Computational Models - Portfolio 1 - Eye-Tracking Analysis

Visual Search Experiment

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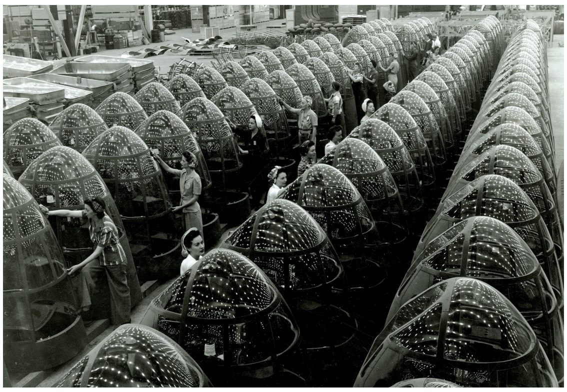
Link to Github:https://github.com/Carolinecasey17/ComputationalModels.Portfolio1.VisualSearch.git

Introduction

In the visual search task we investigated how eye movements would differ across two conditions. In one condition the participant was required to complete a visual search with an ambiguous star shape placed on a complex picture containing repeated elements, EG. repeated sheep (see *Figure 1)*. In the other condition, the participant was required to count the elements in the image, EG. pods (see *Figure 2)*. In this paradigm we were interested in seeing the effect of the conditions on the duration of fixations from the participants. In the counting task, it was hypothesised that there would be short fixations that would move in a systematic pattern over the screen. It was hypothesised that the visual search for the star would result in longer fixations than the counting condition. Aside from the hypotheses, it was speculated that we would see a different search pattern in the visual search condition from the counting condition. The counting condition would likely show shorter saccades moving over shorter distances, whereas the visual search condition would show larger jumps in the saccades, with less search structure, following a foraging pattern (Rhodes, Kello & Kerster, 2014).

Figure 1 & Figure 2 - examples of experimental stimuli



Design

The experiment consisted of 5 pictures for each condition, 10 in total. The participants were dealt into one of two different sequence conditions, one in which they were presented with the visual search task first, then the counting, or vice versa. The participants were randomly allocated to one of these two sequences. The pictures were in the same order for all experiments. The pictures were shown for 20 seconds each, with a fixation cross presented between each trial.

Participants

In the Visual Search Experiment there were 6 participants (female = 4). This experiment did not automatically exclude participants who were wearing glasses, contact lenses and eye makeup.

Apparatus and Material

For the experiment an Eye Link 1000 head mounted eye tracker was used. The eye-tracker recorded at 1000 Hz, tracking monocular eye positions and pupil sizes. The eye tracker was linked and synchronized with a second computer. The second computer ran a PsychoPy (Peirce, 2007) implementation of the paradigm. Furthermore, the second computer continuously recorded time stamps from the initiation of stimuli exposure.

Additionally, the eye tracking data were automatically pre-processed, using the in-built DataViewer software. Pre-processing in this software included the removal of artefacts and the recording of eye blinks, saccades and fixations were identified.

Procedure

Screening

Before initiating the experiment, the participants were pre-screened for potential issues. Issues which could affect the sampling rate consisted of eyeglasses, contact lenses and cosmetics. However, if the participants had any of these troublemakers, they were still allowed to continue onto to calibration. If the machine could still calibrate effectively, they were allowed to participate.

Procedure

The participant entered a classroom mainly lit by means of artificial lighting, with minimal natural light. Next, the participant was seated in front of the eye tracker, with their chin placed on a head mount. For optimal eye tracking, the participant was seated comfortably, approximately 70 cm away from a 30 inch computer screen.

Before the experiment could begin, the eye tracker had to be calibrated with the participant. The eye tracker was calibrated using the Eye Link 1000's in-built nine-point automated calibration procedure. The calibration procedure was repeated until the validation procedure reported average errors below 1 and max error below 1.5.

After calibration, the PsychoPy script was started, and the experiment commenced. The participants were presented with written instructions for the task on the screen. After having read and understood the instructions, they could continue to the experimental paradigm.

In the visual search condition, the participants were shown 5 different pictures and were asked to find a small ambiguous star in the pictures. The participant had 20 seconds to find the star before the picture was changed to a new one. In the counting condition, the participants were required to count out loud as many figures/objects as possible in the 20 seconds the picture was presented.

Results

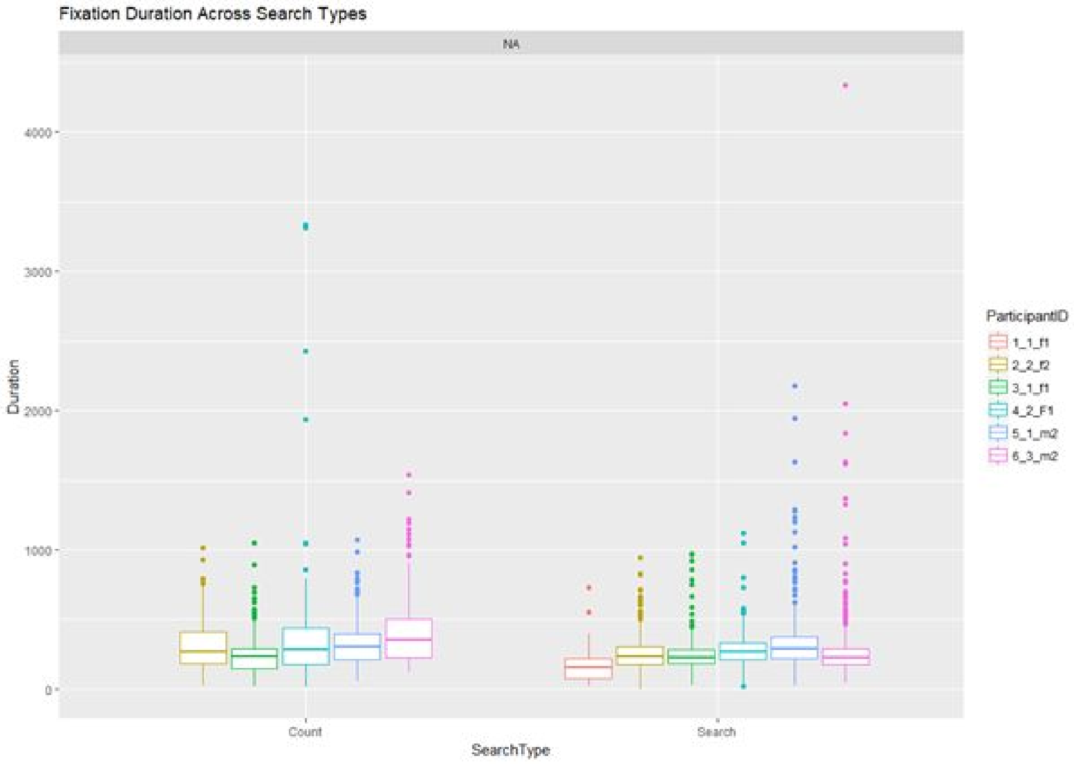
After the data was pre-processed, the duration of fixations was analysed. To analyse the data we built various models and performed a three-fold cross-validation analysis to test which model performed best.

See the results below:

Equation	Mean RMSE
Duration ~ SearchType + (1+SearchType|ParticipantID) $Duration \sim \beta_{0par} + \beta_{1par}SearchType + \varepsilon$	190.929
Duration ~ SearchType + Trial + (1+SearchType + Trial|ParticipantID) $Duration \sim \beta_{0par} + \beta_{1par}SearchType + \beta_{2par}Trial + \varepsilon$	191.1428
Duration ~ SearchType*Trial + (1+SearchType + Trial|ParticipantID) $Duration \sim \beta_{0par} + \beta_{1par}SearchType + \beta_{2par}Trial + \beta_{2par}SearchType * Trial + \varepsilon$	191.3657

The above table shows the mean RMSE of the models after cross-validation. There is very little difference in RMSE, making this process in the analysis of little use in revealing the best model. However, model 3; Duration ~ SearchType*Trial + (1+SearchType + Trial|ParticipantID) showed a significant effect of Search Type ($p = .0256$, $\beta = -113.35$, se. = 36.23), whereas the other two models did not show any significance. Therefore, we have chosen it as the best performing model. This shows that there was significantly longer fixation duration in the Visual Search task compared to the counting task. We visualised the differences in fixation duration across both conditions in a box (see Figure 3).

Figure 3 - Box plot of duration of fixations in both counting and searching condition



We also visualised other results, using scan paths and heat maps to track the differences in search patterns across conditions. This allows us to compare differences in search patterns and saccades across the conditions.

See below:

Figure 4 - Scan path in the counting condition

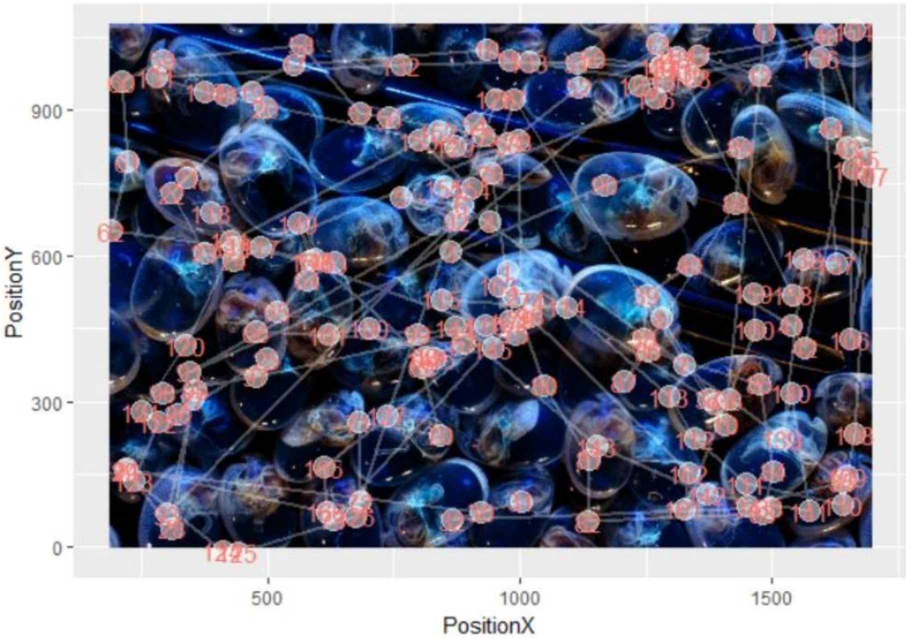


Figure 5 - Heat map in the counting condition

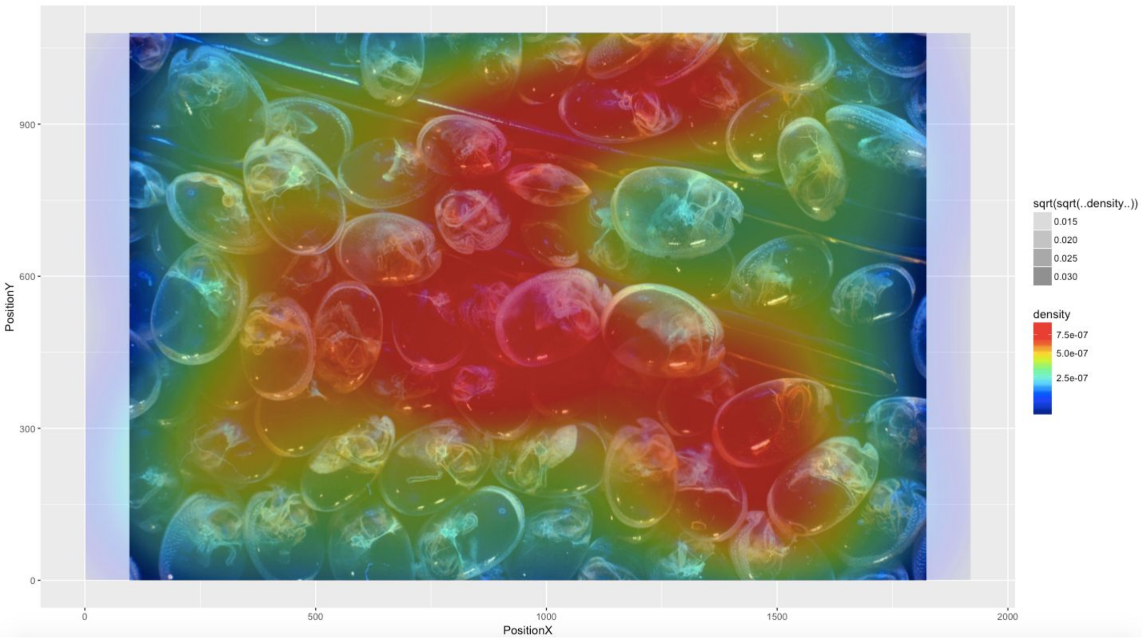


Figure 6 - Scan path for Visual Search condition

Figure 7 - Heat map for Visual Search condition

Discussion

The experimental hypothesis that the visual search condition would reveal a longer fixation duration than the counting condition was confirmed in our results. Fixation duration was significantly longer in the visual search condition compared to the visual counting task. Furthermore, it was speculated that we would see different visual search patterns in the scan paths depending on the conditions. This is also evident; *Figure 4* shows a scan path pattern of the counting condition, where we can see the eye tracks over a large range of the screen, and systematically moves from one individual stimulus to the next. In *Figure 6* we see the eye tracks less systematically over the stimuli, and instead is more concentrated in certain areas, often jumping larger distances between search spots. This follows a foraging pattern, as described by Rhodes & Bryan (2014). We can also see in the heat maps that there is a difference. *Figure 5* shows how the gaze is more centrally concentrated on the image in the counting condition compared to the visual search (*Figure 7*), which is fixated higher on the image. This may be due to that it is easier to find the stimulus in the sky than amongst the sheep, although we do see the gaze does search in the sheep.

In conclusion, eye tracking was used to explore the differences in fixation duration and search patterns across two different visual tasks, a search task and a count task. Our hypothesis that the visual search would result in longer fixation durations was supported through the analysis. However, it would be good to replicate this experiment with more participants to hopefully produce more conclusive results, as the cross-validation had little to show, and the results were quite shaky.

References

Peirce, JW. (2007) PsychoPy - Psychophysics software in Python. J Neurosci Methods, 162(1-2):8-13

Rhodes, A., Kello, Christopher., Kerster, Bryan. (2014). Intrinsic and extrinsic contributions to heavy tails in visual foraging. *Visual Cognition*, Vol. 22, No.6, 809-842.