Acquisition and analysis of eye-tracking data

Does diagonal positioning of stimuli eliminate the left-bias in viewing images?

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1. Introduction

Human perception is inherently selective, with certain visual stimuli capturing attention more readily than others. An important function of attention is to ignore irrelevant stimuli and to select relevant stimuli in the environment for further examination (Lavie et al., 2004). When two images are presented simultaneously, individuals typically direct their gaze towards one image first and fixate on this first stimulus. These fixations are crucial for understanding visual attention and have been extensively studied in eye-tracking research like with some kind of emotional stimuli (Nummenmaa et al., 2006) or by analysing the global visual salience of competing stimuli (Hernandez-Garcia et al. 2020). The focus of this study is on how spatial arrangement influences these fixations, particularly when images are positioned diagonally relative to each other. By exploring whether diagonal positioning can mitigate the commonly observed left-side bias, this research seeks to enhance our understanding of how spatial configurations affect visual attention.

1.1 Background

When two images are presented simultaneously, the subject will typically orient their gaze towards one of the images, rather than the other. These images are also referred to as stimuli, and the focus on one of the two images is known as a fixation. The determination, measurement and analysis of such fixations constitute an essential component of eye-tracking research, particularly in the context of retrospective inference and enhanced comprehension of human eye movements and fixations. However, these fixations are not always a coincidence. Several factors influence human perception, determining which of two images is looked at first and thus creating a bias.

One such influencing factor is the spatial arrangement of the two images in question. This topic has already been the subject of research in eye tracking, whereby the spatial arrangement of multiple images adjacent to one another is examined to determine whether the image on the left or the image on the right is viewed first. It has frequently been demonstrated that subjects tend to direct their gaze towards the left image, a finding that is corroborated by research in this field. In a study by Hernandez-Garcia et al. (2020, p. 13), for instance, a bias towards the left side was observed in 65% of cases. Other research findings indicate that 93% of fixations occur initially on the stimuli on the left side, thereby corroborating the left bias (Cludius et al., 2017, pp. 34-

38). Such images can be arranged in a variety of configurations, including in proximity to one another and in other ways. In addition, research on this topic has shown that when presented in a vertical arrangement, the top image is more likely to be fixated than the bottom image (Nummenmaa et al., 2006).

The results demonstrate a specific asymmetry in human perception, whereby a particular stimulus is perceived as the initial focus in specific spatial configurations. This bias may have multiple underlying causes, including the observed difference between right-handed and left-handed individuals, with the former exhibiting a less pronounced bias, and the potential influence of hemispheric lateralization in high-level brain regions (Ossandon et al., 2014).

1.2 Motivation and Research Question

The aforementioned findings will be employed and integrated into this experiment with the objective of formulating further assertions regarding the spatial configuration of stimuli and the ensuing biases. Furthermore, the experiment is designed to ascertain the influence of a diagonal arrangement, specifically a combination of left-right and top-bottom arrangements, on the left bias. It is possible that this will result in either reinforcement or negation, or alternatively, a counterbalancing effect. This will be demonstrated by the results presented in the following experiment. The objective is to ascertain how different arrangements affect which image is fixated on first. Consequently, the intention is to situate the research findings from this experiment in relation to the current state of scientific knowledge, specifically the aforementioned findings. The aim is to demonstrate whether these findings are consistent and whether new results can be obtained. Additionally, it is important to determine whether different diagonal arrangements can counterbalance the left bias.

This also represents our research question, namely, "Does diagonal positioning of stimuli eliminate the left bias in viewing images?". The aim is to determine which of two stimuli is considered first when they are displayed in different positions relative to each other.

1.3 Hypotheses

Two hypotheses were formulated in advance to ensure that the experiment could be conducted in a targeted manner.

The initial hypothesis is that individuals will initially direct their gaze towards the left-hand image, even when presented with images positioned diagonally relative to one another. Therefore, the diagonal positioning would have a negligible effect on human fixation, as the left image would still be viewed first. This would be in accordance with and substantiate the existing research findings. Figure 1 illustrates the stimuli that are expected to be fixated on the most, based on their position on the diagonal.

The second hypothesis is that a stimulus placed at the bottom left is perceived as more appealing than a stimulus placed at the top right and is therefore fixated upon first. This would indicate that the left bias is stronger than the top bias and would affect the results of the experiment to a greater extent.

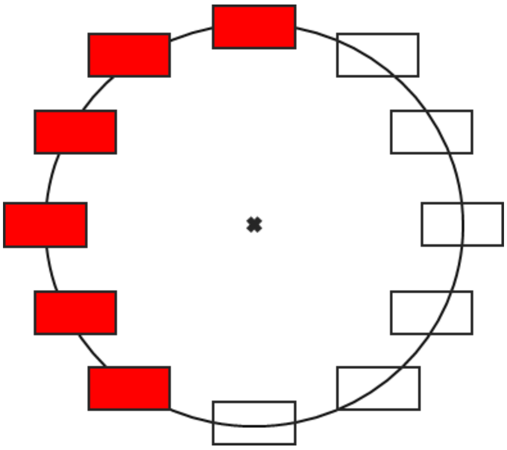

Figure 1: Positions of Stimuli portrayed to the participants.

1.4 Measures

To investigate the research question and the hypotheses, a series of measures were defined in advance. It is possible to differentiate between dependent and independent measures.

The independent measures are the selection and position of the stimuli. These are placed in a random order at predetermined positions to ensure the result of the experiment is as meaningful and independent as possible.

The dependent measures, which are to be evaluated during the experiment to ascertain their influence, are the initial fixations. These are assessed to substantiate or refute the hypotheses. The initial fixations are then employed to ascertain which stimuli were viewed first by the respondent, thereby enabling the drawing of inferences regarding the potential for bias. While other experiments also seek to investigate subsequent events and the way human perception evolves during the viewing process, this experiment exclusively focuses on the initial fixation.

2. Experimental Methods

The experiment was conducted in a controlled, closed laboratory setting with preset lighting conditions to minimize external distractions. Participants were seated on an immovable chair in front of a high-resolution computer screen at a distance of approximately 60 cm. In accordance with their individual preferences, participants were provided with the option of utilizing a chin rest to minimize head movement. They were instructed to complete a task designed to measure their eye movements based on visual stimuli. Each session was approximately 15 minutes in duration and comprised an introduction, calibration of the eye tracker, and the actual experiment. If interested, following the experiment, an in-detail description of the experiment was provided and the current results where shown. At least one research assistant was present throughout each session to monitor adherence to the procedure and to provide assistance if needed. To ensure optimal conditions for infrared tracking of the cornea reflection, the laboratory environment was maintained at a constant lighting condition. This was achieved by turning off the headlights, lowering the shutters, and closing the curtains.

2.1 Participants

The study included 23 participants, comprising 20 males and three females (Table 1). Of these, 22 participants were aged between 20 and 30 years and were graduate students, while one participant, aged between 50 and 60 years, was a full-time employee. Each participant was raised in a country and culture where reading is conducted from left to right and the Latin alphabet is the prevailing script. All participants were recruited through personal social circles and did not receive any form of reimbursement. In accordance with the established inclusion criteria, participants were required to avoid wearing contact lenses, as this could potentially compromise the accuracy of corneal reflection measurements. Additionally, participants were expected to possess sufficient English language proficiency to comprehend the instructions. Besides this, no other inclusion criteria were put in place.

Prior to the commencement of the experiment, all participants were informed of their rights, including the right to withdraw from the study at any point without consequence. Furthermore, participants were required to consent to the utilisation of the recorded, but anonymised data and were informed that the recordings could only be deleted until the paper was submitted. Each participant was required to provide informed consent, thereby ensuring that they were fully aware of the conditions of participation. All participants agreed to the terms and conditions of the experiment. In the event that a participant did not agree or withdrew their consent after the conclusion of the experiment but prior to submission, their anonymised data would have been deleted and excluded from the research.

	Male	Female
20 – 30 years	20	2
50 – 60 years	0	1

Table 1: Gender and age distribution of the participants.

2.2 Stimuli

The visual stimuli consisted of a series of monochrome pictures displayed on a 1920 x 1080-pixel (Full HD) resolution computer screen. All pictures were designed using the stable diffusion features of ChatGPT and Leonardo.AI. This approach allowed an easy adaptation of images in accordance with the specifications of the experiment, thus eliminating any potential copyright concerns. The generation of the images was based on the following prompt, or a slight adaptation thereof: “Please generate simple images of different textures without striking content in black and white”. Only images with low contrast and no striking content were selected (Figure 2) to prevent any disturbance to the participants' perception and to ensure the integrity of the experimental results. Consequently, all images were created in monochrome. This resulted in a total of 23 unique images being used for the experiment.

Figure 2: Examples of selected stimuli.

To maintain participant focus and prevent distraction, participants were assigned a task of counting the number of circles displayed within the stimuli. Thus, all images either featured a circle or decagon with reduced transparency to maintain visual engagement (Figure 2). The decagon was selected as its form closely resembles, yet differs, from that of a circle. This ensured that participants could not rely on peripheral vision to identify the number of circles and were required to examine each image in detail to arrive at the correct count.

Of the total number of images (n = 23), six depicted circles, representing a proportion of 26.08%. This apparently disproportionate figure emerges when the initial set of 18 images containing six circles (33.33%) is considered in relation to subsequent feedback that resulted in the inclusion of an additional five images, thereby enhancing the range of potential outcomes for picture pairing. The task was implemented for the sole purpose of maintaining participant focus. As the images were selected at random from a pool of 23 before each trial, the total number of circles can differ between participants, with a range of 0 to 96 (48 x 2) possible. As this result did not affect or contribute to answering the research question, the results were only collected verbally and not included in the research.

2.3 Study Design

The study was conducted using a within-subject design, whereby each participant was exposed to the same treatments.

The objective of the study was to display twelve different positions located on a circle. The various positions were designated with labels derived from the twelve hours of a clock, allowing for a clear and concise representation of the positions (Figure 3). Each position was allocated a predefined location on the screen and was only displayed in combination with its opposite (e.g. position eleven and position five). To ensure the reliability of the results, each position was displayed with precision on eight occasions.

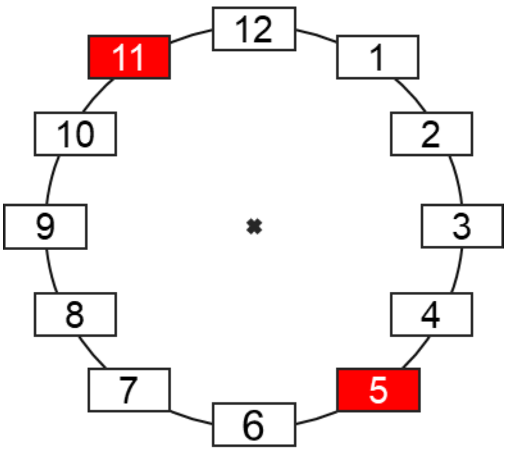

Figure 3: Design of the study.

To prevent any unintended negative impact on the results, a counterbalancing procedure was applied to each pair of images. If image A was displayed at position eleven initially and image B at position five, image B was also shown at position eleven and image A at position five during the experiment. This resulted in 24 unique executions, with 24 executions of counterbalancing.

Accordingly, each trial comprised 48 stimuli. Each stimulus was randomly selected and displayed for a duration of 5000 milliseconds, followed by a 1000 millisecond delay. The random selection of pictures and locations before each trial was implemented as a contingency measure to avoid any negative impact on the results in the event of technical errors or software crashes, or in the case of participants experiencing illness or other circumstances that would prevent them from continuing the experiment. The use of a single predefined sequence of pictures and locations could allow participants who have already completed the experiment partly to predict the subsequent location based on their recollection, potentially leading to a negative impact on the results. The implementation of a random shuffle prior to each trial serves to mitigate this issue, as the order locations and pairing of pictures varies between trials, thereby preventing participants from anticipating the sequence.

2.4 Implementation

Upon arrival, participants were greeted and asked whether they felt well. A casual conversation about their day was then initiated with the aim of fostering a positive atmosphere and reducing any pressures they may have been feeling. Prior to the commencement of the experiment, participants were required to complete a consent form and a demographic questionnaire. They were also informed about their rights, the utilization of their data and the setting of the study. Following this, the participants were seated on the immovable chair and asked whether they wished to utilize a chin rest or not. Subsequently, the eye tracker was adapted, or the participants were instructed to move closer or further away, so that the eye tracker software displayed a green dot indicating the perfect distance for recording.

Afterwards, the experiment was initiated, and the participants were required to familiarize themselves with the instructions. During this stage, they could also request clarification on any potential issues from the research assistants. Once the participants had demonstrated an understanding of the instructions and responded to all queries, they were permitted to proceed to the calibration phase by pressing any key on the keyboard.

The calibration process was conducted using the OpenSesame software, which required the participants to focus on white dots displayed in different positions on the computer screen. Once the calibration process was completed, the research assistants evaluated the results to ascertain the precision of the calibration. In the event that the calibrations did not meet the expected standards, the participants were required to repeat the calibration process until no extreme outliers were present in the different fixated positions. If no outliers were identified and the calibration met the requisite standards, the experiment proceeded to the experimental session.

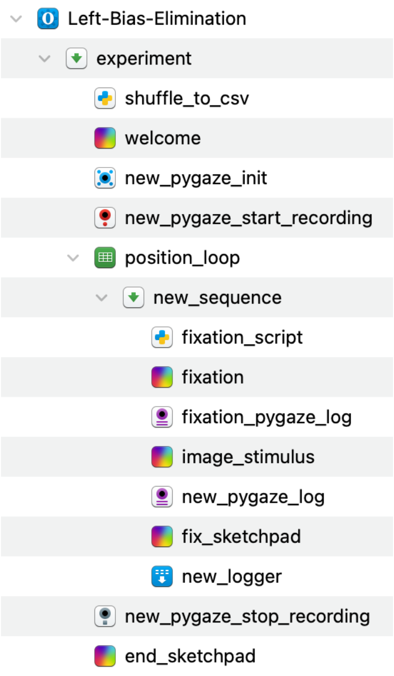

Figure 4: Implementation of the experiment in OpenSesame.

During the experimental session, participants were required to direct their attention to the two displayed images and quantify the number of circles that were visible within. The data set included recordings of eye movements and initial fixations. The experiment was conducted in a single block. The experimental block comprised 48 executions of the position loop (Figure 4), with each trial displaying a stimulus pair for a period of 5000 milliseconds. Additionally, a 1000-millisecond delay was implemented, allowing participants an extended period of rest. At the beginning of each loop sequence, the participants were required to refocus their gaze on a central fixation dot. The OpenSesame software was utilized to detect and record the fixation, thereby ensuring that the participant's gaze was centred before the next pair of images was presented (Figure 5). This process was repeated until all 48 trials had been completed.

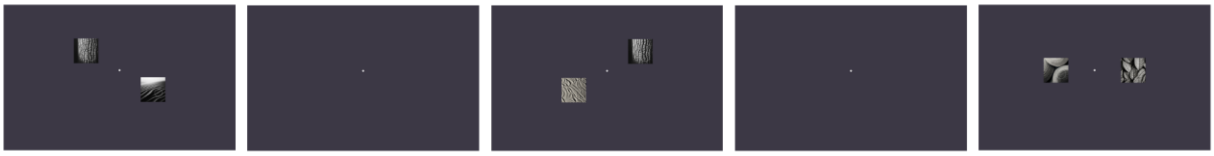

Figure 5: Example of the execution of the experiment in OpenSesame.

Upon completion of all 48 loop sequences, the recording was terminated, and a final screen was displayed to notify the participants of the conclusion of the experiment. The participants were thanked for their participation and invited to raise any questions or provide feedback on the experiment. Furthermore, they were queried as to whether they were interested in the source and outcome of the experiment. Those who expressed such interest were then provided with an explanation of the background and presented with the current results. Finally, the participants were thanked once more and invited to leave.

3. Analysis Methods

To assess the experiment, a complete analysis pipeline that automatically generates the necessary results for the given participant datasets was built. The whole pipeline, which is implemented within a Jupyter-Notebook in Python, can be summarized as follows:

1. Imports
2. Data read-in
3. Defining variables, dataframes and lists
4. Defining functions
5. Data preprocessing & Counting fixations
6. Data visualization
7. Sanity checks

In the following chapters, the most important parts of the analysis pipeline are elaborated in detail. The whole repository containing the script, and all participant data can be accessed here: https://github.com/PatrickEbner/2024-SoSe_EyeTracking

3.1 Preprocessing

In the data preprocessing, the data is prepared for the following analysis in the Jupyter-Notebook. At first, files are read by iterating over the filenames saved in the file directory. Afterwards, they are pre-processed, and the first fixations are extracted. Furthermore, the valid fixations are analysed for their positions and are added accordingly to the position-number where the participant focused. Finally, the dataframe `sum_df` contains a list with the total number of first fixations for every stimuli position from one to twelve.

Preparing dataset

The first step involves data preparation for the following analysis. Next, the data of each participant is stored in one tsv-file and gets read in and saved to a list called `tsv_files`. Afterwards it gets iterated over all entries of that list to save them in a temporary dataframe `df`. Inside these dataframes, unnecessary columns are dropped, and the time is normalized. Additionally, it is ensured that only valid points are taken into account of the analysis. Each dataframe per loop cycle is filtered by the following conditions:

```
(df['FPOGV'] == 1) | (df['USER'] == 'SHOW_STIMULUS') |
(df['USER'].str.contains('COORDINATES')
```

By filtering for these conditions, the number of rows gets reduced. However, every column containing the log entry “SHOW_STIMULUS” must be included to ensure every fixation after showing the new stimuli can be extracted by extracting the specific time for this log entry. The same is true for the coordinates, which must be extracted later to ensure that each fixation was on one of the shown stimuli. Beside this, only rows with a valid fixation gaze point are saved to ensure that the eye-tracker could detect fixations reliable and without any disruptions.

After these steps, the preprocessing is finished and the dataframe can be used to filter the initial fixations in the next step.

Counting fixations

After preprocessing the data, the first fixations after showing a new stimuli pair are extracted. This results in a dataframe with two columns containing the twelve positions and a number that demonstrates how often the first fixation was set on each of these positions. The procedure of extracting these fixations is also implemented in the described loop above about all participant datasets.

In the first step, all last fixations are extracted depending on their specific value for the "FPOGID". After that, the time for the reveal of a new stimuli pair is saved. To do this, the log column is filtered for the keyword "SHOW_STIMULUS". The particular times are saved in a list which is used later to iterate over and extract the fixations after uncovering new stimuli. During the second step, the coordinates from the shown stimuli are also extracted from the column containing the logs. Additionally, they are converted from strings to a list of numbers to make them more usable. The extraction of the coordinates is necessary to ensure that the first fixation lays on one of the shown stimuli and not somewhere else. This is important to ensure that the extracted fixation is valid and can be taken into account.

After extracting the coordinates, another smaller loop begins to iterate over the 48 shown stimuli pairs by using the list with times that have been extracted above. The extracted coordinates are compared with the first fixations after the stimuli are revealed. The function `find_closest_target` does the comparison between the coordinates at which the stimuli were shown and the initial fixation. It takes into consideration the set threshold of 100 pixels. If there was a fixation on one of the two stimuli, the coordinates of this stimulus are given back by the function. Later in the first loop, a mapping of these coordinates to the descriptive name from one to twelve is made. Afterwards, they are counted in the dataframe `sum_df` and used for further analysis in the next parts of the analysis pipeline.

3.2 Data Visualization

For the visualization of the results, four plots have been made in total. The focus of the plots lay in the visualization of the first fixations as well as on the comparison of these fixations for different stimuli pairs.

Count of first fixations on targets

At first, the counts for the twelve different stimuli positions are compared. Therefore, a clockwise layout was chosen. This enhances the direct visualizations of the fixation on each position. For each of the twelve positions the total number of fixations on this position is shown by a triangle bar (Figure 11).

Percentual comparison of different stimuli pairs

The second plot shows the percentage of first fixations by stimuli pairs. Therefore, the opposite positions are visualized combined. For better visualization, the center of 50%

is additionally added. The top-/down-combination of twelve and six is left out because the focus of the visualization lays on the left-/right-difference (Figure 6).

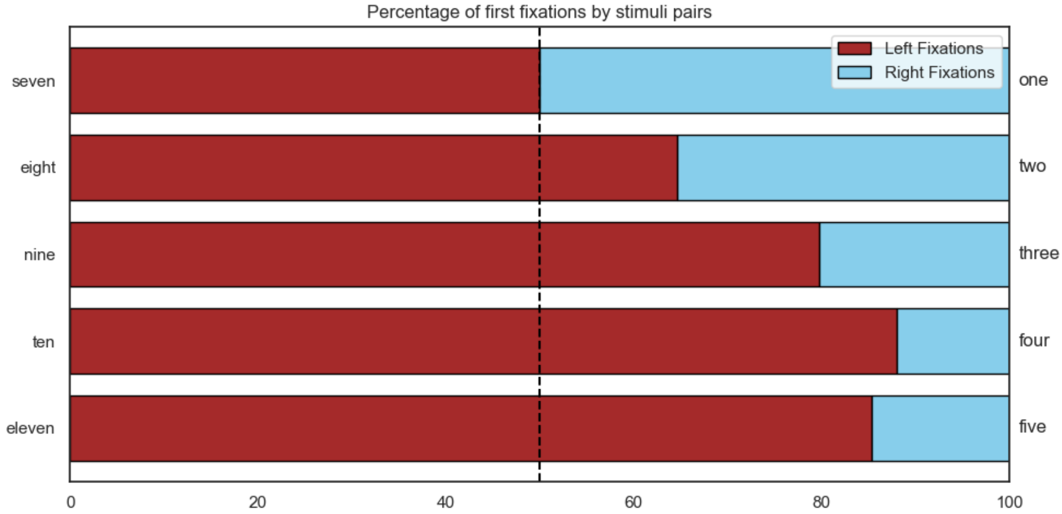

Figure 6: Percentages of first fixations by stimuli pairs.

Pairwise comparison of stimuli pairs

At last, there is the same comparison with total numbers instead of percentages. This time five different histograms show the concrete number of each position compared with its opposite position. As for the percentual view, the top-/down-combination of position twelve and six are left out (Figure 7).

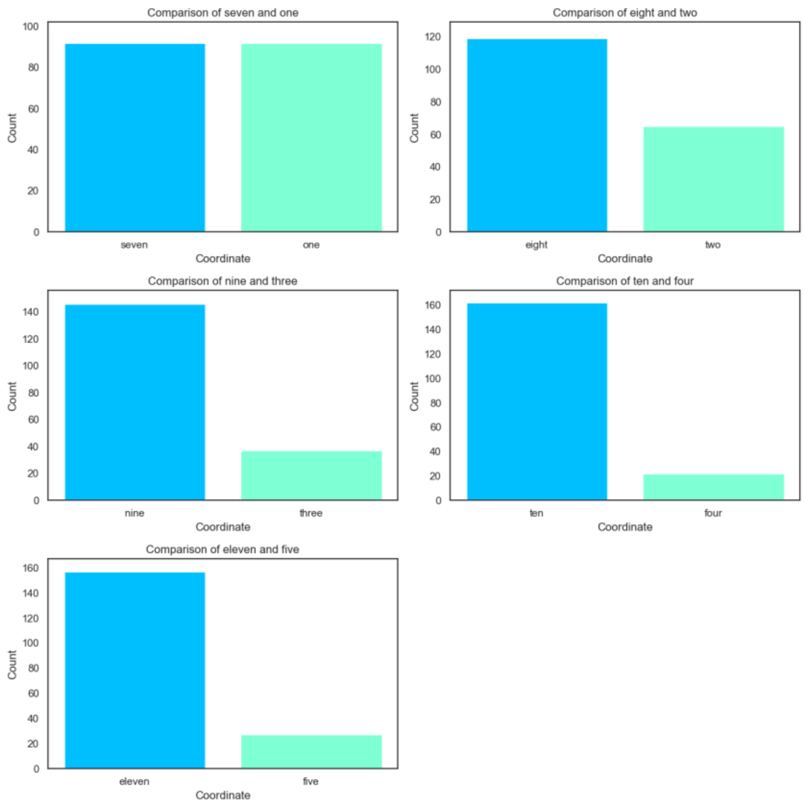

Figure 7: Comparison of specific coordinate pairs.

3.3 Quality control

To ensure the correctness of the analysis, several sanity checks were added. Target of these checks is to count the event frequency of log entries, checking and plotting the number of fixations and the appearance of stimuli pairs.

Count extracted fixations

The first thing to check is the number of extracted fixations. Therefore, the dataframe containing all fixations is taken to visualize the number of fixations for each participant. The following line plot (Figure 8) gives an overview about the overall fixations that have been extracted per participant.

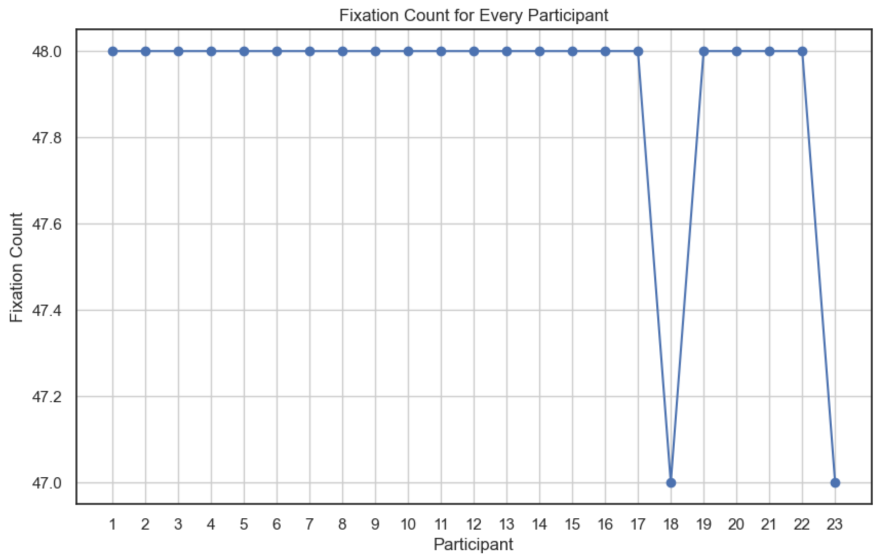

Figure 8: Fixation count for every participant the took part in the experiment.

The plot shows, that beside for participant 18 and 23 every 48 fixations have been extracted successfully. The 47 fixations for the participants 18 and 23 are still within the previously set threshold for a valid dataset. This threshold defines that at least 40 fixations must be extracted successfully. It is set to ensure that the dataset for the specific participant is valid and contains enough valuable data to count into the overall analysis.

There are several options to explain the missing fixations. Possibilities can be the distraction of the participant or unintended influences on the eye-tracker that led to bias in the tracked data, for example caused by changing lightning conditions in the experiment-room. Another possibility is that the radius for counting fixations as set on a specific stimulus is set to 100 pixels around the centre of the stimulus. If the participants first fixation does not land inside this radius, it is not considered. The radius is defined by the width of the screen (1024px) and the scale of the stimuli in OpenSesame (0.2). This scale was chosen for reasons of space so that all the pictures have enough room on the circle and do not overlap. The calculation was as follows: $1024px * 0{,}2 = 205px$. Because the radius and not the diameter is taken in the calculation of the first fixation, the value was additionally divided by two and rounded off to 100.

Appearance of stimuli pairs

The second sanity check ensures that the experiment is balanced correctly. Therefore, the number of stimuli pairs is counted. To do so, the opposite coordinates for the twelve positions are added to each other. Overall, every pair should appear for the same number of times. As seen in the plot (Figure 9), the number is almost equal for each pair. Pair 3 and pair 6 each have one appearance less. This cause can be explained by the two missing fixations for the participants 18 and 23 as described in the previous subchapter. Altogether, the experiment is balanced correctly.

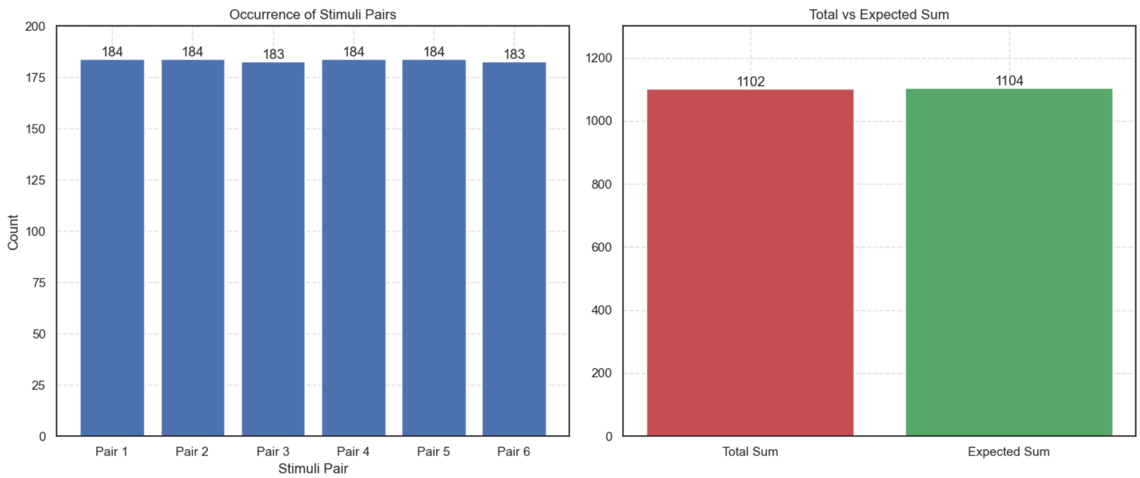

Figure 9: On the left, the occurrence of stimuli pairs is shown. On the right, the total sum is compared with the expected sum.

Event frequency

For the last quality check, the column containing all the logs during the experiment is evaluated. For this, logs have been added to the implementation of the experiment in OpenSesame to be able to read out the timing of occurring events afterwards. The new function `check_event_frequency` is defined to check the frequency of log entries by simply getting a dataframe as parameter input. It uses the pandas-function `values_counts` to return a series of containing counts of unique values in the log-column of the dataframe.

The built function can be used in two different ways. At first, one dataframe can be tested to its completeness in there. Additionally, it is possible to use a combined dataframe containing all participant data and check the total number of occurred events as seen in the plot below (Figure 10). It contains the combination of the events of the data of all participants. Only the 18 most occurring events are visualized.

The plot shows that there are some issues concerning the logs for START_TRIAL and STOP_TRIAL which only 20 and 18 occurrences in total. In fact, there should be 23 each for 23 participants. Nevertheless, these log entries are not that important, because especially missing START_TRIAL entries can be led back to minor problems with the calibration in OpenSesame, which mostly did not work out without any issues and short monitor freeze times at the end of the calibration. Some log entries for START_SEQUENCE and STOP_SEQUENCE are also missing, what is not important as well due to small delay times in OpenSesame. All not complete log entries were not used for the final evaluation of the experiment.

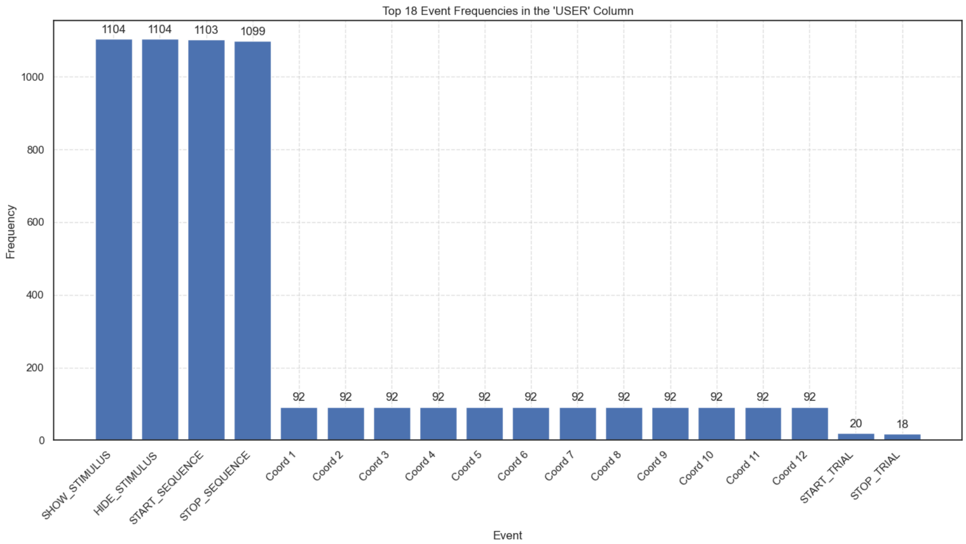

Figure 10: Top 18 occurring events in the column containing logs from OpenSesame.

Furthermore, the plot shows that the important entries are almost all correct. As seen in Figure 10, the SHOW_STIMULUS log has been counted 1104 times, which is caused by 48 stimuli pairs that are shown to 23 participants: $23 * 48 = 1104$. In addition to that, each coordinate gets used the same number of times. They are used 4 times per participant: $23 * 4 = 92$.

4. Results

This study aimed to examine the presence of a left view bias in visual attention using eye-tracking data collected from participants engaged in two image tasks. The hypothesis posited that individuals would demonstrate a tendency to look left first, even when images were diagonally positioned, and that stimuli placed at the bottom left would be more appealing than those at the top right. The experiment involved 48 trials, with stimuli displayed in twelve fixed positions arranged on a circle, always using opposing positions. Participants were required to focus on a central dot before each stimulus presentation to ensure accurate initial fixation data.

The results revealed a consistent left view bias among the participants. Participants predominantly made their first fixations on images located to the left of the fixation dot as shown in Figure 6. This was consistent across various positioning of the stimuli, supporting the hypothesis that a left view bias exists. Approximately 74% of all first fixations were directed towards the left image, indicating a robust left-side bias across participants.

Additionally, the vertical positioning of stimuli influenced visual attention. Stimuli positioned at the same height or above the fixation dot received higher attention compared to those below. The stimuli placed at the bottom right received the least attention, suggesting a combined effect of left view bias and vertical positioning on visual attention.

These observations are illustrated in the radial histogram as seen in Figure 11, which shows the distribution of participants' first fixations across twelve segments corresponding to clock positions. The histogram indicates that the highest frequencies of first fixations occurred in segments "nine" to "twelve," with these segments receiving the most attention. Conversely, segments "one" to "five" had the lowest frequencies, reflecting less initial attention.

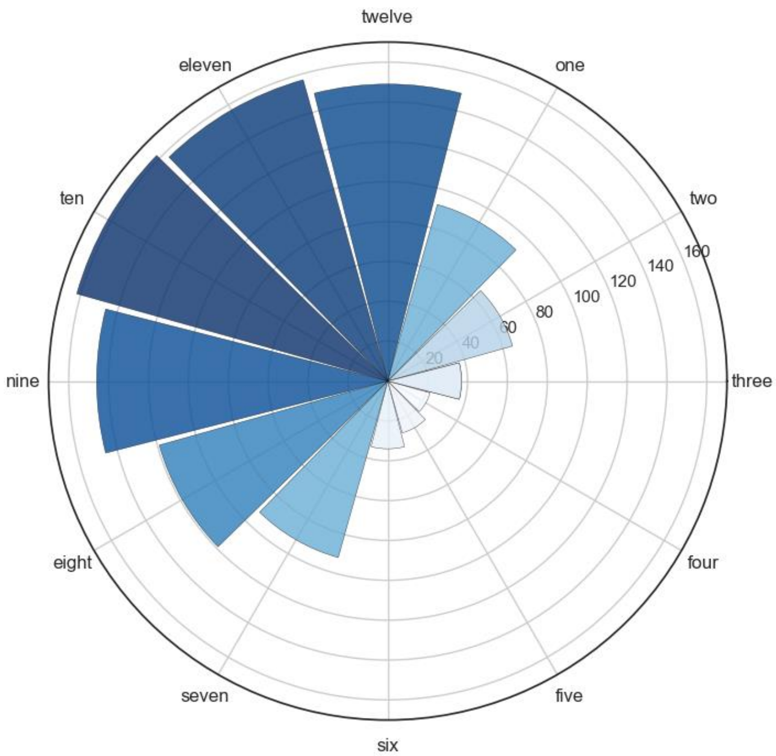

Figure 11: Radial Histogram of Participants First Fixations.

Furthermore, as discussed in the Data Visualizations chapter, Figure 6 provides a bar chart illustrating the percentage of first fixations by stimuli pairs. The chart shows a clear preference for left-side fixations across various pairs of stimuli, reinforcing the left view bias observed in the radial histogram. The left fixations dominate across most pairs, especially from "seven" to "eleven," whereas right fixations are notably fewer.

Additionally, for further visualization, Figure 7, which was also shown in the Data Visualization chapter, shows a detailed comparison of specific coordinate pairs, further illustrating the predominance of left-side fixations. The bar charts compare the counts of first fixations between diagonally opposing coordinates such as "seven and one," "eight and two," "nine and three," "ten and four," and "eleven and five." These comparisons consistently show higher fixation counts on the left coordinates with “seven and one” being the only one with the same counts for left and right coordinates.

These findings confirm the presence of a left view bias in visual attention. Even with diagonal positioning, participants showed a significant tendency to fixate on images to the left of the fixation dot first. The vertical positioning modulated this bias to the upper part of the screen, with images at the same height or above the fixation dot attracting more attention. This supports the Hypotheses that visual attention is influenced by a spatial bias that favours the left side, as well as by vertical positioning, which prioritizes higher-placed stimuli.

5. Discussion

When considering the results of this study, they should be discussed in relation to the question: "Does diagonal positioning of stimuli eliminate the left-bias in viewing images?" and the two hypotheses H1: "People tend to look left first, even with different positioning of stimuli" and H2: "A Stimulus placed bottom left is still more appealing than a stimulus placed top right and will still be focused on first."

The results provided strong evidence to support the first hypothesis. Participants exhibited a significant tendency to fixate first on images located to the left of the fixation dot, even when the stimuli were diagonally positioned. This consistent left-side bias suggests that spatial arrangement, regardless of diagonal positioning, does not eliminate the inherent preference for the left side.

However, the second hypothesis was not fully supported. The stimulus pair positioned with one image at the bottom left and the other at the top right (position seven and one), did not conform to the expectation that the bottom-left stimulus would be more appealing. The results showed that the count of first fixations was approximately the same for both positions. This suggests that diagonal positioning, specifically from top-right to bottom-left, may neutralize the left-bias for this particular pair. Nonetheless, this finding was an exception rather than the rule, as the left-bias predominated in most other stimulus pairs. This indicates that the combined effects of the left-bias and vertical positioning (top versus bottom) do not consistently offset the left-bias.

In general, the experimental results revealed that approximately 74% of all first fixations were directed toward the left image. This finding is consistent with previous studies, where Hernandez-Garcia et al. (2020) reported that around 65% of first fixations were directed to the left, and Cludius et al. (2019) found that 93% of participants first fixated on the left image. These consistent results further validate the robustness of the left-bias in visual attention. Moreover, the experiment confirmed the top-bottom bias observed in prior research (Nummenmaa et al., 2006), where stimuli positioned higher on the screen consistently received more attention than those placed lower. This was particularly evident in stimulus pairs where one image was located at the top-left and the other at the bottom-right, with only a few participants fixating first on the bottom-right image, indicating a strong interplay between the left-bias and vertical positioning.

In addition to discussing the results in relation to the research question, hypotheses, and existing literature, it is equally important to consider the limitations of our experiment, the challenges encountered, and the outlook for future research. These aspects provide a comprehensive understanding of the study's implications and help identify areas for improvement and further investigation.

Firstly, the study was conducted with a limited number of participants, specifically 23, which may affect the generalizability of the findings. Furthermore, the age distribution was skewed, with 22 participants between the ages of 20-30 and only one participant between 50-60 years old. This lack of diversity in age could influence the results, as visual attention patterns may vary across different age groups. Another limitation is the cultural homogeneity of the participants, all of whom grew up in a country and culture where the standard reading direction is from left to right. This cultural background could reinforce the left-bias observed in the study, potentially limiting the applicability of the findings to other cultural contexts where reading directions differ. Despite efforts to counterbalance the stimuli, there remains the possibility that the specific images used may have influenced the participants' choice of first fixation. The distinct visual characteristics of the stimuli, even if controlled for content, could still introduce a bias that affects the overall results.

The project encountered several challenges that impacted the execution of the experiment. Initially, there were issues with the fixation dot, where it did not function correctly, causing the experiment in OpenSesame to advance randomly to the next stimulus pair rather than based on participant input. Additionally, we faced difficulties in filtering the first fixation for each stimulus pair, as only the initial fixations on the images were relevant for measurement. Scheduling conflicts also posed a challenge, given the busy lab schedule and the need to coordinate with all five team members. Furthermore, recruiting a sufficient number of participants was challenging and technical issues arose when OpenSesame occasionally crashed during trials, leading us to attempt recoding the experiment, though the issue was ultimately unrelated to our code. Lastly, an initial error in the Y-axis orientation, where it was mirrored incorrectly, led to a misinterpretation of the data, suggesting a false bottom-top bias that had to be corrected.

Looking forward, this experiment has contributed valuable insights by confirming both the left-bias and the top-bottom bias in visual attention. However, the limitations of our experiment highlight the need for caution when interpreting the findings and suggest that further studies with more diverse participant samples and varied stimuli are necessary to fully understand the effects observed in this experiment. Future studies could benefit from including more stimuli pairs and images, as well as testing participants from a broader range of age groups and cultures to ensure the findings are more widely applicable.

Key lessons learned from this project include the importance of thoroughly testing the experiment on various hardware configurations to ensure that issues are related to the experiment itself and not to software bugs. Participants should only be invited once it is certain that the experiment runs smoothly and that the core features are fully functional, ensuring that the collected data is usable for analysis. Additionally, it is crucial to double-check the orientation of axes to prevent erroneous conclusions, and maintaining effective communication within the team is essential for the success of a long-term project like this experiment.

6. Contribution Table

Task	Claudius	Enno	Maximilian	Patrick	Simon
Milestones					
Creation		o	x	x	o
Presentation	o	x	x	o	o
Final Presentation					
Creation			x	o	
Presentation	x	x	x	x	x
Literature					
Experimental setup		o	x	x	
Input for plots				x	
Experiment					
Picture creation	o	x	x		x
OpenSesame		o	o	x	o
Participant data recording			x	x	
Python					
Fixation detection		x		o	o
Plotting	o	x		x	o
Git		o	o	x	
Report					
Introduction					x
Experimental methods			x		
Analysis methods				x	
Results		x			
Discussion	x				
Report lectorate	x	x	x	x	x

Legend: x = main, o = supporter

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Eigenständigkeitserklärung

Hiermit versichere ich,

- dass die Arbeit, bzw. bei einer Gruppenarbeit mein entsprechend gekennzeichneter Teil, selbstständig verfasst wurde,
- dass keine anderen als die angegebenen Quellen benutzt und alle wörtlich oder sinngemäß aus anderen Werken übernommenen Aussagen als solche gekennzeichnet wurden,
- dass keine anderen als die angegebenen Hilfsmittel verwendet wurden,
- dass die eingereichte Arbeit weder vollständig noch in wesentlichen Teilen Gegenstand eines anderen Prüfungsverfahrens war und
- dass die Arbeit weder vollständig noch in Teilen bereits veröffentlicht wurde.

Stuttgart, den 31/08/2024

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