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A3_6 The Blind Spot Of The Human Eye

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Abstract

In this paper we demonstrate that the blind spot of the human eye can block out small objects from our visual field. We use baseball as an example and it was found that at a certain angle the ball could not be seen for some distance. We then showed that the batter does not have enough time to react and hit the ball when it reappears in the visual field

Introduction

When light hits the retina at the inner surface of the eye, nerve impulses are generated which travel using axons [1] to the brain through the optic nerve. These axons converge and exit at the optic disc. At this location there are no rods or cones [1], and this corresponds to the area where no light is detected. This is called the blind spot. There is one blind spot in each eye, and they are aligned symmetrically. The right eye has the blind spot to the left of the visual axis as shown in figure 1 and the left eye to the right. Consequently the light that hits one of the blind spots can be detected most of the time by the other eye, depending on the centre of vision and this compensates for the loss of vision. One can verify for themselves the presence of the blind spots at the following webpage: *http://serendip.brynmawr.edu/bb/blindspot1.html.*

The brain fills in the gap of the retinal image using intelligent guesswork. It uses a sophisticated process where it makes unconscious assumptions about the statistics of the natural world. Here we try to investigate the area of the field of vision the blind spot occupies by using a baseball as an example.

Investigation

In a game of baseball, the batter has their centre of vision on the pitcher. Here we consider the ball to be thrown at a visible angle from the pitcher’s mound, which has the same vertical distance from the batter, but the horizontal distance of the pitcher from the batter is to the right side of the batter as shown in figure 1. The batter remains looking at the pitcher with their left eye shut or squinting.

We would then like to find out the distance between the pitcher and the batter where the area the baseball makes on the retina falls within the blind spot. This can tell us whether there is sufficient time left after this range in distance, for the batter to react and hit the ball. We first deduce a relationship between the location the ball is thrown with respect to the visual axis and the projected length it makes along the retina, by considering a two-dimensional view of the eye. An object of diameter y_2 at a vertical distance of y_1 from the visual axis and at a horizontal distance s from the cornea [1] makes a retinal image of diameter $y_2' + y_1'$, where y_2' and y_1' are the projected diameters due to y_2 and y_1 respectively, as shown in figure 1. This relationship is given as [2]:

$$\frac{y_2+y_1}{s} \approx n\,\frac{y_2'+y_1'}{0.025\ m}\ , \qquad (1)$$

for small angles, where n is the refractive index inside the eye.

We now find y_1, given that s in a standard baseball game is $\sim$18.4 m [3], the diameter of a baseball, y_2 is 0.075 m [3] and we consider $y_2' + y_1'$ to be the distance from the visual axis to the optic disc. This is when the ball can just be seen (i.e. before y_2' is covered by the optic

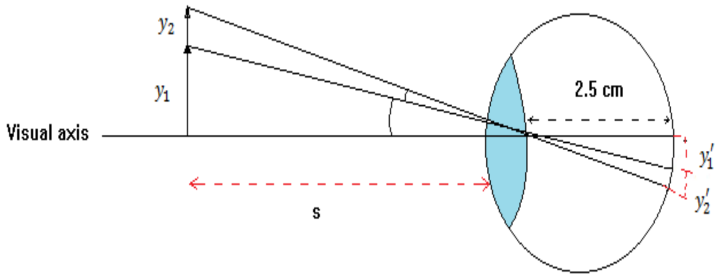

Figure 1. An illustration of an object projected along a length on the retina of a right eye with the optical disc on the left side of the visual axis.

disc). We calculate this diameter of $y_2' + y_1'$, by knowing that the optic disc is 15° from the visual axis, [4] which corresponds to 6.7×10^{-3} m using simple trigonometry. Finally we need the refractive index of the inside eye. Most of the refraction is due to the cornea with a refractive power of 80% [6]. We therefore consider here that the total refraction is due to the cornea. The refractive index of the cornea is 1.376. Using these values and substituting them into (1) gives y_1 = 6.71 m.

Now as s decreases, the diameter of the image on the retina increases. The ratio between y_2 and y_1 is 1 : 89 which is also the ratio between y_2' and y_1'. The ratio tells us that y_2' is very small compared to y_1' and hence we make the approximation that y_2' is a point source on the retina. From this we can say that the projected diameter on the retina is due to y_1' and for the ball to be seen again, y_1' must pass through the length of the optic disc. Thus y_1' increases by as much as the diameter of the optic disc (1.6$\times$ 10^{-3} [5]), so now we take y_1' to be (6.7 + 1.6) $\times$ 10^{-3} = 8.3 $\times$ 10^{-3} m and using the value of y_1 above and the same parameters as before, we get a value of s using (1) of 14.80 m.

An average baseball pitcher hurls at 40.2 m/s [7] past a batter, we assume this is the constant velocity throughout the throw, giving a time to reach the batter after the ball can be seen of $368\ \mathrm{ms}$. The average human reaction time is $\sim 215\ \mathrm{ms}$ [8]. This gives $153\ \mathrm{ms}$ for the batter to change his/her orientation quickly enough to hit the ball. It is unlikely that this will occur and so the batter would probably miss the hit.

Conclusion

We demonstrated that the blind spot is surprisingly big, able to block any small objects from the visual field. The example above only applies if one eye is closed. Of course in practise we use both of our eyes to see and as mentioned above the loss of light due to the blind spot is compensated by the other eye. Even if one eye were to be closed objects such as the baseball do not travel in a perfectly straight line but instead oscillate slightly as it travels to the batter. Nevertheless we can experience the presence of the blind spot from objects that are on a relatively straight visual line.

References

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