Visual delay

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The 80 millisecond rule

Have a friend stand within arms-length and clap. Look and listen. Sight and sound are synchronized. Step back twelve or so paces and have them do that again. Sight and sound are synchronized. That's odd already because sound travels at 340 m/s but even more surprising is what happens at 30 metres. Sight and sound suddenly become separated by 80 milliseconds. The brain compensates for the late arrival of sound out to a distance that corresponds to the limit of shouted conversation. The late arrival of sound sets the clock. We see the clapping as having taken place in the past. For additional reading see … https://blogs.scientificamerican.com/observations/time-on-the-brain-how-you-are-always-living-in-the-past-and-other-quirks-of-perception/

Pulfrich's Illusion

The 80 millisecond rule indicates that we do not always (if ever) see things as they happen and there are other instances of the same thing. Pulfrich's Illusion demonstrates a visual delay for a different reason. An observer watches a pendulum that swings at right angles to their line of sight. The pendulum swings in a plane. They cover one eye with a neutral density filter. They now believe the pendulum is swinging in an ellipse. The effect becomes more pronounced as the density of the filter is increased.

Less intense light extends the delay between stimulation of the retina and the onset of action potentials in the optic nerve. The optical signals reach the brain at different times, but the brain interprets the events as being simultaneous and misinterprets the difference in apparent image position as three-dimensional data. Relative delay times can be measured directly if the relationship between image separation and apparent line of sight displacement is first determined using a two-color diagram known as an anaglyph.

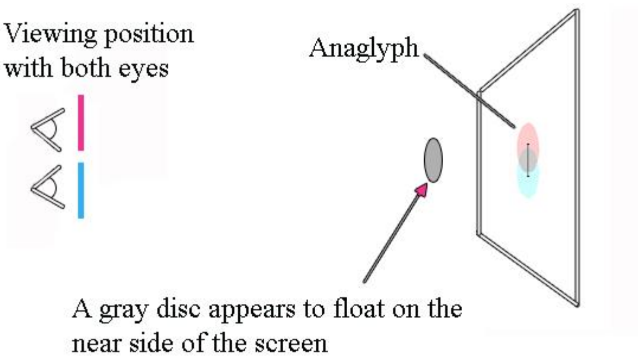


Fig 1 - a single gray disc floats clear of the screen when the anaglyph is viewed through red/cyan glasses.

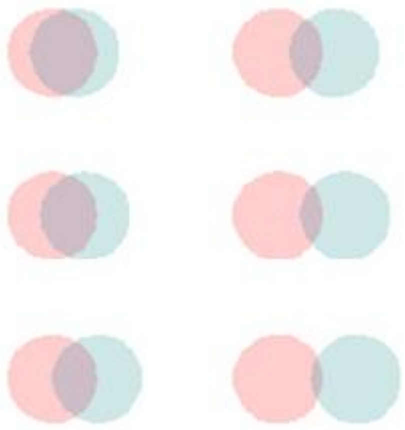
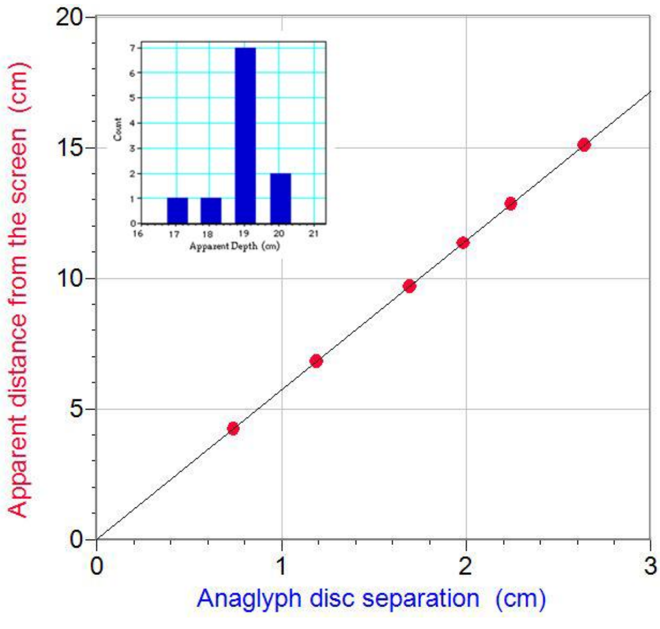


Fig 2 – anaglyphs with different disc separations. (The colors depend on monitor settings and may not be matched here to the red/cyan glasses you may have.)

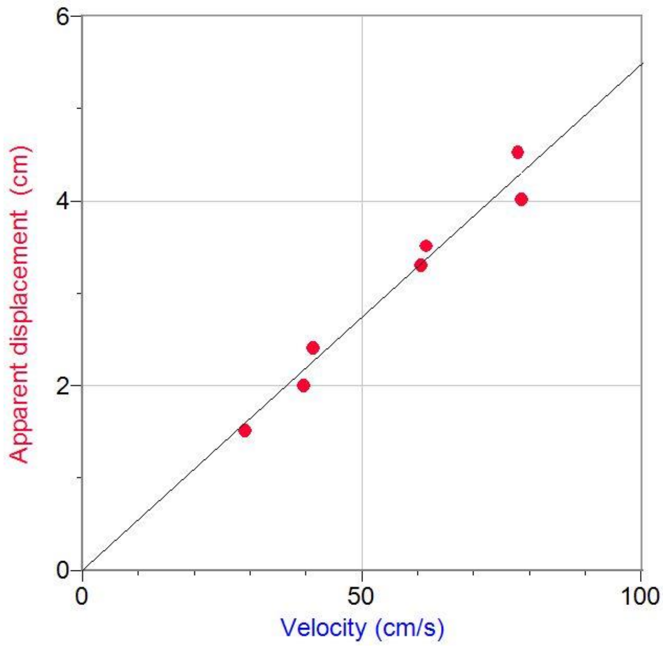
When viewing through red/cyan glasses each eye sees only the opposite color. The brain interprets the angular image separation as displacement along the line of sight. The floating disc can be located to within one mm by carefully bringing a pencil or sate skewer up to the image while viewing with both eyes. Relating apparent image position to the disc separation gives the relationship between the apparent displacement and image separation.



Graph 1 – the graph of apparent depth versus anaglyph disc separation is linear. The inset shows that agreement between twenty observers is within ± 4%. Data from an IB Extended Essay by Bradly Skaggs, ISB Bangkok.

To study delay times a swinging pendulum is viewed from the same distance. Image separation is inferred from the apparent displacement along the line of sight.

The apparent line of sight displacement versus maximum velocity when using a single polaroid filter in bright sunlight is shown below. The relationship is linear as expected.



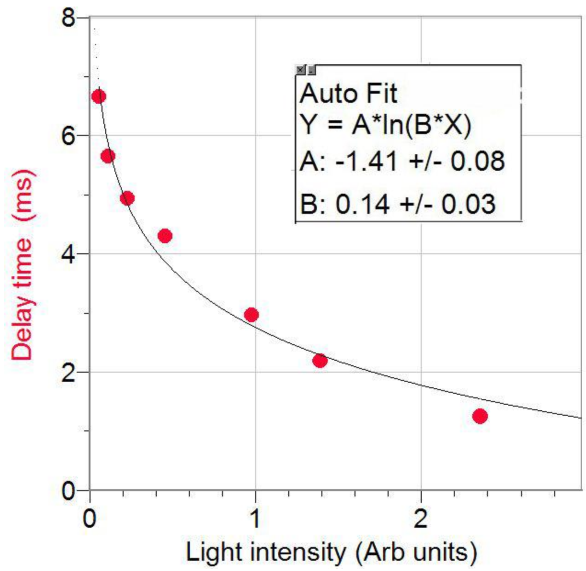
Graph 2 - typical values for students age 16-18. Data: Yolanda Chung ISB.

Since the observed apparent displacement of the pendulum is proportional to velocity, Pulfrich's illusion can be understood as the result of a small delay in signal processing.

Neutral density filters

Skaggs photographed a uniformly illuminated gray surface with b/w film. The resulting negative blocked the same percentage of light across the entire surface. Because the light reduction is due to silver grains the density is equal across all wavelengths resulting in an absence of color. The developed negatives were tested for light transmission with an incandescent bulb set up to shine on a large white piece of Styrofoam. Light intensity was measured using a Vernier light probe with the software package Data Logger Pro. Three negatives were selected as filters with transmission values of approximately 50%, 25%, and 12.5%.

As the density of a neutral density filter is increased Pulfrich's effect becomes more pronounced. With the calibration of the visual system above, the relationship between relative light intensity to each eye and signal delay time can be measured for different filters for different ambient light levels. Preliminary results obtained by Skaggs are shown below in Graph 3.



Graph 3 – delay times and relative light intensity. Data: Bradly Skaggs.

The data appears to fit a log curve in common with many biological functions. More data obtained under carefully controlled conditions is required to confirm the log dependence. In particular data in the 0.5 to 2.0 ms range would be desirable.

The finding here, that signal processing is delayed by milliseconds in dim light explains why a fast moving ball is difficult to hit with a bat in dim light. In particular a cricket match is abandoned as light fades. The difficulty in dim light is not the inability of a batsman to *see* the ball but his inability to see *where* it is. A ball traveling at 30 m/s moves 3 cm in one millisecond. A batsman's timing will be affected by a delay of a few milliseconds.

Suggestions for further work

A study with collection of more data from more subjects is required to confirm the log dependence of the image processing delay with light intensity and in a future study the light intensity scale could be made quantitative.

The measurements here were made with HS students. It may be found in a future study that signal delay is age dependent.