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Ecological warnings

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ABSTRACT

Our visual system has evolved over hundreds of millions of years, and is finely honed for processing natural scenes. It is reasonable to expect that warning signs that can more closely mimic ancestrally alerting stimuli (or "supernormal" versions of such stimuli) in nature would be among the most effective even today. Here we investigate warning symbols from an ecological standpoint, specifically in light of recent research in three areas of vision: color perception, the evolution of writing and typography, and visual illusions. We discuss how the color and geometry of an angry face, for example, may underly the superiority of red color and V shapes in warnings. We also describe simple heuristic ecology-based rules for the design of text in warning signs. Finally, we take up how radial line stimuli and the illusory effects they induce can be harnessed for capturing the attention of an observer, orienting him toward a warning symbol, and deterring him from moving closer.

1. Introduction

A hundred years of visual psychophysics has led to troves of facts about perception, much of it unassimilated. For example, color perception is filled with thousands of pages of arcane details about what we see as a function of a million experimental modulations. And visual illusions are collected like butterflies—named, pinned and filed away into hundreds of museum drawers. Making sense of these piles of facts requires understanding what vision is for, and this necessitates addressing the intimate relationship between an animal and the environment in which it evolved. Such an ethological or naturalistic approach to visual perception may not only give us a better grasp of the design and function of vision, but also lead to better designs for visual displays for human observers, warning displays in particular. Here we describe some implications for the design of warning signs from three such naturalistic research directions by the first author: color (and face) perception (Section 2), the evolution and perception of writing (Section 3), and visual illusions (Section 4). In some cases the research we describe helps to explain why safety science researchers have found certain stimuli to be more effective, and in other cases the research may motivate new kinds of stimuli for safety-related symbols.

2. Faces: color and shape

At first glance, pictograms would appear to be a promising means by which to convey warning messages in a language-independent manner. However, anyone who has played the game Pictionary (basically, a game of charades via doodles on paper) knows how poor we are at inferring meanings from pictograms (Davies et al., 1998)...even when we share the same culture (and household!). When we are from different cultures the difficulties for pictograms are compounded; e.g., a skull and crossbones does not universally evoke caution (Casey, 1993; Wogalter et al., 2006).

Pictograms are likely to be most effective when they tap into evolutionarily ancient mechanisms we are all born with. Images of skulls and crossbones probably played little or no role in the selection pressures shaping us, but a face with an expression of disgust like the green cartoon face of "Mr. Yuk" certainly did (albeit an exaggerated stimulus, see also Leonard et al., 1999). Facial expressions are universal across humans (Darwin, 1899; Ekman and Friesen, 2003), and symbols tapping into the key visual features of facial expressions will acquire a universal meaning. Furthermore, facial expressions have the advantage of having meanings that are emotional, *and* the advantage that facial expressions are highly effective at eliciting emotions in the observer. In addition, a face tends to attract an observer's gaze, enhancing the probability that the observer will see the warning in the first place. It is for these reasons that Mr. Yuk is such an effective warning symbol for poisons.

In particular, Mr. Yuk possesses two modalities of visual information that help it convey its message, one via its green color, and the other via the geometrical shape of its facial features. More generally, facial expressions often have a color and geometrical shape, and it may be that the fundamental evolutionary source of the emotional associations of colors and shapes is the face.

Our faces, and those of primates, have long been observed to undergo color modulations (Darwin, 1899; Hingston, 1933; Wickler, 1967), including blushing with embarrassment, reddening

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with anger, blanching with fear, and becoming sickly green. In fact, recent research has provided evidence that our trichromatic color vision (shared by many other primates) evolved in order to sense these and other skin color signals (Changizi et al., 2006a; Changizi, 2009). First, the research has shown that our cone sensitivities are in fact optimal for sensing oxygenation modulations of hemoglobin, which is the mechanism underlying our skin's ability to redden. Dichromat mammals cannot see these oxygenation-related red/green-axis color signals, nor can other vertebrates with color vision such as fish, birds and reptiles (which have *four* cones, but without the wavelength sensitivities needed to sense oxygenation modulations). Second, the new research demonstrated that the primates with color vision are exactly the ones with bare faces (and often other bare spots like the rump)—even among the prosimians which are usually furry-faced and lack color vision, the two species that *do* have color vision also stand out in having bare faces.

Color vision, then, appears to be an intrinsically socio-emotional perception, which helps to explain why colors have such strong emotional associations (e.g., Osgood, 1960; D'Andrade and Egan, 1974), and why colors are used as they are among human visual signs. Colors are often liberally employed in cartoons, such as in Disney cartoons where even the furry animals can blush. Colors are also used on cartoon faces called "smileys," used for helping to express emotions on the web. Fig. 1a shows the color of these "smileys" when sad, sick and angry, and one can see that, relative to the distribution of colors for happy faces, sad faces tend to be blue, sick faces tend to be green, and red faces tend to be angry. Colors have also long been found to be useful for enhancing visual displays (Christ, 1975). Red, in particular, has long been known to have associations with strength, anger and aggression (Osgood, 1960), and has been identified to be the most alerting color for warning signs (Wogalter et al., 1998, Leonard et al., 1999). This makes good sense given that angry faces in fact *do* tend to be red, and an angry person looking at you is an evolutionarily ancient—and contemporary—cause for alarm. In light of the color-vision-is-for-seeing-skin hypothesis, red's association with strength is connected to the fact that red cannot be signaled without sufficiently oxygenated blood in the capillaries in the skin. A person who is weak and whose arterial oxygenation is low will be unable to fake a red signal, and so red skin signals are *honest* signals of strength. This may underly why atheletes wearing red have been found to have a statistical advantage against opponents (Hill and Barton, 2005; Attrill et al., 2008). ("No matter how much I try, my opponent appears unfazed!").

Although red is the most alerting color, yellow is the next most (Chapanis, 1994; Braun and Silver, 1995; Wogalter et al., 1998), and perhaps it is the color expression of *fear* that underlies this. Whereas hemoglobin oxygenation modulations underly red/green color changes, it is the *volume* of hemoglobin in the skin that modulates skin color along a blue/yellow axis, with more blood being bluer (and darker), and less blood in the skin being yellower (and lighter). Fear, and terror, causes the blood to be kept away from the extremities, and blood volume consequently lowers in the capillaries of skin, and so skin appears yellow and light. Although a fearful person is less dangerous than an angry person gazing at you, the *cause* of fear in another may signal a danger for you as well, and that is why seeing expressions of fear—or just its color—can elicit caution in an observer. Green may be intrinsically less alerting than red because, whereas a red face likely signals anger and imminent danger, a green face may instead signal sickliness and physical disgust in the expressor—not a physical threat.

Facial expressions are not achieved just by color modulations, of course, but by muscular changes on the face, leading to characteristic geometrical shape changes in the mouth, eyes, eyebrows, and wrinkles (Ekman and Friesen, 2003). As the cartoon face in Fig. 1b illustrates, angry faces are not just red, but, even more obviously, possess certain signature geometrical features such as angular eyebrows making a "V" (e.g., Ekman et al., 2002; Lee et al., 2006), or the shape of an "upside-down" triangle as shown. Aronoff et al. (1988) found that angry masks from many different cultures (e.g., America, Ceylon, China, Dan-Guere, Japan, Java, Kwakiutl and Senoufo) possess such "V" features, and it has even been shown that "V" shapes by themselves (i.e., not on a face) generally are deemed more threatening by observers (Aronoff et al., 1988; Aronoff, 2006) and are more effective at capturing attention (Larson et al., 2007). Safety science researchers had noticed this before these latter studies, at least as far back as Riley et al. (1982) who showed that an inverted triangle shape was preferred most highly as a warning symbol. For the purposes of this paper we (in a Cognitive Science of Art course led by the first author) collected symbol data from Liungman (2004). Our data indicate that "V" shaped symbols tend to be more "cautionary" than non-"V" shaped symbols, and that inverted-"V" shaped symbols come in between, as shown in Fig. 1c.

The intrinsic warning advantages to red colors and V shapes may, then, ultimately have their foundation in our evolutionary ecology, and the face in particular. Angry faces display more oxygenated blood in the skin, and our primate color vision has evolved to be able to sense this spectral change, and to perceive it as red. And angry faces have eyebrows that become "V"-like in shape, providing a strong geometrical cue to anger. These fundamental ecological meanings appear to have found their way into the design of safety symbols, and into the visual signs of culture more generally, where red colors and "V"-shapes are often employed for symbols with aggressive or cautionary connotations.

3. Natural scenes and good typography

After a warning symbol has attracted an observer's attention—e.g., by its color or shape—it is often helpful to have brief text describing the nature of the danger or the recommended behavior. The choice of typography of warning displays is thus potentially important for ensuring easy readability. There has accordingly been efforts to gauge which fonts are most effective (e.g., Frascara, 2006). Our eyes and visual systems evolved to be competent at processing objects in natural scenes, and one might *a priori* expect that fonts and letters will be easier to see to the extent that they are more similar to the kinds of contour combinations found in natural scenes. One might even wonder whether culture could have, over time, selected for letter shapes that matched those in nature—typography matched to the topography. Recent evidence by the first author has provided evidence that this is indeed the case (Changizi and Shimojo, 2005; Changizi et al., 2006b; Changizi, 2009), and by comprehending nature's shapes one can better appreciate the shapes our visual systems "like," and potentially be better guided in the design of warning symbols.

Because the geometrical shapes of letters vary considerably across fonts (and across individuals), but do not typically much change in their topology (see Fig. 2a), a topological notion of shape is the apt one for studying letter shape. It is also apt because the geometrical shape of a conglomeration of contours in a scene changes with the observer's viewpoint whereas the topological shape will be highly robust to viewpoint modulations. Fig. 2b shows three simple kinds of topological shape, or configuration: L, T and X. Each stands for an infinite class of geometrical shapes having the same topology. Two smoothly curved contours make an L if they meet at their tips, a T if one's tip meets anywhere along the other (except at the tip), and an X if both contours cross each other. Whereas Ls and Ts commonly occur in the world—as corners and at partial occlusion boundaries as displayed in Fig. 2b—Xs do