Effects of Focused Light on Asymmetrical Visual Search

Zoë L. Feygin

Honors Research Thesis

Department of Psychology, The University of Texas at Austin

Faculty Advisor: David Gilden, PhD

May, 2020

Acknowledgements

Thank you to everyone who supported me and assistant in writing my, heavily revised, senior thesis. In the current global pandemic, I especially appreciate the flexibility and kindness of my family, friends, and mentors. I am grateful to Dr. David Gilden for his expertise and guidance. I would also like to thank Dr. Theresa Jones who was nothing but kind and generous with her time and feedback. Thank you to Taylor Mezzarups for trouble-shooting assistance and helpful brainstorming sessions. Funding for this project came from the College of Liberal Arts Undergraduate Research Scholarship, supported by the Dr. Bailey R. Collins/Ellene Collins Ward/Mary Sue Collins Hibbs Scholarship Fund. Thank you to the CoLA department, and the Collin Hibbs family. Thank you to the 2020 psychology honors cohort for your friendship and assistance in these crazy times.

Abstract

As a result of the recent coronavirus pandemic, universities and businesses alike have been turning to virtual learning and communication. Mediating factors of visual attention are becoming more important, especially with regard to digital displays. Questions like, what is the ideal way to display information are becoming more lucrative. Other studies have established a relationship between luminance and visual search, however, no work has examined the relationship between measures of visual search (i.e. reaction time and error rates) and contrast. There is an established deficiency window in complex visual-search tasks in low luminance scenes. The goal of this study is to determine the effect of targeted lighting on accuracy and reaction time in a complicated visual search task. Participants will be assessed on their ability to locate a plain circle in a field of circles with lines through them.

Visual search asymmetries have been a key discovery in determining the nature of visual search and attention. A visual search asymmetry exists when finding stimulus X among stimulus Y functions differently than finding stimulus Y among stimulus X. Those differences can be observed in different reaction times and error rates. There have been several possible explanations for these differences. Treisman (1998) proposed that search asymmetries occur when the "easier" target has a component of a preattentive basic feature and distractors lack that feature. She posited that it was easier to find presence than absence. Levin and Angelone (2001) found evidence that the asymmetry could be caused by ability to easily categorize stimuli in a study of asymmetry of cross-race faces. An established asymmetric search, searching for a plain O in a field of Ϙ, was used for this study to simultaneously encourage longer reaction times and possibly improve asymmetrical search efficiency. While color is adjusted frequently in terms of the stimuli and distractors, the background of the visual field is usually unmanipulated.

Lighting Adjustments

Due to the anatomy of the human visual system, the clearest part of the visual spectrum occurs in the central six degrees, and the peak of clarity and color accuracy is even narrower within the central two degrees. The part of the eye responsible for that heightened clarity and color is the fovea. While our visual field is wide, it is impossible to take in all available visual information at once. As such, our eyes are constantly adjusting, or saccades, to take in the visual field and conduct search. Once the eye has to move in order to search, reaction times increase.

Inattentional blindness is when a person or participant is unaware of new things that appear in their visual field. The cross test, (Mack & Rock, 1998) was developed to induce inattentional blindness. Participants were asked if the horizontal arm or the vertical arm was longer in an image of an asymmetric cross. The dimensions of that cross changed in each trial and was centered at fixation. After a few trials, a small black square, the critical stimulus, would appear near fixation. 85% of observers failed to notice the critical stimulus. Webster, Clarke, Mack, and Ro (2018) adapted the cross procedure to determine the effect of scene luminance and color on inattentional blindness. They created scenes with canonical color, grayscale (canonical luminance), RGB inverted (non-canonical color and non-canonical luminance), and L*a*b* color-inverted (canonical luminance and non-canonical color). Participants viewed 20 scenes, 3 times each. Scenes had an asymmetric cross, from the experiment above, appear 3.2 degrees from fixation randomly assigned a quadrant. Participants were asked to press the left mouse button if the horizontal line was longer, and the right mouse button if the vertical line was longer. After the cross trial, participants were presented with a letter string. The string was either a related word, a non-related word, or a non-word. Each scene had a string follow it and participants were asked if it was a word or not. After the trials, participants were asked if they saw scenes and what those scenes were composed of. 11% were blind to the canonically colored scenes, 42% to the grayscale, 47% to the RGB inverted, and 31% to the L*a*b inverted scenes. Color and luminance effect inattentional blindness, possibly because non-canonical color and luminance are harder to process quickly. In a second experiment, the procedure was repeated without the letter string task. Participants in the second experiment were less blind to the scenes across conditions, establishing that a higher task load increases inattentional blindness.

People adjusted their search behavior to different lighting conditions (Pauln, Schultz, Geisler, & Gegenfurtner, 2015). In photopic conditions, the likelihood of accurately detecting the target increased when set gaze position was closer to the target, but in scotopic conditions probability of target detection decreased when gaze position was close to the target. Fixations, pauses in eye motion, also occurred for longer and didn't capture as much of the possible display.

Another visual search asymmetry that involves color contrast is one found by Rensink and Cavanagh (1993). They determined that an incorrect shadow in a field of upright or normal shadows can be detected more quickly than a normal shadow surrounded by upside down or incorrect shadow.

Background color of visual field has been compared to color search asymmetry by Rosenholtz, Nagy, and Bell (2004) who found that changing between chromatic to achromatic backgrounds reverse the search asymmetry between targets and distractors with different color saturations. Vries, Hooge, Wertheim, and Verstraten (2013) conducted a similar experiment with black, white, and gray backgrounds. They found that searches got faster when the target was darker than both the distractors and the background, compared to being lighter than both the distractor and the background, or between the two.

Conclusion

Lighting, luminance, and contrast, all have some bearing on visual search capabilities. The findings above don't include the possible effects of multicolored backgrounds, designed to potentially pull focus, on a complex visual search task. The Pauln study suggests that, with a darker background, reaction time could slow down if the target is placed too close to the focused light beam. In the current study, the target is always darker than the background but to varying degrees, depending on whether the target is in the lighter background beam or not. The increased contrast could theoretically decrease reaction time. This study seeks to determine how a background with color contrast effects the search strategy employed during a complicated asymmetrical search with a large set size.

Methods

Design Overview

The primary question is whether the light beam will increase reaction time and decrease error rates. The primary independent variables are the presence or absence of the target, the presence or absence of the light beam, and the position of the target, relative to the beam. The target in all conditions is an O without a line through it. The distractors in all conditions are Os with lines through them (Ọ). Possible target positions include, centered in the beam, off-centered in the beam, close to the beam, midway from the beam, and far away from the beam. The primary dependent variables are reaction time and proportion correct. I hypothesized that targets centered in the beam would have the shortest reaction times and highest proportion correct.

Detailed Methods

Participants. Participants were a coronavirus-induced convenience sample of 4, recruited through Pavlovia (Pavlovia.com), a database of public experiments similar to Amazon's Mechanical Turk. Participants can receive monetary compensation for completing experiments (equal to about 2 cents, USD). Inclusion criteria for the study included a limited age of between 18 and 50 years old, fluency in English, and either naturally perfect vison or the use of some corrective measures. Participants were between the ages of 18 and 37, with no visual impairments. M age = 25.5 SD 7.23. Two participants were excluded for reaction times above 30 seconds, and not engaging genuinely with the task.

Visual Stimuli. A screen with the text, "You will be asked to locate the empty circle in a matrix of circles with lines through them. If there is an empty circle press f. If there is not an empty circle press j. Respond to trails as fast as you can. When you are ready, press space to continue." was presented to participants. When the space bar was pressed, a grid of 11x10 possible targets/distractors appeared (target absent, no beam, condition; Figure 1). In conditions where the beam was present, the beam appeared in one of eight possible locations (all eight conditions are shown below; Figure 2).

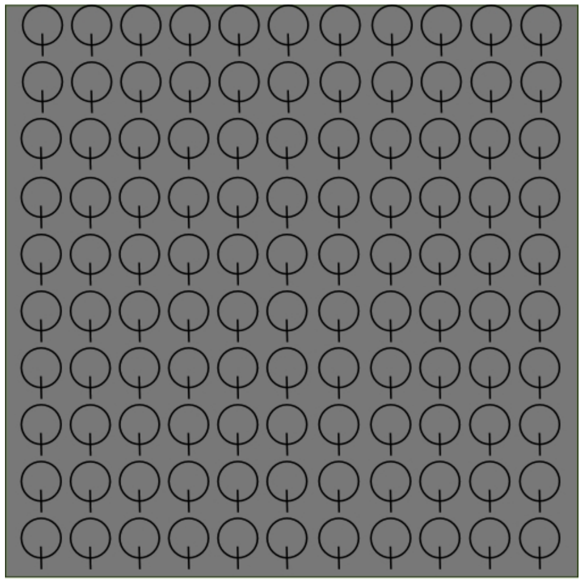

Figure 1. The Target Absent, No Beam stimulus. This stimulus composed 25% of the trials in the experiment.

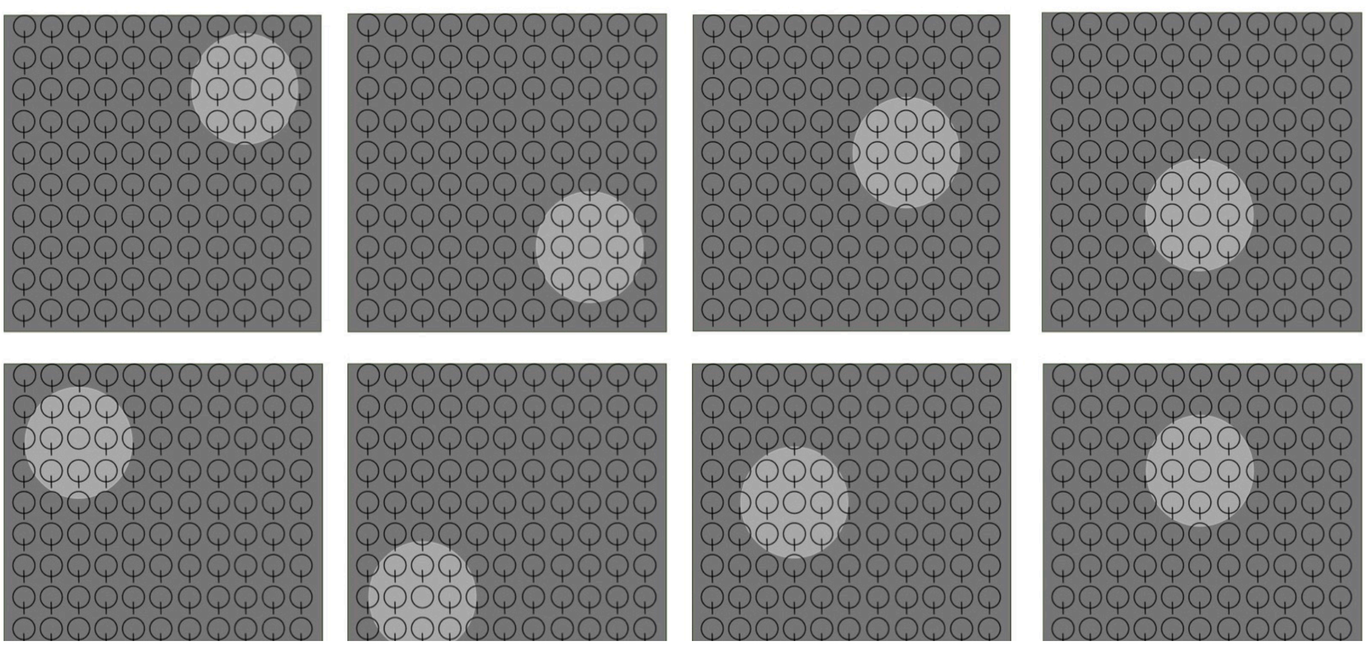

Figure 2 Target Present, Centered in Beam Stimuli. These stimuli composed 8% of the trials in the experiment.

Stimuli that are categorized as close to the beam have targets that occur in the outer perimeter of the light beam, excluding positions in which they would be partially illuminated. Stimuli that are categorized as mid-way from the beam have targets that occur at least 3 grid positions away from the beam, excluding positions where they would be on the outer edge of the grid. Stimuli that are categorized as far away from the beam have targets that occur both on the outer edge of the grid and at least 6 grid positions away from the light beam.

Procedure

After providing informed consent, participants were asked to complete a practice run of the experiment that featured 20 trials. They were shown the instruction slide, described above, and asked to press the space bar when they were ready to begin. Once they pressed the space bar, the first stimulus slide appeared in the center of the screen. Once they either located the target, and were told to press "f", or determined there was no target, and were told to press "j", they were presented with an interstimulus interval, a square of the same size and background color with a small black "+" in the center, that lasted one second. This process repeated twenty times until the practice trials had concluded, at which point they were thanked with another text slide and told to proceed to the actual experiment. In the main experiment, participants were presented with the same instruction slide and trial structure. In the main experiment there were 400 trials with breaks after every set of 100. The breaks included a slide with text, instructing participants to take a break and press the space bar when they were ready to return to the experiment. It is worth noting that the practice trials and the main experiment ran separately on Pavlovia, bringing participant compensation to around 4 cents USD.

Statistical Analysis

Data was analyzed using a single factor ANOVA (to determine the difference between the 3 outside of the beam location conditions and the within beam location. The Tukey method was used in post HOC testing, to determine the significance of differences between paired groups. Paired sample t-tests were conducted to determine the relationship between target presence and absence and beam or no beam conditions. Possibly due to the length and complexity of the experiment, there were some fatigue effects towards the end of the 100 trial blocks. If a trial was +/- 2 standard deviations from the mean and was in the last 20 trials in a block, it was excluded from analysis.

Results

Figure 3 illustrates that reaction time was significantly lower when the target was located within the beam and trials where the target was located either close to the beam, midway, or far away ($F(3,1124) = 34.95$, $p < .00$). Tukey post HOC testing indicated that the only relationships with significant differences were between the in beam condition (M = 1.05, SD = 0.43), and each of the out of beam conditions; close (M=3.41, SD = 1.63), midway (M = 3.97, SD = .71), and far away (M = 3.91, SD = 1.58). This pattern of significance stayed constant when comparing the error rates of these groups (See Fig. 4). Error rates were significantly lower when the target was located within the beam, compared to one of the three out of beam conditions ($F(3,1124) = 8.49$, $p < .00$). Tukey post HOC testing showed that the only relationships with significant differences were between the in beam condition (M = .94, SD = 0.23) and each out of beam conditions; close (M = .52, SD = .51), midway (M = .36, SD = 0.50), and far away (M = .53, SD = 0.51). No significant difference was found between target absent beam and no beam reaction time (p = .31) or error rate (p = .07), shown in figure 5. In target present trials, there was also no significant difference between reaction time for beam and no beam conditions (p = .48), but there were significantly more errors in the no beam condition (M = .27, SD = 0.46) than the beam condition (M = .67, SD = 0.47), shown in figure 6.

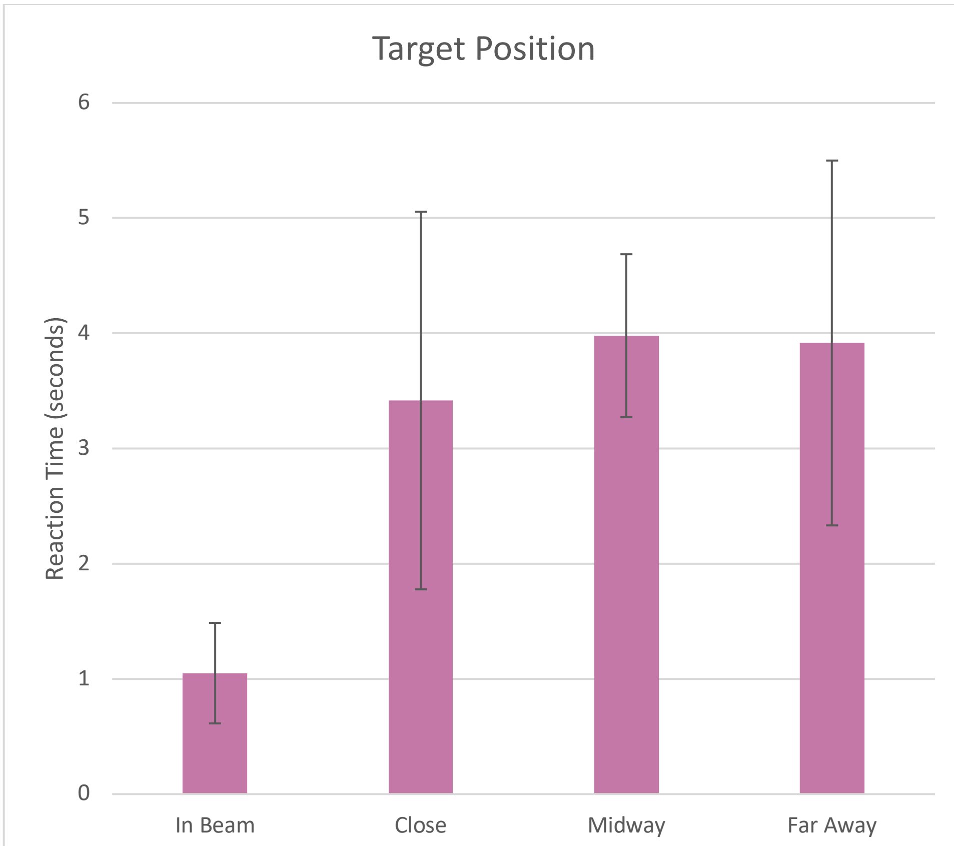

Figure 3 Mean reaction time of target positions. Error bars represent standard deviation.

Figure 4 Proportion correct for target positions. Error bars represent standard error.

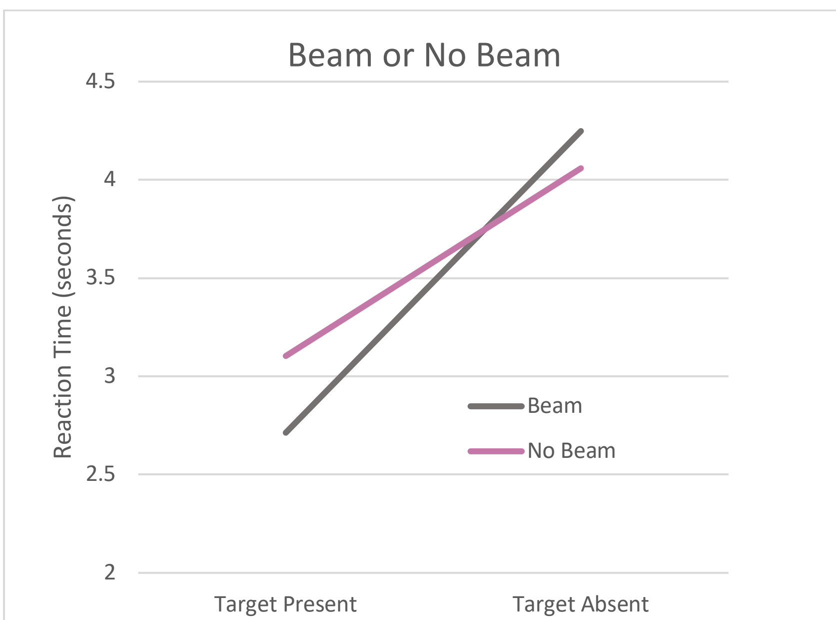

Figure 5 Presence of beam in target present or target absent trials on reaction time

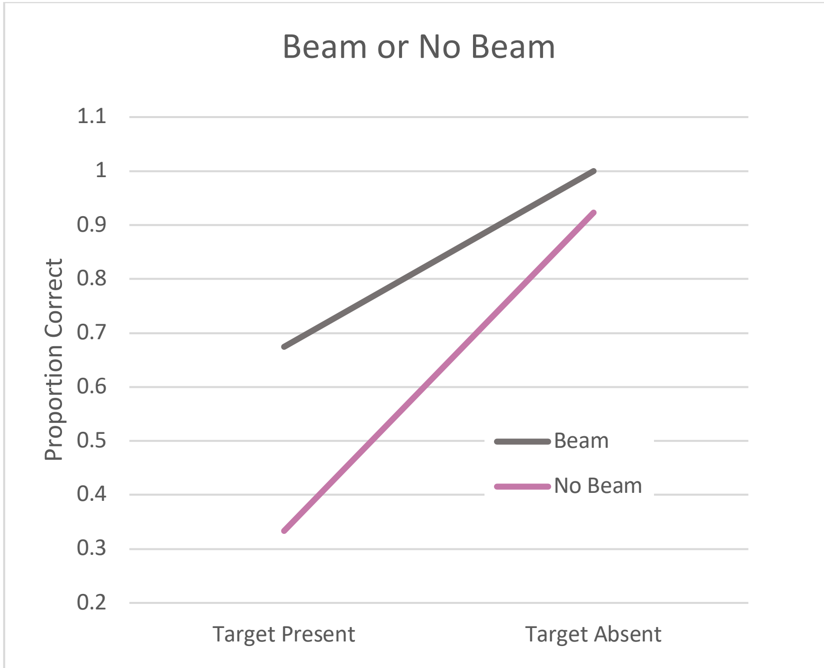

Figure 7 Presence of beam in target present or target absent trials on proportion correct

Discussion

The presence of the light beam did alter search patterns, but not as much as expected. Preliminary data showed a pattern of increasing reaction times as the target moved farther away from the beam, but as more participants were added those effects were lost. It was expected that the light beam would anchor search patterns to that part of the visual field, however, it is possible that people were able to effectively disregard the light beam once it was determined that the target wasn't in the central 3x3 grid. Adding a measure of eye tracking to this study would be a more accurate determiner of the revised search patterns. The main difference, that a target within the beam decreased reaction times and improved accuracy, is consistent with past research. Error rates do indicate that participants were not searching exhaustively, as they would have spent more time confirming the presence of the target and improving their proportion correct. Reaction times did increase significantly in target absent trials, however they were not affected by the presence or absence of the beam. The error rates potentially show a strong "absent" response bias, as the target absent trials did have significantly fewer errors than the target present trials. It is possible that the search task was complicated to the point where it discouraged participants from spending the requisite amount of time looking for the target. This result is most likely due to the small sample size, but it is worth altering instructions to find the correct speed/accuracy trade off in the future.

References

De Vries, J. P., Hooge, I. T. C., Wertheim, A. H., & Verstraten, F. A. J. (2013). Background, an important factor in visual search. *Vision Research*, 86, 128–138.

Mack, A., & Rock, I. (1998). Inattentional blindness: Perception without attention. In R. D. Wright (Ed.), *Visual Attention.* (pp. 55–76). New York, NY: Oxford University Press.

Paulun, V. C., Schütz, A. C., Michel, M. M., Geisler, W. S., & Gegenfurtner, K. R. (2015). *Visual search under scotopic lighting conditions.* Vision Research, 113(Pt B), 155–168.

Rensink, R. A., & Cavanagh, P. (2004). The influence of cast shadows on visual search. Perception, 33(11), 1339–1358. https://doi.org/10.1068/p5322

Rensink, R. A., Cavanagh, P, 1993 "Processing of shadows at preattentive levels" *Investigative Ophthalmology & Visual Science* 34(4) S1288.

Rosenholtz, R., Nagy, A., Bell, N.; The effect of background color on asymmetries in color search. *Journal of Vision* 2004;4(3):9.

Treisman A. Feature binding, attention and object perception. Philos Trans R Soc Lond B Biol Sci. 1998;353(1373):1295-1306.

Webster, K., Clarke, J., Mack, A., & Ro, T. (2018). Effects of canonical color, luminance, and orientation on sustained inattentional blindness for scenes. Attention, Perception, & Psychophysics, 80(7), 1833–1846.