Review of Genie Wired Wall Console with Perceptual Processing Systems

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The human eye has perceptual processing systems. Its capabilities include detecting luminance, change, contrast, motion, size, hue, saturation, and contour. The eye also has limits with age, JND, and night vs day capabilities. The eye has evolved to detect these different factors in order to do things like seek shelter, hunt, detect threats, understand the world, etc. In this review, there will be discussion of the anatomy of the human eye and these perceptual factors as well as a case review of the Genie Wired Wall Console. This interface has benefits of easy open/close garage door button detection and flaws of the light button and security switch being more difficult to detect using the human eye's perceptual processing systems.

Human Eye Anatomy

The eye is a receptor, and the light is a stimulus. Most light humans encounter is from the sun (Yokoyama, S., & Yokoyama, R., 1996). The light that is visible has corresponding photon wavelengths from violet to red (Yokoyama, S., & Yokoyama, R., 1996). The retinas in both eyes have millions of photoreceptor cells (Yokoyama, S., & Yokoyama, R., 1996). There are two types of photoreceptor cells, called rods and cones (Kawamura, 2008). There are around a hundred million rods and a few million cones in the retina (Yokoyama, S., & Yokoyama, R., 1996). Rods have visual pigments called rhodopsins that absorb light and photons maximally (Yokoyama, S., & Yokoyama, R., 1996). Rods allow us to see in the dark; they can distinguish one photon in dark surroundings (Kawamura, 2008). Cones are not as sensitive to light but act quicker with a fast flash response time and are better at spotting motion (Kawamura, 2008). Cones allow humans to see hues across the visible part of the electromagnetic spectrum. There are three different kinds of cones: blue wavelength sensitive (short), green wavelength sensitive (middle), and red wavelength sensitive (long) (Yokoyama, S., & Yokoyama, R., 1996). In the light of day, cones provide the human eye with high acuity (Cepko, 2010). The highest acuity happens in the fovea of the eye (Parker, 2016). The human eye is most sensitive to yellow/yellow-green, as it is in the middle of the visible light spectrum. The eye is more sensitive to blue light at night when rods are activated but during the day when cones are activated, red is more luminant (Rossing, 1999). As the eye ages, the cornea yellows and becomes less sensitive to blue light (National Research Council (US) Committee on Vision). The cornea also flattens and may get fatty deposits, making it difficult to focus and less light comes through (National Research Council (US) Committee on Vision). Many parts of the eye work together for vision.

The eyes adapt to surroundings and move with great control. The foveae work together to focus on an object within the small "field of high resolution" (Parker, 2016, p. 1). In order for sight, rods and cones convert photons, or particles of light, into chemical electrical signals in neurons (Stryer, 1996). Signals from different types of cones create blue-yellow and red-green pathways (Stryer, 1996). Neurons receive signals from rods and cones and then ganglion cells send the signals into the brain (Cepko, 2010). In blue-yellow opponency, a ganglion cell "receives depolarizing inputs from a blue-sensitive 'on' bipolar cell and a summed red and green-sensitive 'off' bipolar cell" (Stryer, 1996, p. 558). The information that the cones generate are sent to the brain through different types of ganglion cells including magno, parvo, and konio cells that all have their own pathways (Yoonessi, A., & Yoonessi, A., 2011). A million ganglion cell axons, all parts of the optic nerve, must bring over a hundred million photoreceptor cells to the brain (Stryer, 1996). Visual pigments release electrical signals to the brain's visual cortex (Yokoyama, S., & Yokoyama, R., 1996). This is how humans are able to see the world.

Luminance, Change Detection, and Object Detection

Magno cells with Luminance and Change Detection

Human eyes are great detectors of luminance and change. Luminance is "the amount of physiologically effective light per unit area of the object" (Shapley, R., & Reid, R. C., 1985, p. 5983). The magno pathways and magno cells detect luminance signals. (Morrone et al., 1990). When luminance and photons decrease, the contrast sensitivity goes down with it (O'Carroll, D. C., & Wiederman, S. D., 2014). However, larger ranges of luminance from dark to light are not always beneficial (Sund, 2022). It is not helpful to have a large luminance range and fatigue the eye, like in a dark setting when rods are engaged. When stimuli change, detection of these changes is done quickly by magno cells (Yoonessi, A., & Yoonessi, A., 2011). Stimuli continually excite photoreceptors, and the rate of action potentials go down (Marzvanyan, A., & Alhawaj, A. F., 2023). But, if a new stimulus appears, the photoreceptors will respond to it (Marzvanyan, A., & Alhawaj, A. F., 2023). The magno cells are sensitive to motion and temporal qualities of stimuli (Livingstone, M., & Hubel, D., 1988). This means that eyes are also quick motion detectors.

Motion and Object Detection

Abrupt onset of new or moving objects are more powerful at capturing attention than stimuli with other qualities (Franconeri, S. L., & Simons, D. J., 2003). Magno cells carry information about change and movement, whereas parvo cells do so with acuity, shapes, sizes, and hues (Purves D, Augustine GJ, et al., 2001). Size stands out, the human eye detects it quickly, "[t]he ability to appreciate the size of an object is a basic visual perceptual function…" (Pantle, A., & Sekuler, R., 1968, p. 162). Contour and shape detection are also the jobs of parvo cells. Environmental factors affect luminance and contour. The eye will detect the luminance level of a stimulus as higher when it is in a darker environment as opposed to a lighter environment (Purves, D., Monson, B. B., et al., 2014). This is also where contour detection happens, "when two fields of different luminances are placed adjacent to one another, a contour is formed at their boundary" and "a dark band is seen" (Stecher, 1968, p. 34). Contour is the outline; it forms the shape of an object. The eye is "programmed to detect contours rapidly" (Wördenweber, 2001, p. 352). Humans detect contours which help to recognize objects and edges.

Hue And Saturation

Hue and Saturation are connected as major factors in vision. Hues are different wavelengths of light that are visible to the human eye, which are also known as color names (Rossing, 1999). If the exact wavelength on the electromagnetic spectrum is not visible, then the eye sees the closest hue that can be identified (Rossing, 1999). Specific hue detection was mentioned in the anatomy of the eye. There are limits to hue detection and these limits vary from person to person. For example, some males are "protanopes and deuteranopes" meaning they are red and/or green color-blind (Wald, 1964, p. 1014). Saturation is "the 'purity' of the color" (Rossing, 1999, p. 8). Saturated color's intensity is "concentrated near the dominant wavelength" and "an unsaturated color includes contributions from other wavelengths" (Rossing, 1999, p. 8). There are spectral colors that are the most saturated, like the pure colors of the rainbow (Rossing, 1999). White light is the least saturated and contains all the colors (Rossing, 1999).

Contrast And Hue Discrimination

Contrast is an important aspect of perception. The eye detects hues with rhodopsin and the three different cone pigments (Yokoyama, S., & Yokoyama, R., 1996). When different hues are next to each other, there is contrast. Orange and yellow next to each other will make the orange look closer to red and the yellow look closer to green (Rossing, 1999). Split complement theory explains the optimum contrast between hues. The color wheel is the visible light spectrum bent into a circle. The optimum contrast color is not the direct opposite compliment color but rather the split complement. The split complement refers to the hues on either side of a hue's complement on the wheel (Plante, T. B., & Cushman, M., 2020). Again, optimum contrast is not maximum contrast. It is hard to differentiate hues next to each other within green, purple, and blue but yellow has been shown to be easier to differentiate (Munsinger et al, 1974). Afterimage can also impact the perception of hue and contrast. Rods and cones keep sending signals for a little while "after stimulus offset" (cone signal decays much faster than the rod signal), leading to afterimage (Coltheart, 1980, p. 62). Hues overlap slightly in the mind as the eye moves around the field of vision, leading the eye to detect hues differently than normal (Rossing, 1999). This connects to how environmental factors also impact perception.

Signal Detection and Just Noticeable Difference

Difference detection has limits. Signal detection theory "offers a sophistication of quantitative analysis and a degree of abstraction that has prompted formal modeling of attention" and "identification of a visual object involves pathways from VI to ventral occipital-temporal areas where shape identification appears to occur" (LaBerge, 1990 pp. 159-161). This is related to just-noticeable difference which is "the change in intensity that results in some fixed value for the probability of detecting the change" (Hernstein, et al 1988, p. 63). Just noticeable difference and signal detection are about the limit to when the eye can detect a signal. JND and luminance are intertwined in a case where, "The risk of experiencing dull and gray images on a display with a low luminance range is therefore low, provided that the JND range is sufficiently high" (Sund, 2022, p. 2276). This means optimum contrast depends on the environment too.

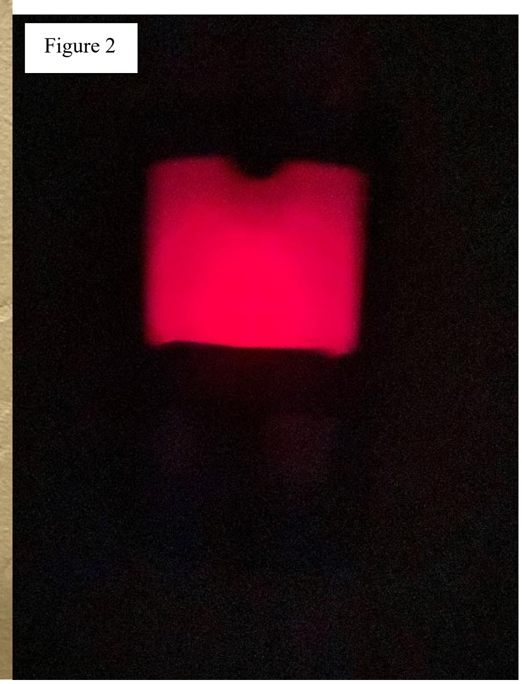
Case Review of Genie Wired Wall Console (to open garage door)

Genie Wired Wall Console

The Genie Wired Wall Console is an interface used to open garage doors. The main user goals are to open and close the garage, see in the garage, and have security. The users are homeowners and/or those living in the home that have access to the garage. Users may be the age of a child to an elderly person. The use environment is in a garage during the day and at night and perhaps with other lights in the garage that are not connected to the Genie system.

Figure 1

Figure 2



Main Button (Open/Close Garage with Light Turning On)

It is important to be able to detect the button that opens/closes the garage door and turns the lights on at the same time, this need is met, so this button will be called the main button. A large white button opens and closes the garage and turns the light on (Figure 1). The white button stands out on the black background, the contrast makes the button easy to detect. The button is the largest button on the display, so the size makes it stand out. Lastly, the button has a red light inside. The red light is not very visible during the day and/or with lights on because the light is not luminant enough with these environmental factors. However, in the dark, the red light is extremely luminant, one of the top factors to making something easily detectable (Figure 2). It is crucial to be able to detect the button in the dark since the user may need to open the garage at night. The choice of a red light makes sense, as it is a color that elderly people can still detect. Red is harder to detect in the dark, but the luminance and size of the button make up for it. The red light in the dark is saturated, again making it easier to detect. The user will instantly perceive that the button works with the abrupt onset of the garage light turning along with the motion of the garage door, after all the human eye is a change detector.

Light-Only Button

Problems arise with the next button. The bottom right button is smaller than the main button and its function is to turn the garage light on and off, without opening or closing the garage (Figure 1). This button is like the other one in that it is white with a black background, there is high contrast in the light for the button as a whole, but it is hard to detect the light bulb symbol because it is white on white. This is a contrast problem, making it difficult for people to detect the symbol. Another major problem is there is not a light inside the button like the main button has. The user would only need this button in the dark. Therefore, it is a bad situation if the user cannot detect the button in the dark. It is extremely difficult to detect the button when there is no light to bring luminance. In the dark, all of the focus would be on the main button, which turns the light on *and* opens the garage door, making the light-only button practically useless as it cannot be seen. This is also a security issue if the user must open the garage for the light to turn on.

Security Switch

The issue of safety connects to the second problem. The bottom left security lock deactivates the outside keypad and remote controls that can open the garage (Figure 1). This switch is easily visible due in the light due to the fact it is a whiter color with a dark background contrast. It has the same problem in that it does not have a light, so it cannot be seen in the dark.

The other problem is that the lock and unlock symbols are black on black and the only way to detect them is with edge perception (they are raised on the interface). Hue on hue is dangerously playing with JND. This is a major problem because it is hard to detect black on black and it is harder to focus with age, making it inaccessible for elderly people who also need home security.

Recommendations for Genie Wired Wall Console

Considering all of the perceptual processing systems of the eye addressed earlier, there are a few recommendations to be made for better signal detection of the security and light buttons to avoid negative JND results. One recommendation is making the light button backlit when the garage light is not on, so it is easy to detect in the dark, and turn the light in the button off when the garage light is on and there is no need for added luminance. Another recommendation is to make the bulb symbol a dark color, like black, for contrast so it can be seen. A third recommendation is to make the security backlit since security is likely to be turned on at night (in the dark). Even if there is a light turned on, the security switch unlock/lock symbols should not be black on black. So, a last recommendation would be to make the symbol a highly visible saturated hue, like yellow, on black so there is high contrast and easy detection. Other than that, the main button’s usability is well-done, easy to detect, and the user will know it works instantly with the abrupt onset of the light and the motion of the door.

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