Portfolio 1 - Eye tracking

Link to GitHub: **HERE**

1.1 Visual Search Experiment

Introduction

The conceptual hypothesis of the experiment was: visual search patterns are affected by task structure and goals. In order to test the hypothesis following experimental paradigm was used.

The experiment had two conditions which differed in the experimental task the subject was performing. In one condition pictures were presented and the task was to count objects in given picture. These objects were for example sheeps, water droplets etc. The other condition required the participant to search for a little star hidden somewhere in the presented image. The technical details of the data collection setup will be explained in methods

In such setting the hypothesis can be operationalized in terms of features of eye events; fixations and saccades. It was hypothesized that the duration of fixations will be longer in search condition than in the counting condition. Similar applies to amplitude of saccades or length of the saccades; the saccade amplitude was predicted to be longer in the search condition.

These two features of the pattern of eye movements in search condition suggest a strategy of searching one part of picture and than “jumping” to distant yet unexplored part of picture.

Methods

Participants

The data were collected from sample of 6 university students (mean age ~ 23). 4 of the participants were females. The participants were not screened for potential issues caused by glasses or contact lenses. The unwanted effects of mascara were however controlled by removing it.

Data Collection

Monocular eye positions and pupil size were recorded at 1000 Hz using an Eye Link 1000 head mounted eye tracker. Each participant was seated approximately 75 cm in front of a 30-inch flat panel LCD monitor.

Prior to data collection, the eye-tracker was calibrated using the in-built nine- point automated calibration procedure, which was repeated until the validation procedure reported average errors below 1 and max error below 1.5.

The eye-tracker was linked and synchronized with a second computer running a PsychoPy implementation of the paradigm and continuously recorded time stamps for the initiation of stimulus exposure.

Data Pre-processing

The eye- tracking data were automatically pre-processed using the in-built DataViewer software. Artifacts were removed. Eye-blinks, saccades and fixations were identified.

Data Analysis

The data were analyzed using R (1) and RStudio (2). The models were built using packages lme4 (3) and lmerTest (4).

The hypothesis about fixation duration was modeled using fixation duration at averaged fixations level as dependent variable. The hypothesis about amplitude of saccades was modeled using amplitude at averaged saccades level as dependent variable. Type of task and trial number were used as predictors. These measures were entered into multilevel linear regression model. The random variance between participants was controlled for with random intercept for each participant and random slope for type of task.

Since the distribution of both dependent variables followed an exponential distribution (Figure 1 and 2) and had a long tail they had to be log-transformed before employing them in the model.

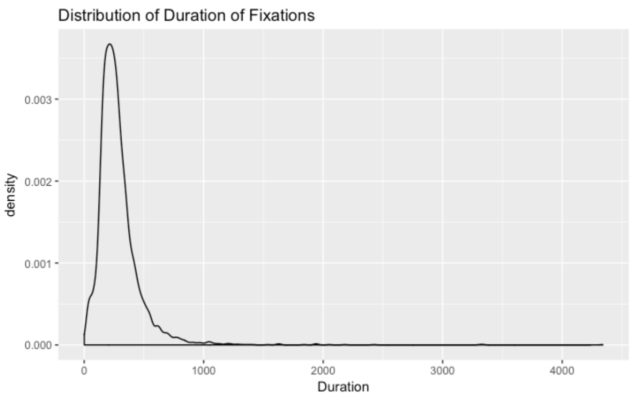

Figure 1: Distribution of fixation duration

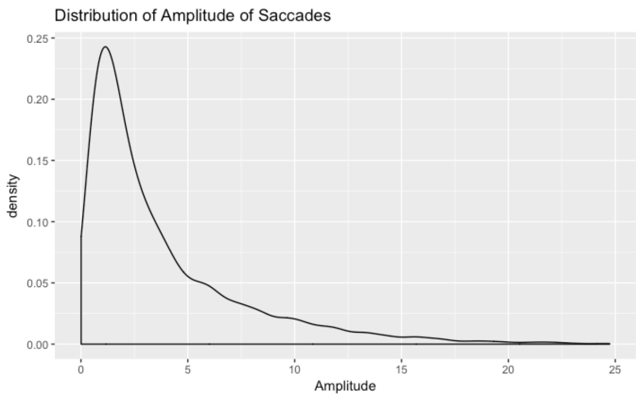

Figure 2: Distribution of amplitude of saccades

Duration ~ Task + (1+Task | Participant)

Amplitude ~ Task * Trial + (1+Task | Participant)

Model	Training RMSE	Testing RMSE	Range of Training RMSE	Range of Testing RMSE
SearchType + Trial + (1 + SearchType | ParticipantID)	0.554	0.554	0.084	0.084
SearchType * Trial + (1 + SearchType | ParticipantID)	0.553	0.553	0.085	0.085
SearchType + (1 + SearchType | ParticipantID)	0.554	0.554	0.084	0.084
SearchType + (1 | ParticipantID)	0.562	0.562	0.089	0.089

Table 1: Result of model selection with duration as dependent variable. The selected model is marked in red.

To identify the model that fits the data the best a 10^4 repeated 3-fold cross-validation model selection was used. Cross-validation folds were divided at participant level and balanced across conditions. Out-of-sample error measured as root mean square error as selection criterion was used. The two selected models were then ran on the full dataset to optimize parameter estimation.

Results

For the duration of fixations models the 3-fold cross-validation selection process repeated 30 times yielded the results reported in table 1. The selected model is reported in table 2.

For the amplitude of saccades models the 3-fold cross-validation selection process repeated 30 times yielded he results reported in table 3. The selected model is reported in table 4.

Predictor	Beta estimate	SE	t-value	p-value
Task_Search	-0.336	0.171	-1.969	0.185
Trial	-0.002	0.01	-0.249	0.803
Task_Search * Trial	0.025	0.012	2.038	0.042

Table 2: The selected model describing duration of fixation

The model supports the hypothesis that in task where the participants were searching for star the fixations were indeed longer. Moreover the duration was increasing with the number of trials indicating that in the last trial the fixations were the longest. To get a precise value in milliseconds of how much longer the fixations were we exponentiate the beta estimate that are in logs. In the first trials of both tasks the duration of fixation in search for star task was 1.026 ms longer than in counting task.

Model	Training RMSE	Testing RMSE	Range of Training RMSE	Range of Testing RMSE
SearchType + Trial + (1 + SearchType | ParticipantID)	0.948	0.948	0.116	0.116
SearchType * Trial + (1 + SearchType | ParticipantID)	0.945	0.945	0.116	0.116
SearchType + (1 + SearchType | ParticipantID)	0.949	0.949	0.116	0.116
SearchType + (1 | ParticipantID)	0.955	0.955	0.116	0.116

Table 3: Result of model selection with amplitude as dependent variable. The selected model is marked in red.

Predictor	Beta estimate	SE	t-value	p-value
Task_Search	0.524	0.159	3.292	0.005
Trial	-0.044	0.016	-2.726	0.008
Task_Search * Trial	0.041	0.021	1.981	0.049

Table 2: The selected model describing amplitude of saccades

The model supports the hypothesis that in task where the participants were searching for star the amplitude of saccades was bigger. Moreover the amplitude was increasing with the number of trials indicating that in the last trial it was the largest. To get a precise value in pixels of how much longer the saccades were we exponentiate the beta estimate that are in logs. In the first trials of both tasks the amplitude of saccades in search for star task was 1.042 pixels longer than in counting task.
To visualize the difference in the patterns a scan path for one participant in 2 trials, one from each task, were created. We can see that the hypothesized pattern in search for star (Figure 1) is clearly present in the plot. There are clusters of fixations which are followed by a jump to a new unexplored region of the image. On the other hand in figure 2 there sort of a grid of fixations as the participant counted the sheeps.

References

(1) R Core Team (2017). R: A language and environment for statistical computing. Version 3.4.3 "Kite-Eating Tree". R Foundation for Statistical Computing, Vienna, Austria.
(2) RStudio (2017). version 1.1.383
(3) Douglas Bates, Martin Maechler, Ben Bolker, Steve Walker (2015). Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67(1), 1-48.
(4) Kuznetsova A, Brockhoff PB and Christensen RHB (2017). "lmerTest Package: Tests in Linear Mixed Effects Models." _Journal of Statistical Software_, *82*(13), pp. 1-26.

Figure 2: Scan path of one participant while counting the sheeps in the image.

1.2 Social Engagement Experiment

Introduction

The conceptual hypothesis of the experiment was that people's emotional engagement is affected by the degree of involvement in social interaction. In order to test the hypothesis following experimental paradigm was used.

Participants were watching a series of short videos. In every video there was a person with a cup of coffee giving it to a person. The videos differed in 3 features: gender of the actor, ostensiveness of the actor and directionality of offering of the coffee.
Directionality was present in two forms in the videos, either the coffee was handed towards the watching participant or to an imaginary person outside of the video frame. Similarly ostensiveness was in two forms, either the actor did not make an eye contact at all or he/she did and winked at the person who was offered the cup of coffee.
All combinations of these 3 features were presented to the participant in random order resulting in 8 types of videos. Participant's task was only to watch the videos.

To test the hypothesis pupil size was measured. The change in pupil size is assumed as a change in emotional engagement of the person. We hypothesized that the bigger the involvement of the participant in the social interaction the bigger the pupil size will get. From that following predictions were generated:

1. Handing the coffee towards the participant will increase the pupil size more than handing it to somebody else.
2. Eye contact plus a wink evokes larger increase of pupil size than no eye contact.
3. The increase of pupil size is larger when the genders of participant and actor do not match compared to matching genders.

Methods

Participants

The data were collected from sample of 6 university students (mean age ~ 23). 4 of the participants were females. The participants were not screened for potential issues caused by glasses or contact lenses. The unwanted effects of mascara were however controlled by removing it.

Data Collection

Monocular eye positions and pupil size were recorded at 1000 Hz using an Eye Link 1000 head mounted eye tracker. Each participant was seated approximately 75 cm in front of a 30-inch flat panel LCD monitor.

Prior to data collection, the eye-tracker was calibrated using the in-built nine- point automated calibration procedure, which was repeated until the validation procedure reported average errors below 1 and max error below 1.5.

The eye-tracker was linked and synchronized with a second computer running a PsychoPy implementation of the paradigm and continuously recorded time stamps for the initiation of stimulus exposure.

Data Pre-processing

The eye- tracking data were automatically pre-processed using the in-built DataViewer software. Artifacts were removed. Eye-blinks, saccades and fixations were identified.

Data Analysis

The data were analyzed using R (1) and RStudio (2). The models were built using packages lme4 (3) and lmerTest (4).

The 3 predictions were modeled using pupil size at samples level as dependent variable. Directionality, ostensiveness, actor gender and time from start of trial were used as predictors. These measures were entered into multilevel linear regression model. The random variance between participants was controlled for with random intercept for each participant and random slope for trial time, directionality and ostensiveness. Time from start of trial was modeled as a third-degree polynomial to account for potential non-linear changes in pupil size over time

Pupil Size ~ Directionality * Ostension * (TrialTime+TrialTime^2) + ActorGender * ParticipantGender * (TrialTime+TrialTime^2) +(1 + TrialTime + Directionality + Ostension | ParticipantID)

To identify the model that fits the data the best a 10^4 repeated 3-fold cross-validation model selection was used. Cross-validation folds were divided at participant level and balanced across conditions. Out-of-sample error measured as root mean square error as selection criterion was used. The selected model were then ran on the full dataset to optimize parameter estimation.

Results

Because the models equations are very long they are first listed in table 1 without random effects as all models had these the same in form reported above in the model equation, associated with a number under which they a further referred as. For the duration of fixations models the 3-fold cross-validation selection process yielded the results reported in table 2. The selected model is reported in table 3.

Model	Number
Directionality + Ostension + TrialTime + (1 + TrialTime + Directionality + Ostension | ParticipantID)	1
Directionality * Ostension + ActorGender * ParticipantGender + TrialTime + (1 + TrialTime + Directionality + Ostension | ParticipantID)	2
Directionality * Ostension * TrialTime + ActorGender * ParticipantGender * TrialTime	3
Directionality * Ostension * (TrialTime + TrialTime^2) + ActorGender * ParticipantGender * (TrialTime + TrialTime^2)	4
Directionality * Ostension * (TrialTime + TrialTime^2 + TrialTime^3) + ActorGender * ParticipantGender * (TrialTime + TrialTime^2 + TrialTime^3)	5

Table 1: All fitted and cross-validated models and their numbers for further refference

Model	Training RMSE	Testing RMSE	Range of Training RMSE	Range of Testing RMSE
1	178.773	178.773	36.133	36.133
2	171.654	171.654	32.751	32.751
3	167.185	167.185	36.965	36.965
4	151.994	151.994	33.705	33.705
5	148.639	148.639	36.636	36.636

Table 2: Results of model selection with pupil size as dependent variable. The selected model is marked in red.

Predictor	Beta estimate	SE	t-value	p-value
Directionalitydiv	-51.51	72.51	-0.710	0.502
Ostension+o	-26.85	33.19	-0.809	0.449
TrialTime	41.59	24.69	1.685	0.162
ActorGenderm	39.11	0.74	52.851	< 2e-16
ParticipantGendermale	453.4	442.6	1.024	0.352
Directionalitydiv:Ostension+o	-28.66	1.187	-24.153	< 2e-16
Directionalitydiv:TrialTime	-11.29	0.834	-13.546	< 2e-16

Ostension+o:TrialTime	-20.88	0.835	-25.024	< 2e-16
ActorGenderm:ParticipantGendermale	-151.3	1.248	-121.171	< 2e-16
TrialTime:ActorGenderm	7.608	0.733	10.386	< 2e-16
TrialTime:ParticipantGendermale	116.2	39.41	2.949	0.041
Directionalitydiv:Ostension+o:TrialTime	48.06	1.185	40.567	< 2e-16
TrialTime:ActorGenderm:ParticipantGendermale	-4.053	1.252	-3.238	0.001

Table 3: The selected model describing amplitude of saccades

Since interactions turned out to describe the data the best and it is rather difficult to understand effects of three-way interactions the results implied by the selected model are visualized in figure 1 and 2 for interaction of trial time with directionality and ostension and trial time with gender of actor and gender of participant respectively.

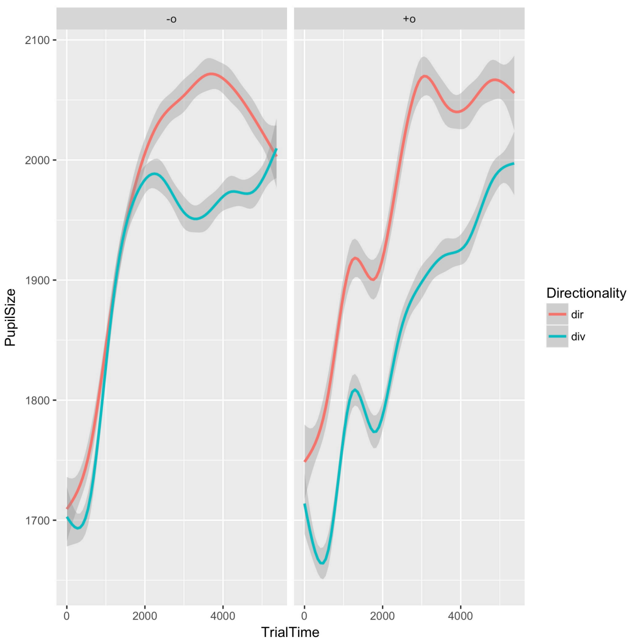

Figure 1: Visualization of an interaction of

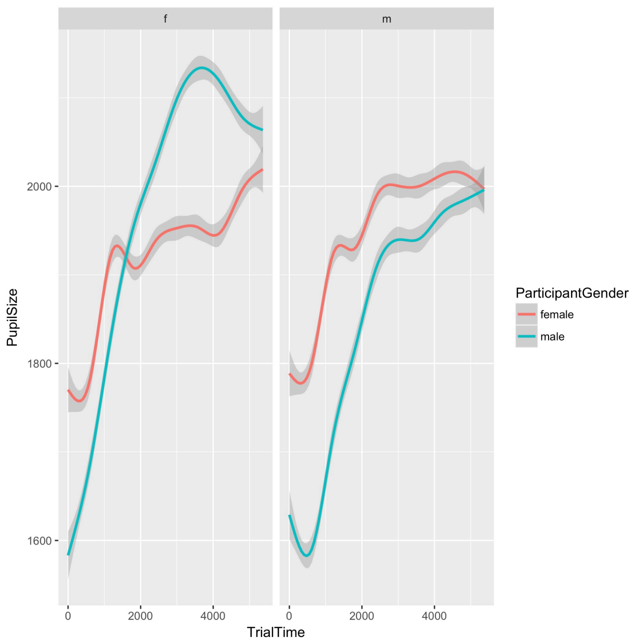

Figure 2: Visualization of an interaction of trial

Let's take the figure 1 first. This plot supports the first part of our hypothesis; pupil is larger when the coffee is handed towards the participant rather than a "third" person. The variation in ostension seems to be increasing this effect. However the second part of the hypothesis is not supported by the data, the ostension does not seem to have an effect on pupil size as all the lines in the plot reach approximately the same maximal point on y-axis.

Now we move to the figure 2. According to our hypothesis we should expect the line for males (blue) to go higher in the left-hand facet of the plot and the opposite should be true in the right-hand facet; red line is higher than the blue one. And that is exactly what we see in the plot. When the participant views a person of opposite gender giving somebody or her/him a cup of coffee the pupil size gets larger than when the person with coffee was of the same gender as the participant. The effect seems to be larger for males as they show larger pupil size when seeing a woman than a female seeing a man. On the other hand pupil size of females stays approximately the same independent of actor gender. Therefore our hypothesis is only partially supported as the effect seems to apply to men and very weakly or not at all to women.

References

(1) R Core Team (2017). R: A language and environment for statistical computing. Version 3.4.3 "Kite-Eating Tree”. R Foundation for Statistical Computing, Vienna, Austria.

(2) RStudio (2017). version 1.1.383

(3) Douglas Bates, Martin Maechler, Ben Bolker, Steve Walker (2015). Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67(1), 1-48.

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