Elements of Visual Sensation and Perception

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Our understanding of the world relies significantly on our sense of vision and perception, allowing us to detect and interpret signals. Over millions of years, the human eye has evolved for survival, becoming adept at identifying safe habitats, evading predators, and gathering dependable sustenance (Nilsson, 2022). Out in the world, this visual advantage allows us to identify and categorize objects vital for daily living. However, in product design, overlooking physiological and perceptual limitations increase the risk of human error, “which might be critical in life-or-death scenarios” (Hu et al., 2022). This essay discusses the visual sensory system, including the properties of light and perception, neurological structures, and signal detection. Furthermore, the Zara website, a fashion retailer, will be reviewed for its design implications in relation to the visual sensory system, offering recommendations to prevent human error and improve usability.

Elements of the Visual Sensory System

Visual sensation begins with a physical stimulus in the form of electromagnetic radiation, or light energy. This energy contains physical properties that are detected by neurological components within the eye, primarily retinal photoreceptors, and are perceptually processed. The subsequent sections describe light energy and detection mechanisms in more depth.

Visible Light and Perception

The light we see is a small range of radiant energy apart of a larger spectrum of electromagnetic radiation. (Fairchild, 2014). We call this spectral field the Visible Light Spectrum, which “ranges from 400 to 700 nanometers in wavelength” (Rehman et al., 2022). While visual sensation pertains to the physical properties of light and “informs about habitat quality and current conditions,” perception is a psychological process that “provides information on the current situation and allows for the planning of actions.” (Nilsson, 2022).

Luminance.

Luminance is a physical value representing the intensity of light directly from the source measured in candelas per square meter (Purves et al., 2004). Presented as the amplitude of light energy, luminance weighs most significantly in contrast sensitivity, which is the primary form of object recognition in the visual system (Yedutenko et al., 2021). More on contrast will be discussed in later sections.

Hue and saturation.

On the Visible Light Spectrum, hue is the measurable frequency of a signal’s energy, measured in Hertz (Hz) (Davis, 2018). It contributes to our psychological perception of color, however, while color perception relies on multiple other characteristics of light, hue is an independent, physical property "regardless of lightness, saturation, or any of the other attributes" (Fairchild, 2014). Saturation, defined as the "colorfulness relative to the brightness of the stimulus," is the purity of the hue from the light source (Fairchild, 2014).

Brightness.

Brightness is the "perception of the amount of light emanating from a stimulus," directly correlating with a signal's luminance (Fairchild, 2014). Unlike luminance, brightness is an unquantifiable element of human sensation and "can only be evaluated by asking an observer to report the appearance of one stimulus relative to that of another" (Purves et al., 2004).

Illuminance, illumination, and environmental conditions.

Illuminance, measured in lux, is the "amount of light exposure" from a source onto an object (Dautovich et al., 2018). Illumination, or the lighting quality of the environment, is affected by ever-changing lighting conditions, revealing that illuminance "cannot be detected reliably" (Kelber & Osorio, 2010). To maintain visual consistency, processes like light and dark adaptation adjust to the existing illumination of an environment" (Fairchild, 2014).

The Physiology of the Eye

The eye comprises a multitude of parts that contribute to the sensation of light from the physical environment, the first touchpoint being the cornea. The cornea "refracts and transmits the light to the lens," which is located behind the cornea and helps in focusing images onto the back of the eye (Willoughby et al., 2010). The iris regulates the amount of light that enters through the pupil, an opening centered between the iris. Lastly, the ciliary body surrounding the iris "controls the power and shape of the lens" to focus images based on the eye's distance to the object, a process called accommodation (Willoughby et al., 2010).

The retina.

Once light passes through the outer optic structures, it reaches the retina, a multilayer structure containing neurons that process various wavelengths of light into three-dimensional images (Mahabadi & Al Khalili, 2023). These neurons are spread across the peripheral, macula, and foveal regions, contributing to distinct modes of light detection (Willoughby et al., 2010).

Photoreceptors.

Rods, constituting about 95% of the light-detecting neurons in the retina, are responsible for scotopic vision, or the vision of light in low-light environments (Mahabadi & Al Khalili, 2023). With rod density increasing toward the peripheral region of the retina, rods evolved for nighttime survival (Mahabadi & Al Khalili, 2023). In response to this hypersensitivity to low light, rods cannot function well in the day, “as they are ‘photo-bleached’ and need 20 minutes to recover” (Mahabadi & Al Khalili, 2023). Bleaching refers to the inactivity of these cells when hit with highly luminant light. (Mahabadi & Al Khalili, 2023).

The other 5% of retinal photoreceptors are cones, which are highly concentrated in the macula and more primarily, the fovea, allowing for great visual acuity in the daylight (Mahabadi & Al Khalili, 2023). Critical in color perception, or photopic vision, there are three cone types that absorb different wavelengths of light: “red light (64%), green light (32%), or blue light (2%)” (Mahabadi & Al Khalili, 2023). All three cone types are responsible for trichromacy, the three-dimensional perception of color, correlating with the “perceptions of lightness, chroma, and hue of a scene” (Fairchild, 2014). Red and green sensitive cones, concentrated in the fovea, are most perceptible in well-lit conditions, as the fovea has high visual acuity in the daylight. Blue sensitive cones, sparsely scattered toward the peripheral region, coexist with night-sensitive rods, contributing to difficulty focusing on blue light in the day but being more detectable at night (Mahabadi & Al Khalili, 2023).

Once rods and cones pick up light signals from the environment, information is transferred to the ganglion cells (Yedutenko et al., 2021). The ratio of rods to ganglion cells is much higher compared to that of cones, contributing to the “greater amount of visual data” in perception (Mahabadi & Al Khalili, 2023). The larger rod-to-ganglion cell ratio is responsible for poor visual acuity in rods (Mahabadi & Al Khalili, 2023). Once information is processed by the ganglion cells, it is sent through the optic nerve and up to the brain for further perceptual processing (Yedutenko et al., 2021).

Signal Detection and Discrimination

Signal detection is the process of detecting light based on its features, which is a matter of contrast, or “the variations of light intensity occurring in time and in space” (Yedutenko et al., 2021). Luminance, the primary factor of contrast, has a positive correlation with contrast sensitivity, such that “as luminance decreases, the ability to discriminate patterns decreases” (O'Carroll & Wiederman, 2014). While signal detection relies on a signal strength, independent of surrounding stimuli, signal discrimination relies on the “relative intensities” between stimuli (Solomon, 2007).

Contrast and Its Influences

Contrast has a threshold that determines the lowest, or minimal, and highest amount of light that can be reliably discriminated against for signal detection (O'Carroll & Wiederman, 2014). In signal discrimination, the threshold that describes the minimum amount of difference between the signal strength of two signals is called Just Noticeable Difference (JND) (Kelber & Osorio, 2010).

In prolonged signal exposure, an evolutionary feature called contrast adaptation enables the eyes to ignore “slow uninformative changes in signal contrast” while remaining highly sensitive to abrupt onsets “that may signal important events in the environment” (Gardner et al., 2005). Abrupt onset refers to the sudden change in the viewer's environment and guides visual attention as a survival mechanism (Jonides & Yantis, 1988).

Along with luminance, the most weighted factor in contrast, signal detection is also influenced by size, revealed in that smaller targets “no longer fill the receptive field of a single receptor,” resulting in difficulty detecting features of small images (O'Carroll & Wiederman, 2014). Additionally, hue and saturation play a role in signal detection, although Hillstrom and Yantis (1994) note that deliberate awareness of these attributes is required in guiding attention. An additional factor of signal detection is motion, whereby certain ganglion cells are specialized to “fire when motion within their receptive field center differs from the motion in their surround” (Yedutenko et al. 2021). Finally, edge detection also plays a role in signal detection. Retinal neurons have receptive fields that have an opposite polarity with its surrounding neurons and fire at a higher rate when they intersect a contrast boundary compared to when they “fall entirely on one side of the boundary or the other” (Purves et al., 2004). Therefore, the difference in luminance of two areas defined as an edge increases contrast sensitivity (Purves et al., 2004).

Case Study: Zara.com

Many retail websites are often characterized by various accessibility challenges regarding call-to-action buttons and other information display features. This section examines some of these features in an expert review of Zara, a high fashion retailer, to determine usability issues presented by the visual stimuli on its website.

Low Contrast

There are numerous places in Zara’s digital product that mark poor contrast, as determined by the latest Web Content Accessibility Guidelines (WCAG). As depicted in Figures 1.1 and 1.2, the vertical carousel home pages feature image backgrounds that make the foreground text appear poorly visible. Utilizing WebAIM, a contrast checking tool, we find that the navigation menu and the selected background image in Figure 1.1 have a contrast ratio of 1.29:1 while the selected area in Figure 1.2 has a ratio of 1.51:1. Poor homepage visibility also applies to the category text “New” in the bottom right corner of Figure 1.2, as the contrast ratio of text to background is 1.65:1. These ratios, taken from the lowest contrast areas of the screen, suggest that people may fail to notice available categories and features such as ‘Kids,’ ‘Home,’ ‘New,’ and the search bar in Figure 1.2, which is almost entirely undetectable as the signal does not pass the minimum contrast threshold. For reference, the minimum contrast ratio for visibility is 4.5:1 according to WCAG (AA) guidelines, elucidating that Zara’s homepages are not accessible for people with normal vision and even more so for people with poor vision.

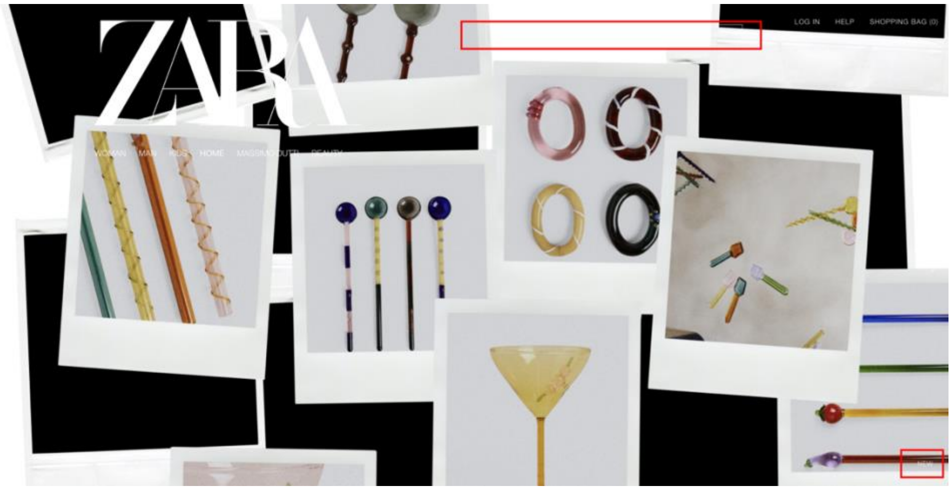
Figure 1.1

Home Page Carousel Background 1

Note. The red stroke rectangle in the upper left corner is not a part of the Zara website and is just a markup to call out the website features described.

Figure 1.2

Home Page Carousel Background 2



Note. The red stroke rectangles in the top center and bottom right corner are not a part of the Zara website and are just a markup to call out the website features described.

The poor discrimination in low contrast signals arise from the low firing rate of retinal receptors, which, in Figures 1.1 and 1.2, are attributed to by the minimal luminance difference between the foreground text and the background image (Yedutenko et al., 2021). Visibility issues only increase with age, often stemming from age-related macular degeneration (AMD) which causes a "loss of photoreceptors in the fovea, and thus, a loss of central vision (Rehman et al., 2022). To address this issue, I recommend increasing the contrast of the foreground text to background image by making the navigation menu black rather than white or changing the images to be darker so that the white text of the menu maintains a visible contrast level. This recommendation aligns with the forthcoming section's review of motion on the homepage.

Motion

The homepage, although it might be aesthetically pleasing and fitting of the Zara brand, also causes signal detection issues through motion. The moving image on the home page, as can be seen in Figure 2, may dominate a customer's attention, as it overpowers the contrast of the navigation menu. Given that customers typically seek out the navigation menu on a homepage, decreasing the dominant signal strength of motion is necessary to guide attention to the contrast of the navigation menu. This will help in decreasing the overwhelming rate of firing in motion sensitive neurons to that they can be more perceptive to other modes of contrast on the page (Yedutenko et al., 2021). My recommendation is to decrease the use of motion in the background image by using a dark, static image to reduce the signal strength from motion, while enhancing the signal strength from the white menu text.

Figure 2

Home Page Motion Background

Note. This gif was created through a laptop screen capture and a gif website creator called makeagif.com.

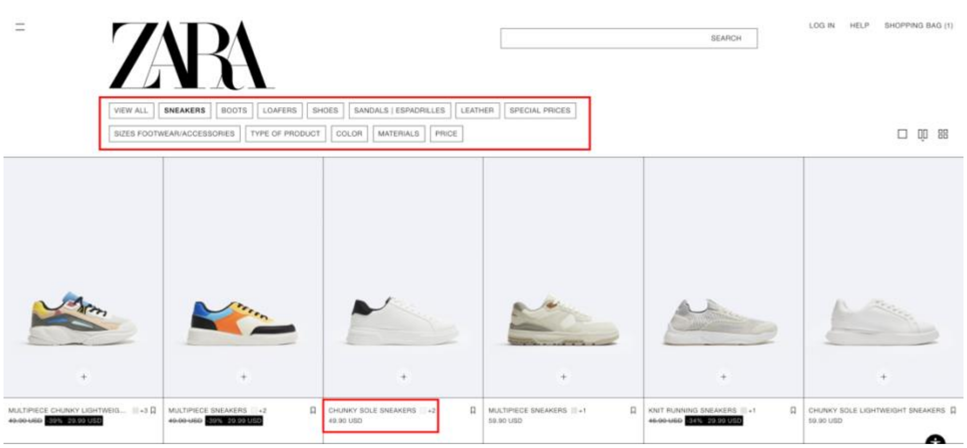
Size

Text and signal size also seems to be an issue in signal detection and discrimination in Zara, particularly in the product browsing pages and product details page. In the product details page depicted in Figure 3.1, the lower-level categories indicated above the product images have the same size, except for the selected category "Sneakers." Despite this category selection, the minimal contrast difference, particularly in the subtle bolding reflecting size difference, has low visibility, posing a challenge in knowing the page one is on if the products are ambiguous. Furthermore, product prices [Figure 3.1], which are often of high importance to customers, lie just below the product title description. However, the small text size and insufficient contrast between the title and the price might fail to easily guide one's attention to the price. For this, I recommend using a color like red, which is highly visible, and more apparent boldness to distinguish between selected categories and unselected categories, as well as draw more attention to the prices.

On a positive note, Zara achieves effective contrast sensitivity in the design of the sale prices [see Figure 3.2] indicated with white text on a highly contrasted black box, achieving a contrast ratio of 21:1. This design increases the likelihood of customers perceiving the price of the product quickly.

Figure 3.1

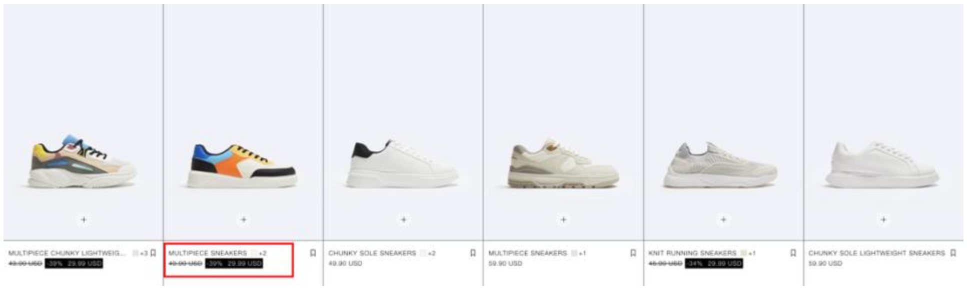
Product Browse Page – Category Menu



Note. The red stroke rectangles in the left and bottom centers of the screen are not a part of the Zara website and are just a markup to call out the website features described.

Figure 3.2

Product Browse Page – Product Description



Note. The red stroke rectangle in the bottom left of the screen is not a part of the Zara website and is just a markup to call out the website features described.

Conclusion

In summary, visual sensation and perception prove to be complex and multifaceted processes, encompassing a multitude of influences such as the physics of light, neurological structures in the eyes, and signal detection and discrimination. In the latter part of this essay, connections were drawn between the elements of the visual sensory system and the visual stimuli presented in a case study review of Zara.com. Here, various characteristics of the website were identified, highlighting their susceptibility to human error susceptibility and offering key recommendations to improve usability. This essay illuminates the importance of adopting a visual sensory approach in product design to consider the limitations of the human visual sensory system and prevent human errors.

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