Report: Visual Search

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Introduction and theory

As cognitive scientists we care about the eye-mind hypothesis, in which we theorise that eye movement can reflect specific cognitive processes. Therefore, using eye-tracking technology, it is possible to test models of cognition empirically and use it to infer knowledge about mental states.

In 1967, Alfred Yarbus published his book "Eye Movements and Vision" (2013), in which he discovered that a person's eye movement was not solely dependent on the information in a picture. Rather, it was also influenced by 1. the task that the person was facing and, 2. the information that the person would hope to gain from the visual scene.

When a person is being tasked to scan the visual environment for a specific object (do a visual search), then the eye movement is both driven by bottom-up and top-down like processes. A study done by Rhodes, Kello, & Kerster (2014) proposes a similar type of processes. The *extrinsic* (similar to the concept of bottom-up) and intrinsic (top-down) factors. Rhodes found these to contribute in explaining scanning patterns in visual search tasks (Rhodes, Kello, & Kerster, 2014).

In other words, the scanpath of the eyes is influenced not only by extrinsic factors such as the given task and the stimuli presented on the screen. It is also influenced by intrinsic values or goals that the participant is given or brings to the table.

We expect scanpaths to differ depending on the amount of intrinsic and extrinsic factors in the given experimental setup. In this experiment, we do not expect any intrinsic differences between conditions: Afterall, this is a within-in participant design.

However, we are manipulating the amount of extrinsic influence. A task in which participants are asked to count key objects in an image relies heavily on the content of the image - an extrinsic factor. In the other task, however, the participant is searching an image for a random, out-of-place target. In the latter setup the image does not contribute information for the participant in his goal of finding the target, and is thus less extrinsic.

We will investigate how variables like saccade amplitude, velocity of saccades, and duration of fixation will differ depending on the task at hand, as suggested by the original study (Rhodes, Kello, & Kerster, 2014).

Hypotheses

We expect that the more extrinsic nature of the counting-task will influence in the gaze patterns. We expect different gaze-patterns for the two conditions: Find target-task versus counting-task.

The gaze-pattern is investigated through four different measures:
1. Saccade amplitude, 2. velocity of saccades, 3. duration of fixations.

So, what do we expect to find from these?

H1. Saccade amplitude
We expect to find more visual foraging in the *find target*-task relative to *count object*-task. We thus expect to finder longer saccades - higher saccade amplitudes - in the *find target*-task relative to the *count object*-task. This stems from previous literature on Levy-walks used in visual foraging.

The *find target*-task is less extrinsic than the *count object*-task. The tasks are equal in terms of demand related to task. However, the *count object*-task relies heavily on the content of the stimuli - the participant is counting the crucial objects of the image. Whereas, in the *find target*-task, the little star that is search does not actually have relation to the image. Therefore, the participant does not gain helpful information in finding the star from the semantics of the image.

H2. Velocity of saccades
We expect the velocity of saccades to be lower in the *find target*-task relative to the *count object*-task. In the latter task the goal for the next fixation is known and planned in advance. Thus we can expect high velocity. Whereas more aimless browsing is required in the former, requiring relatively low velocity.

H4. Duration of fixations
We expect there to be a difference in duration of fixation: The browsing associated with searching for the star is expected to be associated with shorter fixations.

Experimental design

A. Participants
Participants in the experiment were [how many?Possibly 12] Cognitive Science-students during an eye-tracking workshop in 2018 and 2019.

B. Stimuli

The stimuli presented in the experiment consisted of 10 images from National Geographic's 'Photo of the Day'-website. Each image was presented to the participant for 45 seconds.

C. Conditions

The experiment is a within-participant setup: Each participant were assigned 2 conditions - first 5 trials of one condition, and then changing condition. The order of conditions were shuffled across participants. Likewise, which images appeared in which condition was shuffled, too.

The two condition-tasks were:

1) The 'Count Objects'-task. The participant is counting the objects prevalent in the cluttered image

2) The 'Find Target'-task. The participant is searching a cluttered image for a small, white star

Above: Example of stimuli-image. In the 'Find target'-task the participant will search the image for a small star (same target for all stimuli). For the "Count N"-task the participant will count the amount of sheep in the picture (different object for each stimuli).

Relating the hypotheses

The first condition allows us to investigate eye movement during natural visual search, where the participant is not restricted to look at specific areas of the screen. In this way, we can see if differences can be explained in terms of intrinsic factors.

The second condition is a more stimulus driven design, as the participant has to look at specific objects on the screen. This allows us to investigate if differences can be explained in terms of extrinsic factors.

Preprocessing of data

The preprocessing of the data consisted of the following points.

A. Preprocessing in DataViewer

The eye-tracking data (x/y coordinates,velocities and pupil size) were automatically pre-processed using the in-built DataViewer software. Artefacts were removed. Eye-blinks, saccades and fixations were identified.

B. Estimating error

Validation error was used to exclude participants and model measurement error.

C. Filtering out target-finders

Filtering was used on fixations longer than six seconds to exclude whenever a participant found the star in the 'Find Target'-task.

D. Scaling

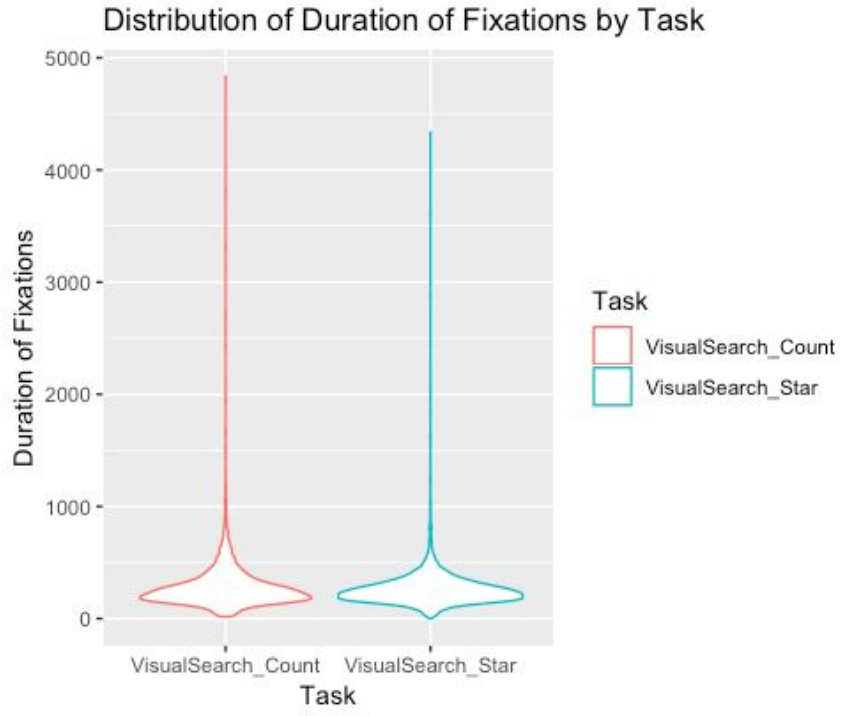
Fixation duration and start time were scaled

E. Investigating the data using plots

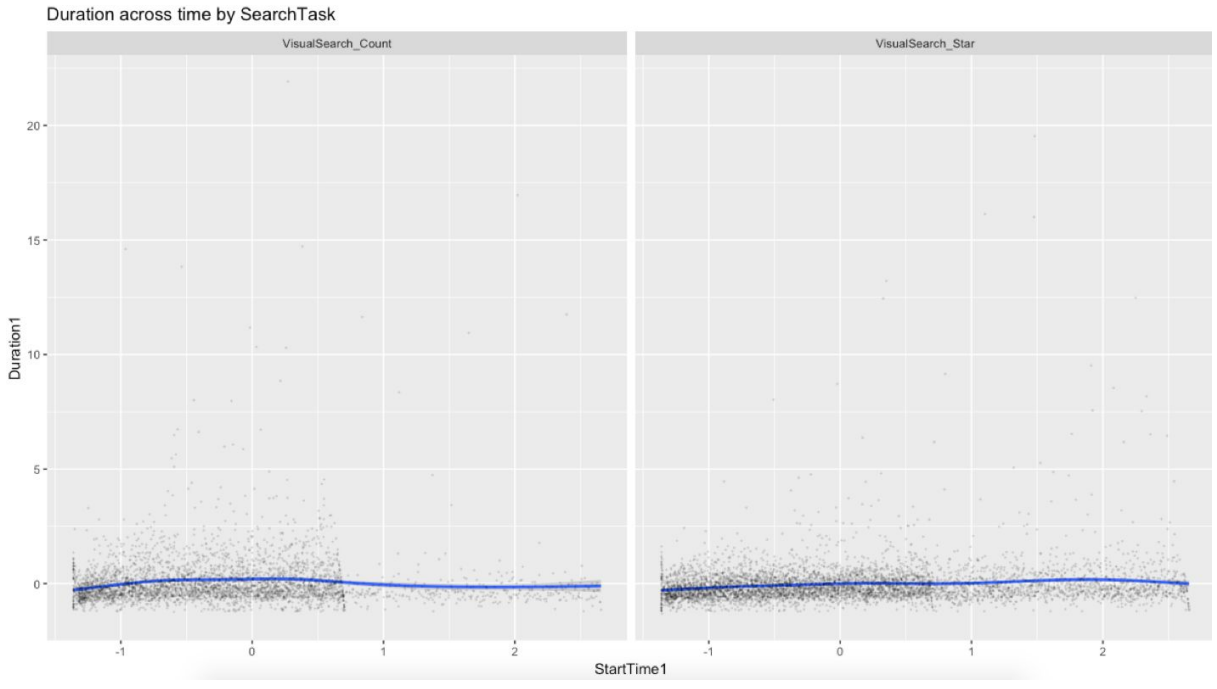
Pupil size and fixation duration were plotted for each participant (**plot 1-6**).

- Eyeballing the data, it seems that durations of fixations are a little longer for participants in the 'Count Objects'-task than in the 'Find Target'-task. However, it seems that amplitude of saccades is bigger for the 'Find Target'-task than the 'Count Objects'-task and more constant over time. Likewise, the velocity of the saccades seems to be higher and more constant over time for the 'Find Target'-task than the 'Count Objects'-task.

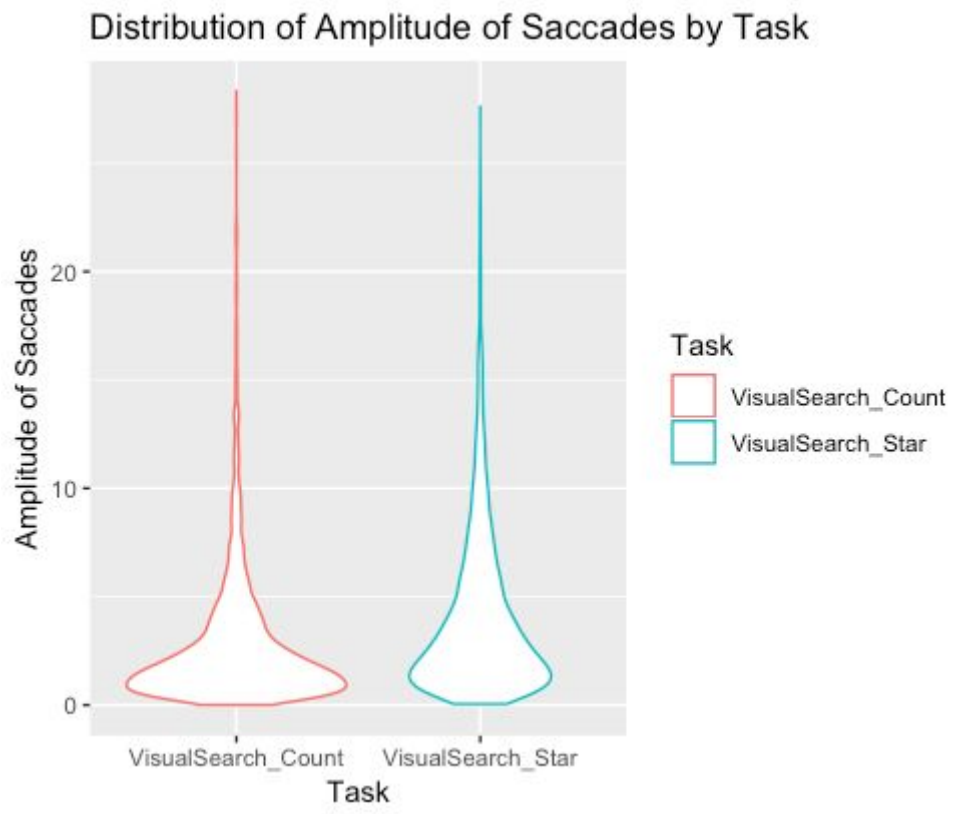
Plot 1: This plot visualizes the Duration of fixations for *count object* and *find star*.



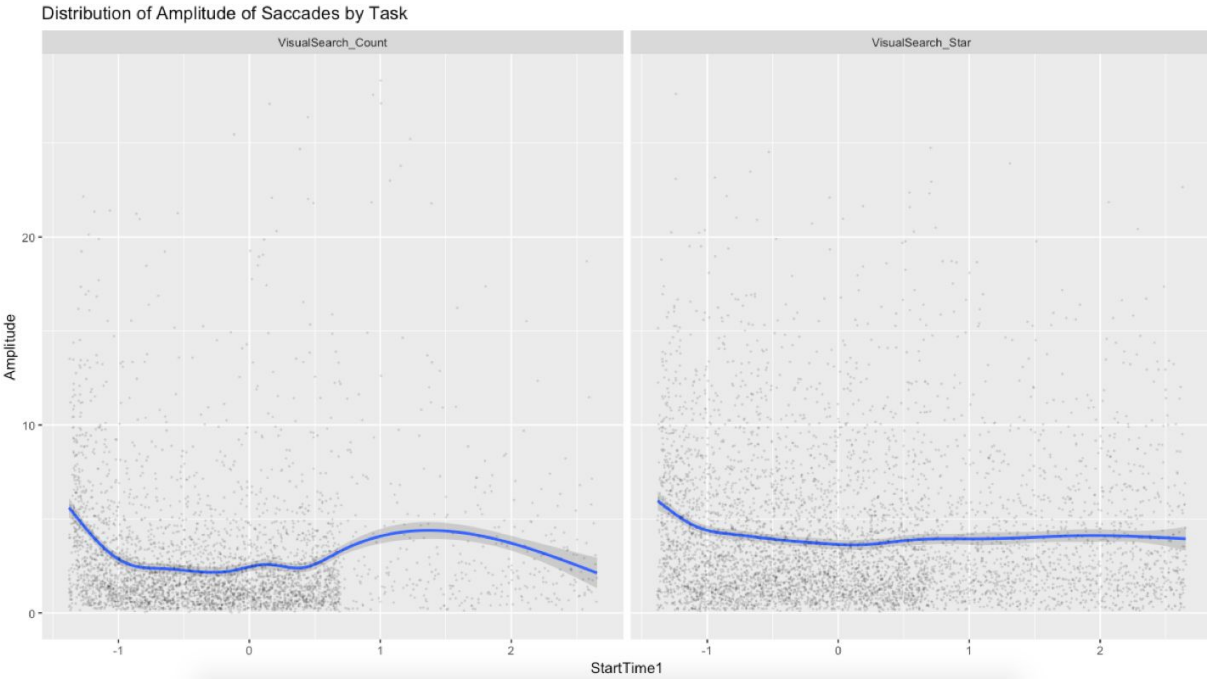
Plot 2: These plots visualize the Duration of fixations across Start Time for the two tasks.



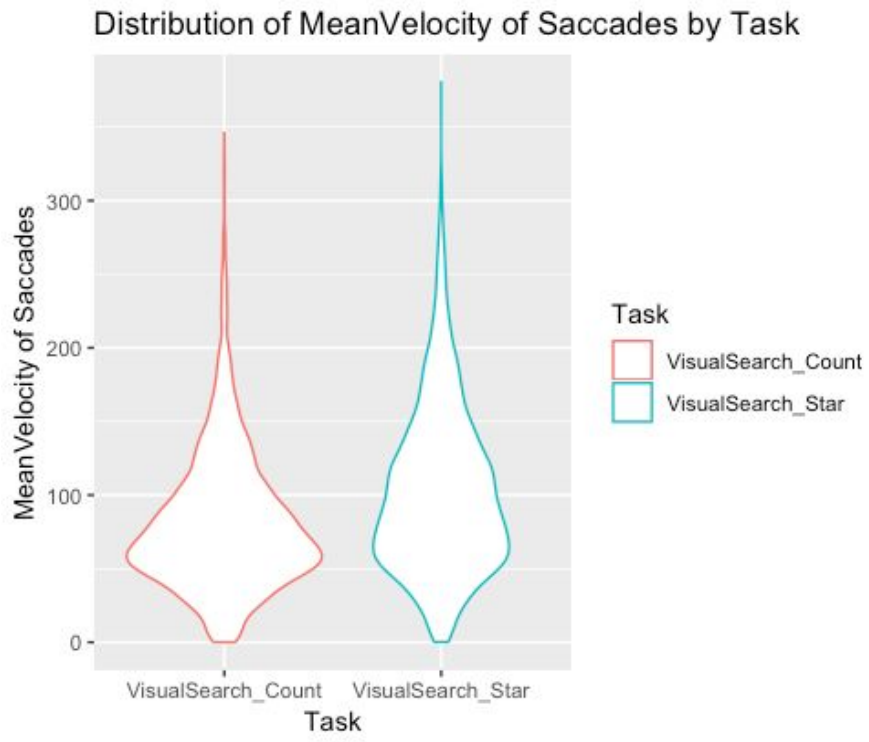
Plot 3: This plot visualizes the Distribution of Amplitude of Saccades for the two different tasks



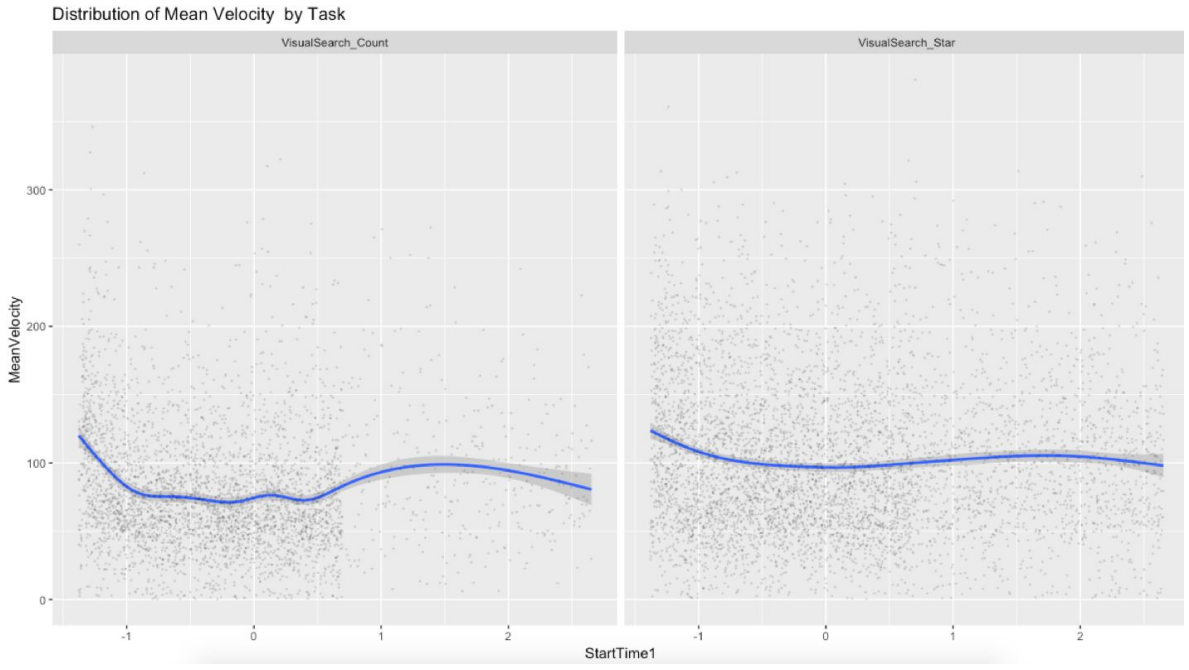
Plot 4: These plots visualize the Amplitude of saccades across Start Time for the two different tasks



Plot 5: This plots visualizes the Distribution of Mean Velocity of Saccades by task.



Plot 6: These plots visualize the Mean Velocity of Saccades across StartTime by Task.



Results

Mean Velocity Model

MeanVelocity ~ Task + StartTime1 + (1 + Task | ParticipantID)

Predictor	**Estimate**	**Standard Error**	**p-value**
Intercept	4.338724	0.052997	< 2e-16 ***
Task Star Search	0.254210	0.082758	0.00213 **
Start Time_scaled	-0.069969	0.005886	< 2e-16 ***

Amplitude of Saccades Model

Amplitude ~ Task + StartTime1 + (1 + Task | ParticipantID

Predictor	**Estimate**	**Standard Error**	**p-value**
Intercept	0.93558	0.07356	< 2e-16 ***
Find Target	0.42486	0.13268	0.00136 **
Start Time_scaled	-0.11412	0.01064	< 2e-16 ***

Velocity of Saccades Model

MeanVelocity ~ Task + StartTime1 + (1 + Task | ParticipantID

Predictor	**Estimate**	**Standard Error**	**p-value**
Intercept	4.338724	0.052997	< 2e-16 ***
Find Target	0.254210	0.082758	0.00213 **

Start Time_scaled	-0.069969	0.005886	< 2e-16 ***

Duration of Fixations Model

Duration ~ Task + StartTime1 + (1 + Task | ParticipantID)

Predictor	**Estimate**	**Standard Error**	**p-value**
Intercept	5.685825	0.063798	<2e-16 ***
Find Target	-0.139207	0.055949	0.0128 *
Start Time_scaled	0.075373	0.008459	< 2e-16 ***

Discussion

Revisiting the hypotheses

In this experiment we wanted to investigate whether there was a difference of eye gaze pattern between the two tasks.

H1. Saccade amplitude

For saccade amplitude we found the expected relation between task and saccade amplitude. Amplitude was higher for *find target*-task compared to *count object*-task. This finding is in line with former findings of Levy-walks associated with visual foraging.

H2. Velocity of saccades

We expect the velocity of saccades to be lower in the *find target*-task relative to the *count object*-task. This was also the finding we got from the experiment. This finding is in line with the intuition that the latter task entails aimless browsing requiring relatively low velocity.

H3. Duration of fixations

We expect there to be a difference in duration of fixation: The browsing associated with searching for the star is expected to be associated with shorter fixations. The hypothesis was confirmed by our experiment's results, confirming that the duration of fixations is significantly higher in the *count object* task than in the *find target* task. Supposedly, in the *count object* task the subject has to fixate longer on particular parts of the image, whereas in the *find target* task visual foraging is required to solve the task, which resulted in shorter durations of fixations.

All in all, the three initial hypothesis were confirmed by our results, suggesting that there is difference in extrinsic and intrinsic processing, which is displayed in our results for duration of fixations, velocity and amplitude of saccades.

Limitations to the experiment

There were a few limitations to the experimental set-up as well as implementation of the experiment.

Calibration problems

On the day of the experiment in 2019, the eye-tracker did not manage to calibrate to the individual's eyes. Therefore, the calibration put into use was from a different person. This obviously contributes some error to the measurements.

Amount of participants

The amount of participants in the study was quite small, consisting of only 12 participants. Furthermore, for one of these participants, only the eye-tracking data from one of the two tasks was tracked.

Participant-bias

All the participants in the experiment were Cognitive Science students, who had already been introduced to the procedure and the aim of the experiment. This must be assumed to bring in some bias, which might have changed the behavior of the participants.

Relevance of findings

This study contributes to the findings by Alfred Yarbus, that a person's eye movement is not only dependent on the information in a picture, but influenced by the task that the person is facing and, 2. the information that the person hopes to gain from the visual scene.

References

Rhodes, T., Kello, C. T., & Kerster, B. (2014). Intrinsic and extrinsic contributions to heavy tails in visual foraging. *Visual Cognition*, *22*(6), 809-842.

Yarbus, A. L. (2013). Eye movements and vision. Springer.

Link to our code:
https://github.com/sebsebar/Alouishes/blob/master/Port%201%20-%204th%20semester.Rmd