Case Study 1
Eye-tracking

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Eye-tracking is a technique used to measure where and for how long a person (or an animal) looks within their visual environment (Duchowski, 2017; Holmqvist et al., 2011). It is widely used in social and natural sciences to study cognition & behavior, as well as in applied sciences (medicine, education, marketing, ...).

There are different ways how eye-tracking can be done. Modern eye-tracking devices use infrared light and high-speed cameras (recording frequencies are typically ranging between 60Hz and 2000Hz). The device records the position of the pupil and the cornea (measured by following the reflection of the infrared light from the cornea). Together, these two positions can be used to calculate the direction of gaze relative to the eye-tracking device. Following a procedure which calibrates the eye-tracking device, it is possible to map the direction of gaze onto the subject's environment, such that we can infer where was the subject looking (e.g. a specific point on a computer screen in front of the subject).

There are multiple levels of analysis of eye-tracking data that can be broadly categorized into three groups:

- **Raw data** The original video recording of participant's face including the pupil and corneal reflection, meta-data associated with the calibration procedure, as well as additional information regarding the experimental procedure. Data on this level is typically not shared publicly because sharing videos with subjects' faces would typically not comply with guidelines of ethical research and other legal requirements (e.g., GDPR).
- **Pre-processed data** The result of a pre-processing step that analyses the video recordings in order to convert the raw data into tabular data that is relatively easy to work with. Typically, each row of the eye-tracking file represents a single measurement. An eye-tracker that records with a frequency of 60Hz should therefore produce about 60 rows of data for every second of recording. The columns of the data usually are:
  - ***timestamp***. The time of the data point, usually measured in ms since the eye-tracker has been turned on.
  - ***x*- and *y*-coordinate**. The horizontal and vertical positions of gaze projected onto the screen dimensions. If both left and right eyes

were tracked, then gaze coordinates of each eye would be reported in separate columns.

- ***pupil size*** (alternatively pupil diameter). Measurement of the pupil size. This variable can sometimes be a subject of interest on its own, though usually it is used as a proxy for detecting other events (e.g., blinks). If both left and right eyes were tracked, then puil size of each eye would be reported in separate columns.
- ***events and messages***. Any sort of messages sent between the computer that administered the experiment (i.e., presented the stimuli to the participant) and the eye-tracking device. Event messages can for example show in the pre-processed data to mark an onset of a stimulus, a change in the scene presented to the participant, etc.
- ***validity and blinks***. Additional information produced by the pre-processing procedure. Depending on the procedure (and eye-tracker) used, these columns might contain information about data quality (e.g., whether or not the eye-tracker lost signal from the eye) or additional processing (blink detection).

- **Processed data** Any data that results from processing further the pre-processed data. Typically (but not always), the pre-processed data would be parsed in order to classify eye-movement events such as fixations and saccades. Fixations and saccades are two key components of eye movements in visual perception.
  - ***fixations*** are brief pauses of the eyes when they are focused on a specific point in the visual field. During a fixation, the eyes remain relatively still, allowing the brain to process visual information coming through the eyes. Fixations typically last from 200 to 600 milliseconds, depending on the task and the complexity of the scene.
  - ***saccades*** are rapid, jerky movements of the eyes that shift focus from one point to another. Saccades occur in-between fixations and can move the eyes quickly, covering distances ranging from a few degrees to several degrees of the visual field. They help direct attention to different areas of interest.
  - ***other eye movement events***, such as smooth pursuits, post-saccadic oscillations, or nystagmus can also occur under certain conditions, though they will not be subject of the current analysis.

Data

The data set is available here: `https://osf.io/sk4fr/`. The original report associated with the data is written by Strauch et al. (2023).

The data were collected in the Dutch Science Museum Nemo in Amsterdam, the Netherlands, during 2023. Visitors of the museum had the option to participate in the study. Participants viewed a feature-rich picture for 10 seconds without any instructions, while their direction of gaze was being recorded. The original study contains data from n =2,607 participants, but the online repository provides additional updated data set with a couple of thousands more participants.

Raw data is not available for this data set. Pre-processed data are stored in separate .csv files and contain the x and y coordinates of the gaze, the pupil size, timestamps, and messages (that indicate stimulus onset and offset times, etc). A separate .csv file contains demographic information about the participants (gender and year of birth).

The online repository contains processed data from the original study that contains the information about fixations (fixation average x- and y-coordinates, fixation durations, etc) of n=2,607 participants, and contains code that allows one to parse the pre-processed data into processed fixation data.

Intructions

Your ultimate goal is to analyse the data in order to answer the following two questions

- There is an ongoing debate on how people determine where and when to look. While there is an increasing understanding of individual differences in eye movement patterns (De Haas et al., 2019) as well as understanding mechanisms of timing of fixations and saccades (Nuthmann et al., 2010), eye-tracking experiments have typically too homogeneous samples to make inferences about how are these differences related to age. The current data set provides an opportunity to look into those effects. One hypothesis is that fixation durations would typically decrease with age during childhood, but increase later on in life. Test this hypothesis.

- Investigate whether there any systematic patterns in fixation durations over the course of the experiment; do fixations become shorter or longer over time? Do they become shorter first and longer later on? etc.

It is up to you what methods you will chose the answer these questions, as long the methods you chose are reasonable within this context. The questions above are intentionally left a little bit vague. You are allowed to pose these questions as testable hypotheses that you will assess with your statistical analysis. You should be able to justify your choices, verify assumptions behind the methods you use, and discuss alternatives and how your choices might have impacted your conclusions regarding the broad questions asked above. The report should fully describe your analysis pipeline, providing descriptive and inferential results.

You are supposed to use the entire (updated) data set to do your analysis. This means you will have to use the pre-processed data and convert it into a data set of fixations before you can carry out the analysis.

You will have the first two weeks (October 8 - October 22) to process the data using the already existing code in the online repository. If your group does not manage to process the data until October 22, it will result in a decreased final grade for the project.

On October 22, we will release the processed data so that even groups that couldn't process the data themselves can continue with the analysis.

Bonus - robustness analysis

The conclusions you will make will depend not only on your analysis choices, but also on the way how the raw data has been processed into the final fixation data. Of course, a different pre-processing and processing steps could also lead to different results.

As a bonus answer, you can investigate how robust are your conclusions to the choices made during the processing pipeline used to identify fixations. Process the eye-tracking data again but with a different method and run your analysis on this alterned data set. Discuss whether changing the processing pipeline changes your conclusions.

To change the processing pipeline, you can chose either of the following approaches:

- **Change hyperparameters of the current processing pipeline**. You can change some of the hyperparameter settings of the fixation detection algorithm of Hessels et al. (2020) in the 'constants.py' file and run the processing again. Investigate which settings affect your analysis results the most and discuss whether your conclusions depend on which settings you chose.
- **Implement your own processing pipeline that detects fixations**. Implement your own method that detects fixations from the pre-processed data. You do not need to implement anything sofisticated; any basic method would do. For an overview of basic methods, see Salvucci and Goldberg (2000). Compare the results to ones that you obtained using the original method and discuss whether your conclusions depend on which algorithm you chose.
- **Add noise to the pre-processed data**. You can add random noise or randomly insert missing data into the pre-processed data. Parse this augmented data with the method used in the original article to investigate to what extent are your conclusions robust against decreasing data quality.

Robustness analysis done well has a high chance of upgrading your final grade significantly.

References

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