements rapidly extracted from an image is the impact of contours on amygdala activation. In a preference study comparing responses to everyday objects with curved or sharp edges, Bar and Neta (2006) found that respondents preferred objects with curved contours compared with comparable objects that had pointed features and sharp-angled contours. They hypothesized that this partiality stemmed from an inherent perception of potential threat conveyed by sharp visual elements.

The amygdala was significantly more active in subjects viewing everyday sharp objects (e.g., a sofa with sharp corners) compared with their curved-contour counterparts.

A follow-up study by these researchers used fMRI to test this hypothesis, and it was found that the amygdala was significantly more active in subjects viewing everyday sharp objects (e.g., a sofa with sharp corners) compared with their curved-contour counterparts. This difference was more significant for the LSF compared to the HSF features in the image. The authors concluded that a "preference bias towards a visual object can be induced by low-level perceptual properties, independent of semantic meaning, via visual elements that on some level could be associated with threat. Our brains might be organized to extract these basic contour elements rapidly for deriving an earlier warning signal in the presence of potential danger" (Bar & Neta, 2007).

Research on spatial frequencies indicates that the emotional response to a visual image is im-

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mediate, extracted from the global properties of an image including shape, orientation, and proportions, which supports Zajonc's classic work (1980) on global properties of images, and the subsequent work by Ulrich (1991) on the theory of preferenda discussed earlier in the theoretical foundation section.

Discussion

Emotional Response to Visual Images: Key Brain Areas

As discussed in the Phan et al. (2002) article, it is important to remember that whenever a visual stimulus is viewed, the visual cortex is activated. An entire complex process is in place, which enables "seeing." But during emotional processing certain regions of the brain are activated in addition to the visual cortex. The activation of these areas indicates that the brain has processed the visual image beyond the sensory perception of "seeing" something. In other words, mapping brain areas indicates how what a person "sees" makes him or her "feel."

Key brain areas identified in the literature review include the medial prefrontal cortex, which has been shown to play a general role in emotional processing across all individual emotions. For pain perception, the ACC acts as a central component in the modulation of pain. It is also activated when anticipating incoming aversive events. In addition to these cortical structures (situated in the cortex, which forms the outermost sheet of neural tissue in the human brain), Table 2 lists some of the prominent subcortical brain structures involved in this process, which have been discussed in this article. The subcortical region of the brain is literally "anything beneath the cortex." These brain areas include the amygdala, insula, hippocampus, and thalamus. The amygdala, insula, and thalamus are responsible for the rapid-processing emotional response, and the hippocampus is responsible for memory. These four areas can be identified as *regions of interest* (ROI) for future fMRI studies to investigate how visual images can affect feelings in the hospital setting.

It is important to note, however, that many more areas, both cortical and subcortical, are involved in the processing of a single visual stimulus, and this is not an exhaustive list. The amygdala can be considered the single most important ROI in the brain when considering the impact of visual images on fear, anxiety, and pain. The important role of the limbic regions (amygdala, thalamus, and hippocampus), which are older than other parts of the brain, in the emotional response to stimuli and associated with the primal fight-or-flight response, supports Zajonc's theory of a quick evaluative system that defines human response to visual images, especially under stress.

Visual Properties and Emotional Response

A valuable insight gleaned from the review of the literature was mapping the "emotional" properties of images along the dimension of valence and arousal. For example, images with low valence and high arousal (the second quadrant in Figure 2) would typically be used to induce fear or anxiety. By contrast, images with high valence and low arousal (the fourth quadrant) would have the opposite effect and be considered restorative. Interestingly, given that arousal has an independent link to increased stress response (skin conductance), even positive images that are too "exciting" (first quadrant) could be inappropriate for high-stress areas in healthcare. The relationship of novelty, arousal, and activation in the amygdala suggests that highly novel stimuli can trigger a fear response and therefore may be inappropriate in extremely high-stress settings where the primal response does not have time to be overridden by a higher-level reflective response.

Research on the impact of facial expressions on emotional processing is relevant from the perspective of image selection for hospital-based art programs, popular media for distribution, and patient-provider interactions. Facial expressions indicating fear (indicative of the presence of a threat) can be as fear-inducing as the source of the threat. Ambiguity in facial expressions can induce fear and anxiety. Facial expressions that are difficult to read, or that might seem anxious or fearful, should be avoided. Research that establishes that fear responses are greater when facial expressions belong to one's own cultural group can be extrapolated to imply that the same holds for positive emotions. This finding argues for cultural diversity in images selected for hospital environments.

The research on rapid extraction of context by low spatial frequencies of an image (which provide information on broad structural properties such as contours and configuration rather than details that aid recognition) ties back to the theory of a quick evaluative system and the theory of preferenda, which argue that global properties of

The amygdala can be considered the single most important region of interest in the brain when considering the impact of visual images on fear, anxiety, and pain.

the same image can shape the viewer's perception and trigger a fight-or-flight response. The rapid extraction of contour information and its impact on the amygdala suggest that issues of content and form must be addressed together. The quick evaluation system of any image provides a fundamental sense of well-being (whether or not there is a threat). This response forms the basis of subsequent emotional belief and aesthetic judgment, which involve higher-level cortical processes. This review does not address the issue of aesthetic judgment, but a previous work (Nanda et al., 2009) explores the issue of neuroaesthetics in the context of emotional processing.

Insights on Specific Image Content

A look at the neuroscience literature confirms that a quick evaluative process is in place when viewing visual images; it triggers an emotional response (of fear, anxiety, or pain), which is closely linked to physiological responses. It also offers clues about image properties that elicit negative emotional responses and should therefore be avoided, including (1) fearful or angry faces; (2) ambiguous subject matter; (3) high novelty and unfamiliarity; (5) lack of realism; and (4) sharp contours.

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The classification of images along the emotional dimensions of valence (from unpleasant to pleasant) and arousal (from exciting to relaxing) provides a useful tool to determine appropriate content for images in healthcare settings. Arguably, images in high-stress areas of the hospital should have high valence (positive content) and low arousal (calming). Other areas of a hospital could be suitable for more medium- to high-arousal images while maintaining positive content. The ability to map emotion along two discrete dimensions (valence and arousal), and to evaluate visual images according to these, is a valuable tool to guide image selection for different areas of a hospital.

These insights from the literature review cannot be considered an exhaustive guide for image selection in hospitals, although they do support previous work on this subject by Ulrich (2009) and Hathorn and Nanda (2008). They also raise some red flags to be aware of when selecting images for hospitals—whether art, media, or an overall theme.

Limitations

The subject matter of this review was too large for the scope of this study. Emotion is a big subject, and each subsection—fear, anxiety, and pain—comprises a significant body of frequently overlapping literature. This review, although systematic, does not provide an exhaustive synopsis of neuroimaging studies on the emotions of fear, pain, and anxiety. In comparison to fear, the body of literature on anxiety and the emotional aspect of pain is smaller. Moreover, with new articles being published every day, a literature review can become dated very quickly and must be updated with new information constantly. Table 1 lists the key articles identified in this review dating from 1996 to 2010. Secondly, detailed information on image properties and image selection was lacking in many articles, which narrowed the pool of articles considerably. Many key articles were identified by using reference lists rather than the first key word search in the PUBMED database.

Although initially the authors were interested in seeing how images of nature—especially images that had been shown to be restorative—affected fear, anxiety, and pain, no articles in the review addressed this issue specifically. Arguably, images in the neural literature reviewed were used to induce an emotion, or to be emotionally evocative rather than restorative, i.e., returning to a state of calm. This made it difficult to tie the neuroscience data to the guidelines and theories that form the cornerstone of image selection in evidence-based design today.

Future Directions

This article attempts to navigate some of the new information in the field of cognitive sciences, such as cutting-edge neuroimaging studies, from the perspective of design and visual imagery. It also identifies the key brain areas responsible for processing fear, anxiety, and pain to provide a basis for future studies that seek to link brain behavior to specific design elements that could have an impact on emotional response. Although significant work has been done in the field of neuroesthetics (see Nanda et al., 2009, for a short introduction), it has been more about cognitive rather than emotional responses to visual images.

In healthcare design, the primary focus on health, well-being, and aesthetics is closely linked to emotional concerns. Two clear lines of investigation emerge from this review: (1) to undertake fMRI studies on identified regions of interest in the brain in response to image types supported by the evidence-based design literature after carefully analyzing the visual properties of the images. Such an exercise could also address fundamental questions about whether the content or form of an image has a larger impact on perception, and offer insights into the interaction between the two; (2) to undertake a literature review of studies that address activation of the identified regions of interest in response to visual stimuli. Focusing on specific regions of interest in the brain rather than on overarching emotional frameworks (which extend the scope of the study), enables a more focused investigation into visual properties and corresponding brain activation. Of particular interest are studies of the amygdala, because the amygdala has a critical role in processing emotions, as well as in our fundamental, primal sense of well-being.

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Implications for Practice

- Viewing images can have a direct impact on emotional processing centers in the brain; thus, art for healthcare facilities must be carefully selected.
- "Restorative" images are defined by content with high valence (positive) and low arousal (calming).
- When viewing novel/unfamiliar images, the brain struggles to create a context. This typically involves a failure to retrieve memories, which is linked to anxiety. This struggle often contributes to making great abstract art by allowing viewers to come up with their own interpretation. For highly vulnerable patients, however, the anxiety related to this process may be more acute and the primal emotional response can override the higher-level cognitive response. Art should be selected with this trade-off in mind.
- Fearful expressions on faces can trigger a greater fear response in a viewer than viewing a direct threat; thus, facial expressions should be carefully considered when selecting figurative art.
- The following elements in a visual image should be carefully evaluated and, if possible, avoided in high-stress areas: fearful/angry faces; ambiguous subject matter; high levels of novelty and unfamiliarity; lack of realism; and sharp-edged contours.
- The primal response to images is triggered by a quick evaluative system that rapidly extracts information from an image; this depends on global cues rather than a high level of detail. Form and content relate to global cues and must be addressed together when choosing art.
- Emotional impact must be balanced with aesthetic value in the context of healthcare art.