# Modeling the Attentional Capture of Color in a Visual Interface Design

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Introduction:

Color plays an important role in many aspects of visual cognition. Colors create boundaries between objects, convey meaning, and are associated with moods. When humans are first born and their eyes open, they are exposed to colors for the first time, and simply put, every experience in their life involves color in some way. Everywhere we look, we see color, and the process of this perception is extremely interesting due to the machinery in our eyes and brain that is able to process it. When light hits an object, some frequencies of that light are absorbed, while others are reflected. The reflected light then hits our eyes and stimulates photoreceptors in our retina. The three photoreceptors that detect color are the short-wave cone, which responds to blue, the medium-wave cone, which responds to green, and the long-wave cone, which responds to red. Based on the intensity with which each of these receptors is activated, the relative colors are superposed in a way that allows for all the colors perceivable by humans to be made with a different combination of the activation of each of the cones.

Color is important to the human experience for many different reasons. These aspects have been studied in a field known as color psychology. Color psychology states that color can influence the perceptions of objects unconsciously without people being aware of those qualities (Elliot & Maier, 2014). Like stated before, colors are used to convey meanings and are associated with moods. For example, the color red is associated with anger while the color blue is associated with sadness (Elliot & Maier, 2014). Color psychology has now been adopted by marketing and branding as a way to influence consumers' reactions and emotions to products or companies. For example, the logos of many fast-food restaurants include the colors of red and yellow, since these are colors that are said to stimulate and increase appetite. Green, on the other hand, has associations with being healthy and good, unlike most fast foods, so fast-food or fast-casual restaurants that want their consumer perception to be that they are healthier than competitors or eating at their establishment will be healthy for them, include green in their logo. Such is the case for Subway and Sweetgreen, just to name a few. Social media companies also utilize the importance of color to their perception. It is not hard to find a social media company that has blue in its logo. In fact, most do. Companies such as Facebook, LinkedIn, Zoom, and Skype all use blue in their logos as the color apparently elicits a feeling of trustworthiness, which is very important to social media sites as a place that disseminates news and information to a large audience (Elliot & Maier, 2014).

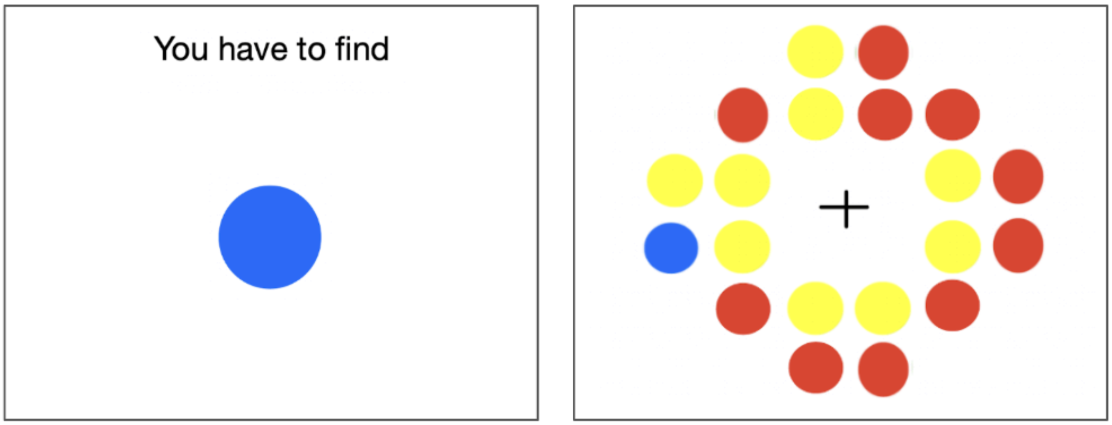
The scientific merit of this study does not stop at its focus on colors, its focus on visual interfaces also is very important in today’s technological climate. The use of computer technology grows ever bigger as analog and physical measures (barometers, gauges, etc.) are being phased out to computer-integrated systems with computer screens (Andersen & Maier, 2017). Therefore, it is important that the design of these objects are efficient, clearly defined, and easy to find (Andersen & Maier, 2017). Because of these reasons, the investigators sought to find out if different colors commanded a different attentional capture.

The researchers proposed two different hierarchies that might explain the differences in color attention. The first hierarchy is called the Perceptual-Primacy account. In this account, primary colors are hypothesized to have a higher attentional capture than secondary colors (Andersen & Maier, 2017). There are also two definitions of primary colors. There are the artistic primary colors based on pigments and color theory and those are red, blue, and yellow. The artistic secondary colors are orange, green, and purple. The second group of primary colors are the biological primary colors which are based on the cones in the eye and are red, blue and green. The biological secondary colors are orange, yellow, and purple. The second hierarchy is called the Emotional-Conveyance account which hypothesizes that warm colors (red, orange, and yellow) will command a higher attention than cool colors (green, blue, purple) (Andersen & Maier, 2017). This is assumed because warm colors are associated with action moods, while cool colors are associated with soothing or relaxing moods (Andersen & Maier, 2017).

We also generated two more potential hierarchies for color attention. The first we termed as environmentally relevant colors. We hypothesized that colors with a high relevance to our environment (red, green, yellow) would command attention better than colors that have a low relevance to our environment (orange, blue, and purple). The way these colors were decided was by looking at colors currently used in our environment that we pay attention to. For example, red, yellow, and green are used in traffic lights as well as red and green being used for exit signs. The second hierarchy we propose is based on colors that humans have been evolutionarily disposed to notice. We hypothesized that colors that may have been crucial to survival would command more attention than other colors. The evolutionarily-important colors are red, green, yellow, and orange, while the unimportant colors are blue and purple. We classified these colors in their place because red is the color of blood and berries (both poisonous and non-poisonous). Green is the color of trees and plants and can signal shelter. Yellow and orange are the colors of fire. Blue and purple are known as not being found in nature very commonly.

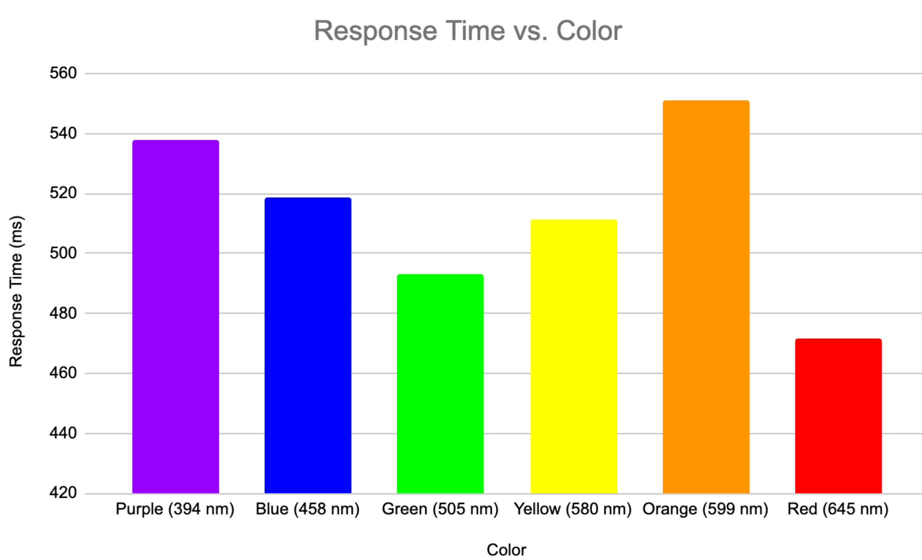
Experimental Design:

The experimental design we attempt to model is a visual search of a pattern of 20-colored dots. The participants were told to search for a single circle in the pattern that had the target color. All other 19 dots were of different “distractor” colors. The participants would press a button indicating that they had found the target color. What was being experimented on was how the response time changes with a change in the target color. The independent variable was the set of colors (red, orange, yellow, green, blue, purple) while the dependent variable was response time.

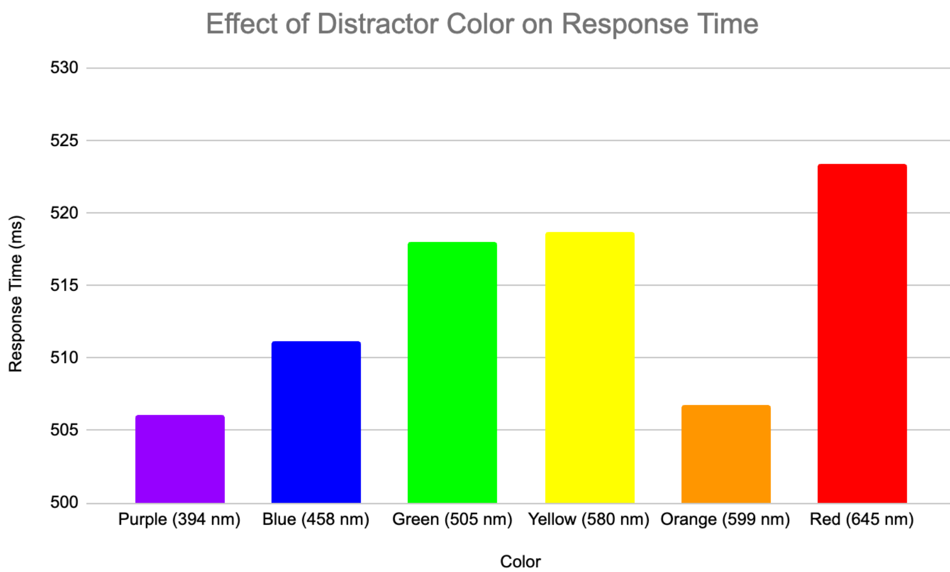



<u>Results:</u>

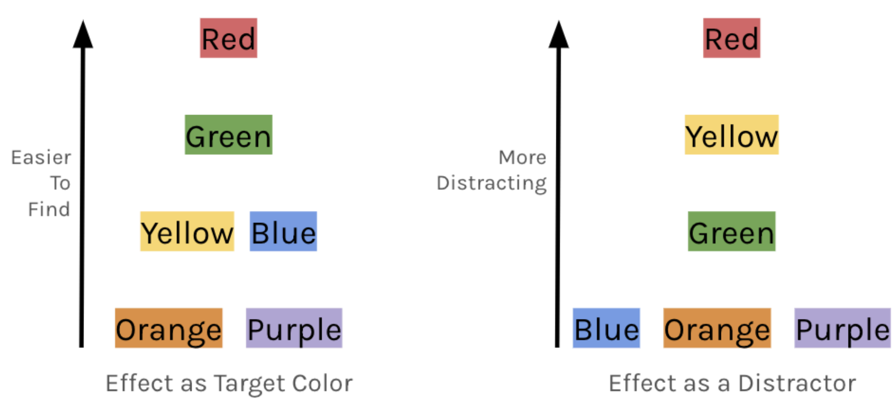
The researchers found that red was the color that was found the fastest, while orange was the color that was found the slowest.



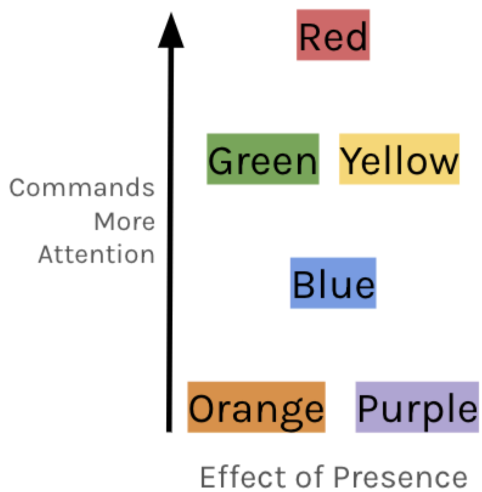
The researchers also did an analysis on how the presence of certain distractor colors affected response time and found that red was a more distracting color than colors such as orange and purple.




Based on these results, we created two sets of color hierarchies, each based on a different paradigm of the results. One hierarchy is based on the effect of the color as the target color, while the other is the effect of the color as a distractor.

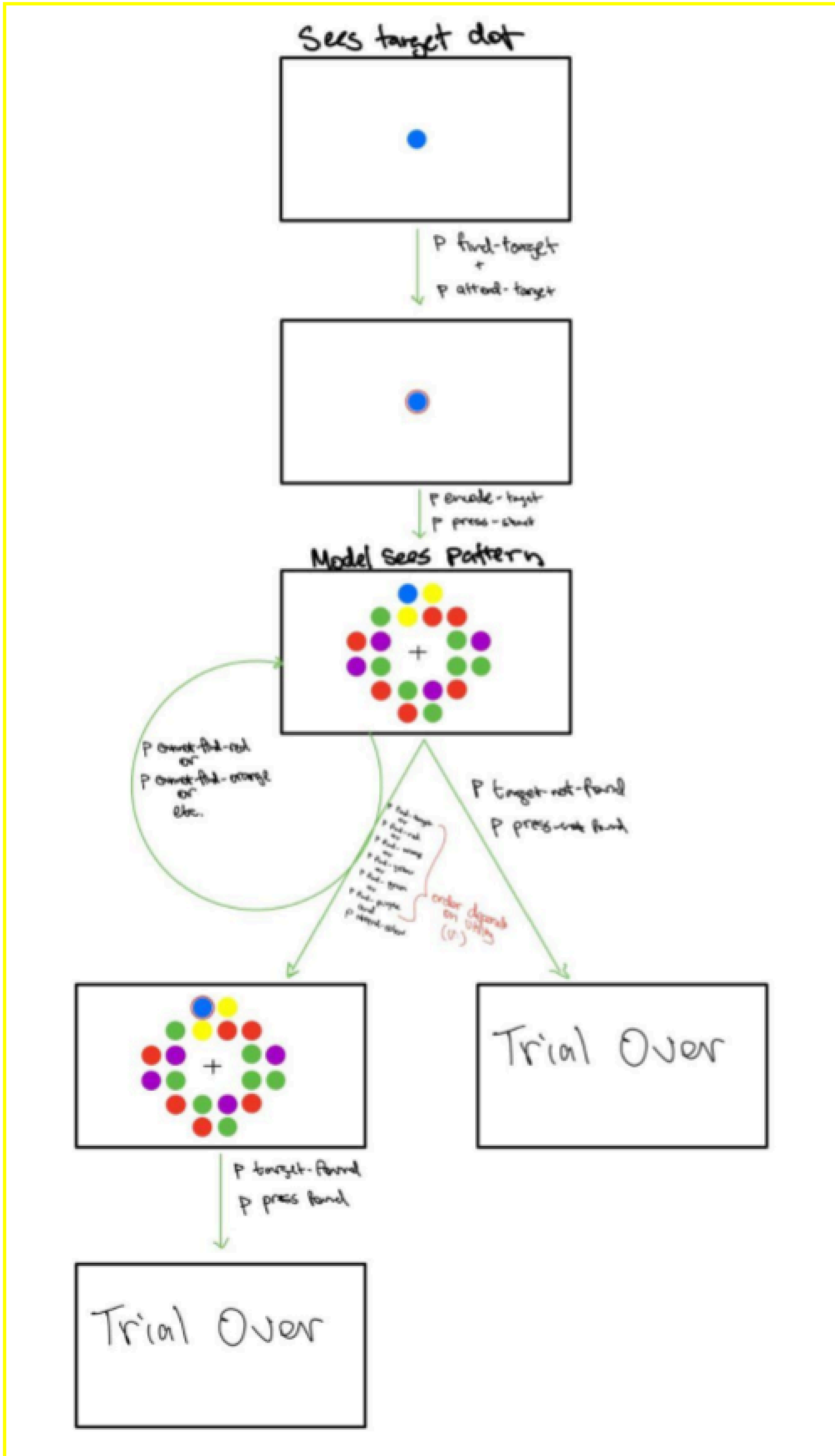


Once we had these two hierarchies, we combined them to make a single hierarchy that ranked the colors in terms of how they commanded attention. This is the hierarchy that we will be implementing into ACT-R to model the results found in the study.




<u>Description of the Model:</u>

Our model is done in ACT-R due to the ability of ACT-R to do production conflicts, utility matching and focus attention on different environmental factors. We coded in our model the ability to participate in this experiment. It is able to look around a screen, search for a target color and press buttons to indicate whether the target color is present or not. We also included a production for searching for each particular color (ex. find_red, find_yellow) as well as a production that searches for the target color (find_target). Ideally, the model (and humans) would just do the find_target production, due to production conflicts with the other find_(color) productions, they may get distracted and look at a different color.


Sees target dot
P find-target
+
P attend-target
P encode-target
P press-start
Model sees Pattern
P target-not-found
P press-not found
P target-found
P press found
Trial Over
Trial Over

This is how we hope to garner the results that were found in the Andersen & Majer paper that our project is based on. If red is the target color, only yellow and green can distract it. Blue, orange, and purple cannot. If yellow or green are the target color, they can be distracted by each other, as well as red and sometimes blue. Orange and purple cannot distract yellow or green. If blue is the target color, it can be distracted by red, yellow, and green, and could maybe be distracted by orange and purple, though it is not unlikely. Orange and purple can be distracted by all colors. Once the model finds the target, it will press a button signifying that the target color was found and that it can move onto the next trial.

Our model differs from the original experiment in that our pattern consists of 20 squares, not 20 dots/circles. This is because this change does not matter for encoding color for ACT-R purposes. Also, the environment swapped out orange for the color black. This is because orange was unable to be added to the environment. Nonetheless, the black squares get encoded as orange, so there is no change to the actual model. We also increased the number of finsts to 20 so that the model does not go in an endless loop of searching the same color over and over again.

We originally wanted our model to work more like how the eye works in that its focus would be centered on the middle of the screen and move to the dot with the highest salience (commanded the most attention) first. This is because the eye of the participant would be drawn to the color of that dot. Then the model would do a check to see if that was the target color. If not, the model would move to the neighbor of the dot with the highest salience. Then it would check if that dot was its target. This cycle would continue until the target color was found. This method would have been really hard to implement into ACT-R because the model would have to know the relative salience of the colors beforehand.

(P find-target; this initializes the goal to correct values, and loads the visual location into the buffer

(P attend-target; this focuses attention onto the target dot

(P encode-target;this loads the target into imaginal and goal

(p press-start;this presses the space button once the target is found and encoded to imaginal

(P find_target;This attempts to find the target dot within the visual search space

(P attend_color; This production attends the color found in the previous step, by focussing attention onto the dot found in the previous step

(p cannot-find-(color); if the visual search for the red dot fails, it registers into goal that the color is not present, and continues the visual search of the space

(p cannot-find-target;if the visual search for the target dot fails, it registers into goal that the target is not present

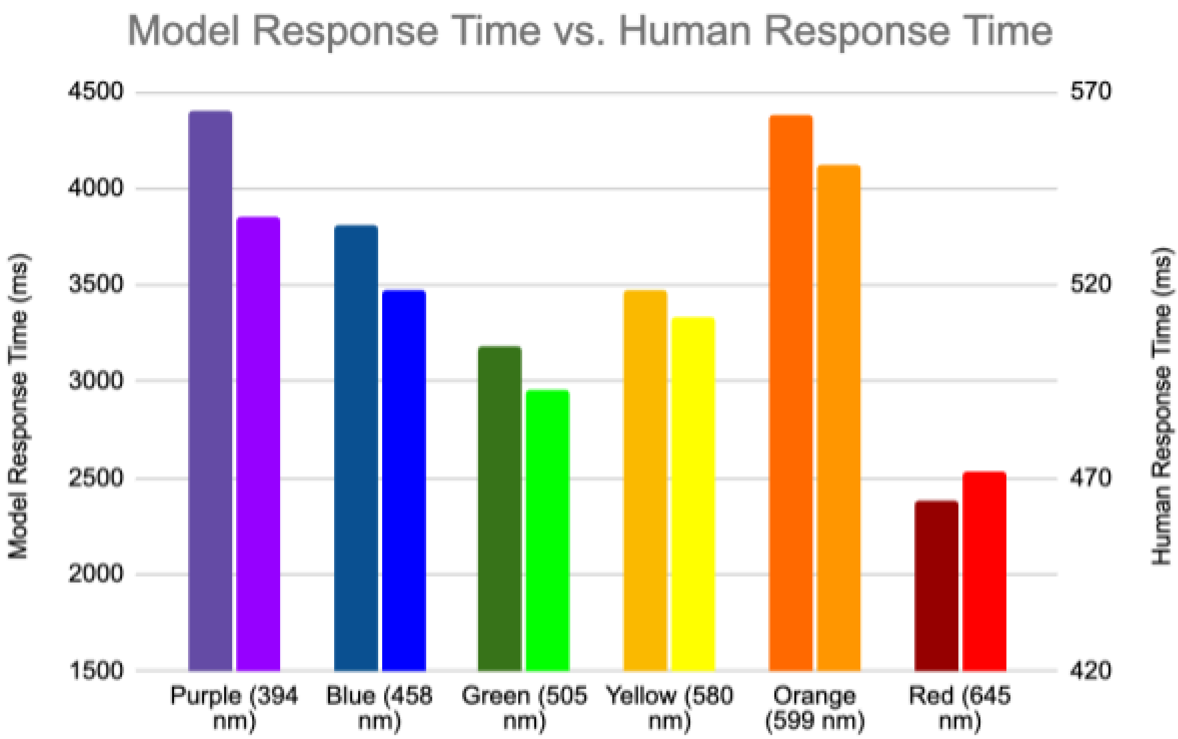
(p target_found;if the target is found, it moves on to choose what button to press

(p target_not_found; if the target is not found, it moves on to choose what button to press

(p press-found; presses p if target is found

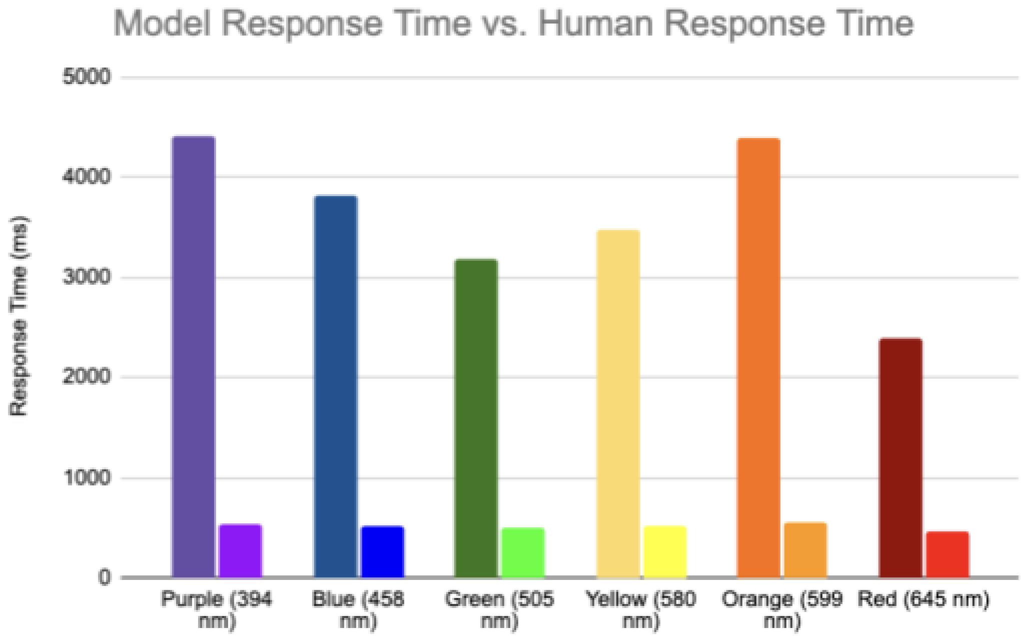
(p press-not-found; presses q if target is not found

Results:




*Model Response Times are the left bars for their respective color and refer to the left y-axis while the Human Response Times are the right bars and refer to the right y-axis

Though our model's time in completing the trials were slower than the human participants, they showed the same pattern in the order of colors that they were found in (bar one exception). The one exception is that the model found purple slower than orange (though their times were very similar). The times, however, did fit the hierarchy we made. The correlation between the two data sets was 0.98 and the mean deviation of the model's data is 590.44 compared to the mean deviation of the model's data which is 21.91, though it is important to mention that our data points are of a higher magnitude than the human data, because our model performs the visual search less efficiently than humans.




This is the graph showing how large the magnitude of our model's data was in comparison to the human data

Discussion:

Our model did many things well. For example, it was able to get distracted by colors that commanded attention more. Another thing that it also did well, which is analogous to humans is that it could go back and forth between colors. There are some instances where the model would look at all the circles of a color with a higher salience and then move on to the next color in an iterative way but there was also some instances in which it would only look at a few of the dots of one color before moving on to another color and going back and forth between colors. Our model also seemed to find the colors in the order of the hierarchy we created on page 8. Another thing that it did well was that it was able to encode what the target color was.

Some insights of the model include how errors are handled. The model incorporates error-handling mechanisms in that if it fails to find a target, it clears the visual buffer and continues searching. Another insight is resource allocation in which our model allocates resources differently for searching for different colors, suggesting that it can remember multiple aspects of its search strategy which allows it to not fall into a dangerous cycle that stalls the model.

Some areas for improvement could be making the outputs more efficient and faster. The response times in the paper were less than a second and hovering around 500 milliseconds. Our best runs of the model had the fastest response time around 2 seconds. Another area for improvement could be a more organic search strategy. Even though in the original experiment, the subjects' eye movements were tracked, the researchers neglected to include that in their paper. Thus, we are unable to know how the subjects traversed their way through the pattern. If we knew their search strategies, or the most common one, we would more likely be able to encode that into ACT-R and possibly get a response time closer to the results from the paper. Some areas of further research is to look at how varying the size of the dots can affect response time too. Also, there are more colors than the 6 that were tested on since color is a spectrum. There could be other colors or shades or tints of colors already tested that elicit a better response time than those tested on in this experiment.

# References

Andersen, E., & Maier, A. (2017). *The attentional capture of colour in visual interface design: a controlled-environment study*. DS 87-8 Proceedings of the 21st International Conference on Engineering Design (ICED 17) Vol 8: Human Behaviour in Design, Vancouver, Canada, 21-25.08.2017. https://www.designsociety.org/publication/39870/The+attentional+capture+of+colour+in+visual+interface+design%3A+a+controlled-environment+study

Elliot, A. J., & Maier, M. A. (2014). Color Psychology: Effects of Perceiving Color on Psychological Functioning in Humans. *Annual Review of Psychology*, *65*(1), 95–120. https://doi.org/10.1146/annurev-psych-010213-115035

# Appendix

The way to download our code is to have the color_task.py and the subash-ismail.lisp file. The subash-ismail.lisp file may have a number attached to it, but that shouldn't matter. To run a trial the code is color_task.trial(). If you just want target-present trials, the code is color_task.trial(#,1,True) where # is the number of trials you want to see. If you want target-absent trials, switch the "True" to "False". To run the experiment, you should run color_task.experiment(). Again, to get only target-present trials, the code is color_task.experiment(1,True). This will run 360 target-present trials. If you'd like to change the number of trials, go to the environment and search up "def setup_trials" and you can change the number of trials for the target-present condition. If you'd like target-absent trials, again change the "True" to "False". The ACT-R architecture is needed - it can be downloaded online.