Biological Processing System: Color and Contrast in Vision.

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Introduction. Designing successful user interface is a tough balancing act between the needs/abilities of the user and the needs/capabilities of the business. At the application level, the balance is achieved through the choices of verbal and graphical messages, workflow and information structure, etc. At the screen level, the same balance is achieved through careful use of color, contrast, position, movement, size, shape, etc. to engage the senses in the way that helps the viewer comprehend the relationship among the various elements of the design while at the same time guides the user toward actions that present the greatest value for the business "behind" the application or web site. This paper focuses on what happens at this level, and in particular, on using color and contrast to help prompt certain user actions, while inhibiting others.

Introducing the case study: Shutterfly.com. Shutterfly.com is an online photo-processing, sharing, and printing service. Just like many of its competitors—ophoto.com, snapfish.com, and others—it lets its customers upload their pictures digitally (or mail in their film), fix and enhance their pictures, share their pictures online with others, and order high quality prints in various sizes. From the business/revenue point of view, the requirements boil down to funneling the customer to the revenue-generating activity: ordering prints. The challenge is, therefore, to (a) get the customers to sign up, (b) guide them through the uploading process, and (c) get them to start ordering pictures. While a major part of this burden rests on the terms of the service, prices, print quality, and so on, the site's design must facilitate this process as well. Throughout this paper, we'll evaluate how well color and contrast are used to guide the user toward this transaction. But, first, let's turn our attention to some of the most basic properties of the human eye and their role in light perception.

The human eye. In *Information Visualization*, Colin Ware (2004) compares the human eye to a photo camera: there's "a lens, an aperture (the pupil), and a film (the retina)" (p. 38). This is about where the similarities end, however. The retina contains two types of receptors—rods and cones—each performing a different function. The properties and physical distribution of rods and cones on the surface of the retina give our visual system the following general properties (from Ware, 2004; Wickens et. al., 2004):

- Vision is sharpest, or most acute, in the fovea—the middle 2 or so degree area of the retina—because the concentration of closely spaced cones is highest there. Acuity falls off sharply outside of the fovea, since that is the domain of the sparsely spaced rods;
- Color is also the best in the fovea, because, unlike cones, rods are color-blind;
- Rods' sensitivity adjusts with light stimulation. In fact, at maximum sensitivity, it takes as little as a single photon of light per rod over only a dozen or so rods to produce a sensation (Haber & Hershenson, 1973, p. 50). Cones, on the other hand, have relatively low sensitivity that does not change with the amount of light stimulation;
- Low light "performance" in the fovea is poor, because the fovea is devoid of light-adapting rods;
- With greater distance from the fovea, or eccentricity, visual acuity drops significantly. However, motion sensitivity drops much slower: we can detect that something is moving even if we can't discern what it is.

While these properties have a great significance in how we perceive the world around us, most of them are also important in designing artificial environments, including graphical user interfaces. For example, at Shutterfly.com, the buttons to continue or end a task are located so far away from the area where the user looking to complete the task that the button will be well outside of his or her foveal vision (Figure 1). Since the button is small, the user will need to look around the screen to notice the button. The button's label is no help either: it is unreadable at this eccentricity.

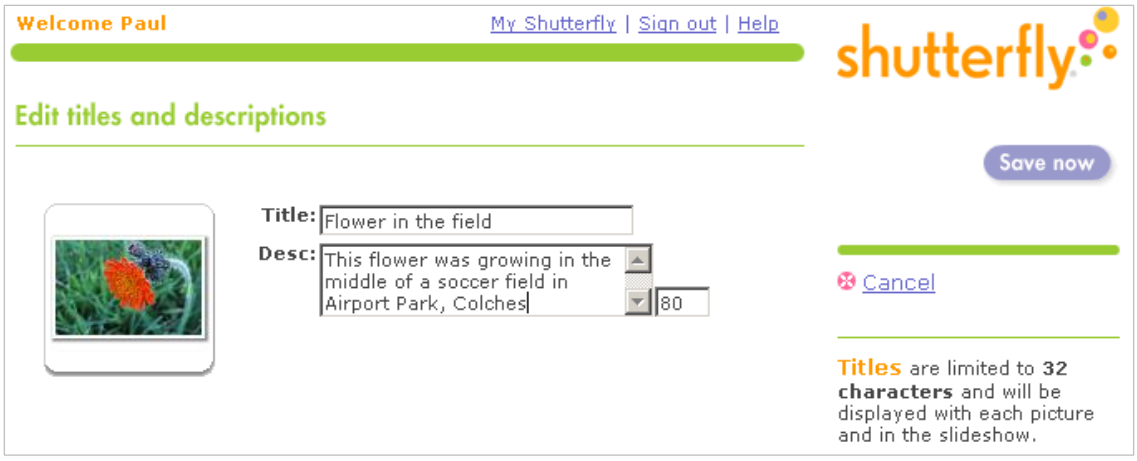

Figure 1. The "Save Now" button is too far away to the right from the text fields in the middle.

One approach to correcting this might involve making the button larger. Unfortunately, it would have to be very large to be readable that far out into the periphery of the visual field. Another solution might involve using motion: making the button blink or change shape. After all, motion sensitivity is relatively high even at the outer extremes of the visual field. Unfortunately, this is likely to be distracting for the users, reducing their ability to concentrate on entering the text. Therefore, the most appropriate solution in this case seems to be placing the button right next to the lower form field, where it would be much more noticeable to a user whose gaze is fixated on the form fields.

Perception of brightness. While the absolute minimum detectable light level is not of much interest to a designer, the minimum perceivable *change* in object luminance *is*, especially at normal reading light levels. Ralph Haber and Maurice Hershenson, in their book *The Psychology of Visual Perception* (1973), cite studies showing that at normal reading levels luminance change of 10% or more between two simultaneously visible patches of color is noticeable, falling to only 1% when the light level is relatively high (p. 105). Of course, luminance alone is not the only determinant of whether a change in brightness is detected. The size of the area that changes plays a role too: the greater the area, the less luminance change is required for the change to be detected (Haber et al., 1973, p. 107).

This concept of "just noticeable difference" plays an important role in a designer's choices of luminance contrast, especially when setting text on lightly colored (or gray) backgrounds. The challenge is here is to keep the text background color distinct from the page background, while maximizing luminance contrast between the text and *its* background. At Shutterfly.com large areas of light grey are used to group related objects (Figure 2a). While it is true that the light gray areas have more than enough contrast with the background to be noticeable, the choice of using a dark gray color for text means that the text vs. background contrast is lower than it would be had black been used for text instead. The contrast between the link color and the gray background is lower yet (see the "Remove effect" link in the "Effects" area on the right of Figure 2a). In fact, when measured with an eyedropper tool in Adobe Photoshop in Lab color mode, the luminance contrast ratio between the link and the background is lower than the ISO-recommended minimum of 3:1 (Ware, 2004, p. 83). This low contrast is especially alarming

given that Shutterfly.com's user population is likely to include elderly, whose level of retinal illumination decreases by as much as 90% as pupil size decreases (study by Winn, Whitaker, Elliot, & Phillips as cited in Scialfa, 2002) and the lens becomes opaque and yellows (study by Weale as cited in Scialfa, 2002). The yellowing of the lens also makes blue colors seem less saturated, because, according to the opponent process model of color, yellow yields gray when mixed with blue in equal amounts (Ware, 2004, p.111). In order to reduce the contrast-related problems at Shutterfly.com, the following changes are suggested: lighten the gray backgrounds slightly, use black for body text, and use a darker, more saturated blue for links that appear over a gray background (Figure 2b).

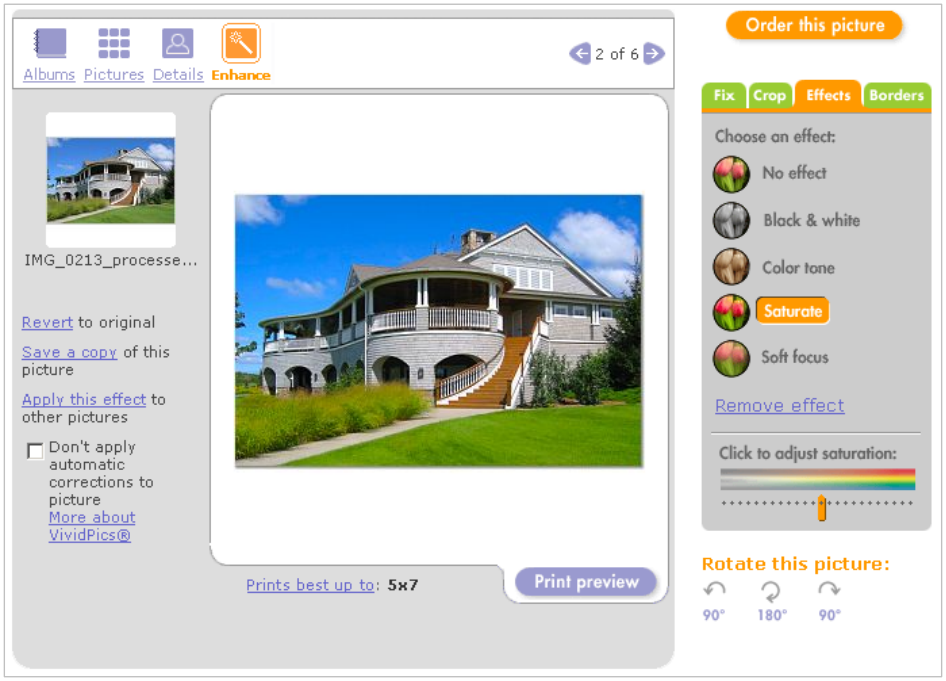

Figure 2a. The light gray shading is too dark, the dark grey text is too light for optimum reading.

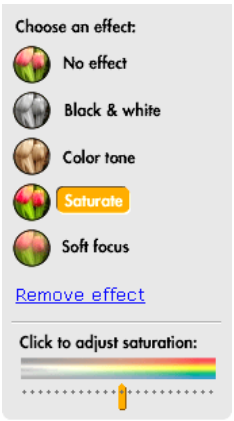

Figure 2b. Changes to text, background and link colors have been applied to improve contrast.

Another place where contrast is compromised, if only slightly, is the white tab labels for both green and orange tabs. One solution would be to decrease the luminance of these colors to increase their contrast with the white text. However, we could also enhance edge contrast by applying a drop shadow to the white text (Figure 3).

Figure 3. Drop shadow is added to the tab on the right to enhance edge contrast.

Perception of Color. Stare at a patch of red-purple on a white page for several seconds, then look at a white area of the page. You will see a spot of greenish blue—red's complement—float on the page for a few seconds. We've all done this afterimage exercise at some point in school, perhaps without even realizing the importance of the concepts it demonstrates. "The physiological phenomenon of afterimage is often used as proof that complementary colors are the basis of harmonious design" notes Frank Mahnke in *Color, Environment and Human Response* (1996, p. 87). In fact, "it is on this visual phenomenon that Munsell based the entire structure of his color theory. The opposite color on his color wheel is what the afterimage would be" writes Donis Dondis in *A Primer of Visual Literacy* (1989, p. 51). Dondis (1989) goes on to say that experiments with simultaneous contrast—where a neutral gray patch is tinged with the complement of the color surrounding it—"show that the eye is seeing the opposite or contrasting hue, not just in the afterimage, but at the same time it is viewing a color" (Dondis, 1989, p. 52). Dondis (1989) cites this phenomenon as "another piece of evidence that indicates [our] … intense need to reach for complete neutrality…" (p. 52). Let's see how well the color palette of Shutterfly.com satisfies this need.

The colors used at Shutterfly.com include orange, blue, green, red and shades of gray; light gray for backgrounds and dark gray for text. Orange is used for headings, important action buttons, "you are here" indicators for the tabbed navigation tools, and to highlight photo correction tool settings. Blue is the color of links, less important buttons, and icons. Non-selected tabs, certain headings, and horizontal rules are green. Red is used almost exclusively for "important" messages. From the standpoint of the color wheel (balancing colors on hue alone) the two most commonly used colors on the site—orange and blue—are in balance: orange is approximately complementary to blue.

Psychophysiology of color. Each hue has the ability to affect a human being psychologically, physically, or both. Here are the effects of several common colors (from Mahnke, 1996):

- Red stimulates. It is the most dominant and dynamic of all colors. Red objects appear to advance, because due to chromatic aberration in the lens, the lens has to adjust to focus red on the retina, rather than behind it.

- Orange also stimulates, especially at highest saturation. However, at this high saturation it can be perceived as intrusive;
- Green is tranquil, relaxing. It is also most restful to the eye, since the eye focuses green wavelengths exactly on the retina.
- Blue is similar to green in its relaxing effect. However, it can be perceived as cold. In fact, Johannes Itten, in his book *The Elements of Color* (2001, p. 45), cites a study in which workers placed in a blue-green room felt colder than the ones in a red-orange room. In addition, since blue wavelengths are focused in front of the retina, blue objects appear to recede when the lens adjust to bring them into focus.

So what kind of feelings does Shutterfly.com generate and how does it use this to influence the viewer? Let's start with the obvious hue: orange. As the most active, intrusive color in the site's color palette, orange calls attention to itself. Since the strategic goal of the non-member home page is to get visitors to sign up for service, orange is used well to make sure the "Sign Up" button and the special offer ("First 15 Prints free) get noticed (Figure 4). The shadow behind the button makes the button seem like its lifting off the page toward the viewer, reinforcing the advancing effect of the hue itself.

Figure 4. Orange elements dominate the non-member home page.

On the same screen, blue is used for headings of less important areas—areas of the site where the user can get more information about the service before signing up. Blue's passive nature makes it an appropriate color to use here, ensuring that these areas do not compete visually with the "Sign Up" button.

Orange is also used well to prompt another strategically important user action on the new user welcome screen: uploading pictures (Figure 5).

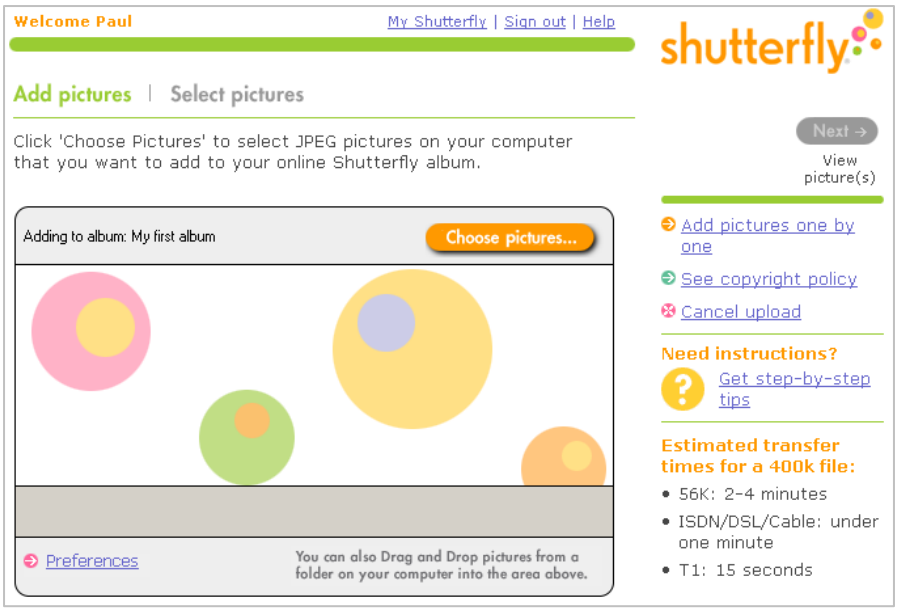

Figure 5. The orange face of the "Choose pictures…" makes it impossible to miss.

Unfortunately, on the subsequent pages, orange becomes overused, losing its "look at me" effect somewhat. For example on the "Enhance Picture" screen, orange is used not only for the site's logo and the money-maker—the "Order this picture" button—but also for the current tab, tool, and picture view selections (Figure 6). As a result the "Order…" button loses it eye-catching dominance. The proliferation of orange elements also increases the page's overall stimulation level. Using a less saturated orange—or maybe even darker, less saturated yellow *instead* of orange—on the tab, tool, and picture view selections would cut down visual stimulation and draw more attention to the "Order…" button (Figure 7).

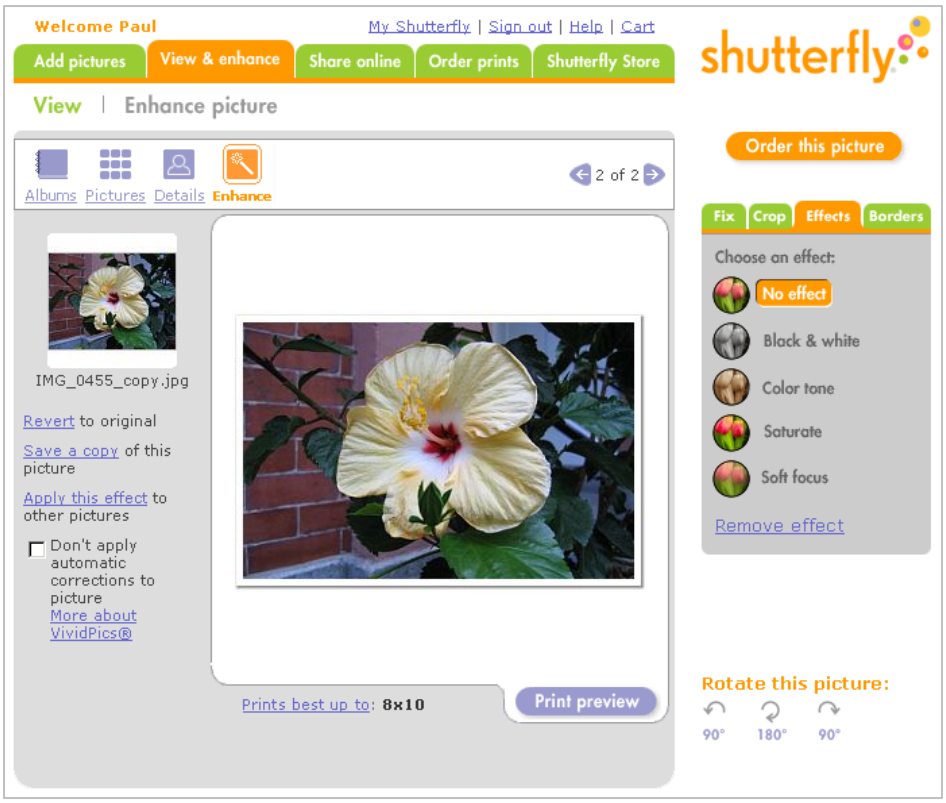

Figure 6. Orange elements multiply, masking the “Order…” button and creating undue visual stimulation.

Figure 7. Dialing down the orange.

The screen in Figure 8 is the first step in the process of ordering a print. It presents a departure from using orange for the default—and the most wanted—action button: the "Next" button is blue, which is a cool, passive color. Although the button's placement—consistent with all other "Next" buttons on the site—helps, using orange would be more effective here in helping users move forward with ordering.

Figure 8. The blue "Next" button.

Notice the use of color in the "Okay to print?" column to visually reinforce the indicator of whether the picture is suggested to print at the size indicated. While using the green/checkmark and red/X combinations works well in cultures where green means "go" and red means "stop," these symbols will have little meaning in places of the world where these two colors are used differently. The same is true for the shapes of checkmarks and Xs.

When it comes to color, the rest of the photo ordering process follows the "orange = go forward," "blue = go back" color coding scheme (the back buttons area blue). In doing this, site's design does use the natural properties of orange and blue to effectively to guide the shoppers forward through tasks and, ultimately, toward the company's most wanted customer response.

Reproduction of color: inherent differences between display and output devices. Shuttefly.com gives it's customers several ways to "get creative" with their pictures: they can crop pictures, add borders, and apply creative photo effects. While cropping and adding borders are not likely to produce unpredictable results, one creative effect—saturate—has the potential to backfire by resulting in printouts that don't look like the picture shown on the user's screen. The problem is due to the differences in the range of reproducible colors (or gamut) between RGB (additive; monitor) and CMYK (subtractive; printer) color spaces: printers just can't reproduce the same range of colors that monitors can (Heid, 1992, p.229).

At Shutterfly.com, when a customer pushes the slider in the "Saturate" tool to increase saturation, it becomes very easy to "push" the bright, saturated colors in the picture right out of the CMYK gamut. As a result colors that look vibrant on the screen (in a wider-gamut RGB color space) will look darker and less saturated when converted to and printed in the CMYK color space. Of course, this problem is made even worse by the fact that this computerized conversion may result in colors that look not only dull, but downright unnatural, even if mathematically close to the original colors (Roth, 1992). The reason why this is strategically important for Shutterfly.com is customer satisfaction: showing a bright picture on the screen, but disappointing customers with dull-looking prints. One solution for this problem would be to limit the range of adjustment in the saturation tool. Unfortunately, this does nothing for pictures that are overly saturated to begin with. In addition, the ability to oversaturate images beyond the CMYK gamut is still useful if monitor is the intended output device (i.e. online picture sharing). This makes a "smart" print preview—converting the picture from RGB for CMYK color space when the user clicks the "print preview" button—a better solution.

On the plus side, no brightness or contrast correcting tools are offered. While they do seem useful at first sight, the variations in monitor brightness, contrast, and, most importantly, gamma settings would lead many customers into the trap of adjusting their pictures to look good on their monitor only to have them come out washed out or too dark in print. Instead, a VividPics® processing feature is applied by default to all pictures to ensure optimal color and contrast.

Summary of recommendations for Shutterfly.com.

- place buttons closer to fields to which they “apply,” making them more readily noticeable;
- lighten the light gray backgrounds slightly and make the text that appears over these backgrounds darker to maximize contrast, and therefore, readability;
- use darker and more saturated blue for text links that appear on gray backgrounds to increase their contrast with the background and to make their color more visible for the aging viewer;
- consider enhancing the edges of white text on colored backgrounds where darkening the background is not acceptable;
- use less saturated orange for the site’s navigation and picture editing tools to cut down on the overall (relatively high) level of visual stimulation;
- use orange consistently for the button that takes the user forward in a task;
- convert pictures to CMYK color space in “print preview” to show printable colors better representing the color saturation and balance as it would appear in the print.

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