Abstract—The recent developments in the eye tracking technology lead to new insights in how humans read, yet little is known about how the layout affects the comprehension. In this study, the differences in the understandability and the reading behaviour of different page orientations (i.e. portrait and landscape) of a scientific poster are investigated. An eye tracking experiment was designed to find out whether the participants focus more on different areas in different orientations and whether the orientation has any effect on the reading behaviour or the overall comprehension of the poster. The participants’ gazing were recorded and mapped onto the document using homographies. The saccade and transitional analysis over 30 participants concludes that the portrait orientation is better for remembering specific details while the landscape orientation supplements a high level understanding.

I. Introduction

Posters play an essential role in scientific communities by conveying information to the audience. Thus, studies showing how to create favourable posters are quite helpful. Posters are important to attract attention since they can “speak for themselves” [1]. This is related to the fact that posters show complex information in a structured way [1], [2] and that visualisations have a huge impact on communication and understanding [3]. A major field of study is the analysis of layout and its effects on the reading behaviour and the understanding of the reader.

Some research has already been conducted to analyse the effects of the layout. For example, Mozaffari et al. [4] investigated how line spacing affects the reading behaviour and found out that it has significant influences on the ease of reading and the required reading time. They also had a look on different layouts of scientific papers [5]. They compared the Association for Computing Machinery double column format with the Springer Lecture Notes single column format. One finding was that people reading the double column format spent more time looking at formulas while needing less reading time in total.

The effects of different line widths were analysed by Beymer et al. [6] as well. Similarly to the study of Mozafari et al. [5], their work is in agreement on shorter lines increasing the reading speed. However, they noticed shorter lines caused less reading coverage because the readers omitted some paragraphs while reading. The most interesting implication of this work is probably that shorter line lengths increase the retention significantly.

This study compares the effects of different page orientations (i.e. portrait and landscape) on the understandability of scientific posters and focuses on printed hard-copies. The eye tracking technology is used to find differences in the reading behaviour: A wearable eye tracker captures the scene and acquires data during the entire reading process. Afterwards, the gaze data is mapped onto an image file of the poster using homographies. Lastly, this data is analysed to answer the questions whether the page orientation has an effect on the overall comprehension of the poster, whether it makes readers focus more on different areas and how it influences the reading behaviour.

The structure of the paper is as follows: Section II gives information on the experimental setup, Section III explains the data acquisition process and Section IV presents the data analysis and the results. The paper is concluded in Section V; some limitations of this study and ideas for future work are stated in Section VI.

II. Experimental Setup

This section presents information on the poster creation process, the participant selection, the used eye tracking device and the experimental setup.

A. Poster Design

The goal is to analyse whether the page orientation (i.e. portrait or landscape) of scientific posters has an influence on the understandability and the reading behaviour. Therefore, two versions of the same poster were created. Both posters have size $A_0$. There were several discussions with people from the local university's psycholinguistics department to improve the poster. The contents of the poster deal with another eye tracking study that was not yet published when this study was conducted. Thus, it was impossible for the participants to have knowledge of the contents of the poster before attending the experiment. This is important to ensure the results of the questionnaire are not skewed.

The changes between the two versions are limited to the page orientation and positioning only, i.e. font, font size etc. are identical. Thus, the major difference is the positioning of the paragraphs and figures.

B. Participants

30 master level students from the department of Computer Science in the local university participated in this study. They were divided into two groups of 15 subjects each. One group read the portrait, the other one read the landscape version. The
participants were asked to state their average grade they have at the university to make sure both groups are comparable. The portrait group has an average grade of 2.39, the landscape group of 2.14. The scale of the grades ranges from 1.0 (very good) to 4.0 (sufficient).

C. Apparatus

The SMI ETG 2.7\(^1\) eye tracker operating at 60 Hz was used in this study. It has a scene camera, which records the field of view with a resolution of 960 x 720 pixels and 30 frames per second. There are several infrared light sources for each eye. Humans cannot perceive this infrared light, but the reflections are captured by the device and can be used to measure the eye movement. This is a lightweight wearable eye tracker and thus does not require the user to limit their head movements. Some properties of the eye tracker were computed during a test session for a single person before the experiment:

- average horizontal precision: 0.17\(^\circ\)
- average vertical precision: 0.702\(^\circ\)
- average accuracy: 1.365\(^\circ\)

D. Experimental Setup

Before starting the experiment, the participants were informed they would have to answer a questionnaire afterwards. The questionnaire contained twelve questions in total and required both multiple choice answers and writing free text. There were eight easy questions that referred to topics of the poster (e.g. 'What were the research questions?') and four difficult questions whose answers were individual words such as the tracking frequency or a particular cell in a table. However, one of the difficult questions referring to the funders in the Acknowledgement section was ignored in the analysis because some of the participants knew the name and had an advantage when answering this particular question. Additionally, a spelling mistake was introduced intentionally to see how thoroughly the poster is read.

The participants read the poster from a distance of approximately 2 metres. The eye tracker was calibrated using the 3-point calibration process (i.e. participants had to focus on three different points, the offset of the device was adjusted accordingly) and a verification was performed to see whether the calibration was sufficient.

III. DATA ACQUISITION

Information on how the data was acquired and processed is given in this section. In order to see how the poster was read, the gaze first has to be mapped onto the document; the raw data cannot be used without this step because of differing head movements.

A. Fixation Detection

The eye tracker captures the position of the gaze twice for each frame in the video, i.e. the data representing the continuous movement of the eye is not entirely available. A gaze location is a triple \((t, x, y)\) that indicates the position of the gaze \((x, y)\) in the frame of the video captured by the scene camera at time \(t\). But having continuous data is not necessary because the eye remains almost still for a short time when humans look at something (for example a word during reading). These fixations are considered if the gaze position remains mostly unchanged for a short time period (the minimal duration for humans to process what they are seeing is about 150 ms according to Rayner et al. [7] and Manor et al. [8]). These fixations have to be detected because the duration of the individual gaze positions is not long enough. Thus, several gaze positions lying close to one another are combined to form a fixation with a longer duration. This is done using the dispersion approach (see e.g. Holmqvist et al. [9]) also used in other eye tracking experiments by Biedert et al. [10], Buscher et al. [11] and Al-Naser et al. [12].

B. Gaze Mapping

The aim is comparing the reading behaviour of the different participants. But so far, the only available data are the fixations and their positions with respect to the video. It is not possible to compare fixations like this from different participants due to differing head positions. Therefore, object recognition, i.e. trying to find the location of the poster within the frames of the video is performed. To achieve this, there are algorithms to detect and compute local features of images. These describe so-called keypoints, which in turn can be used to compute a homography [13] between the video frame and the softcopy of the poster (a document with original resolution 1984 x 2787px or 2787 x 1984px respectively). A homography is essentially a mapping from a plane onto another. In this case, from the wall the poster is pinned to onto the image of the poster. Thus, it is possible to map the fixation’s coordinates onto the image and compare the fixations afterwards.

Several different algorithms were tested to compute these keypoints for the video frames and the poster image. In a pilot study, SIFT (Scale-Invariant Feature Transform) [14], SURF (Speeded Up Robust Features) [15] and ORB (Oriented FAST and Rotated BRIEF) [16] were used and compared in respect to the accuracy, precision and processing time. Fig. 1 shows some results of this comparison using many of the

\(^1\)https://www.smivision.com/eye-tracking/product/eye-tracking-glasses/
The saccade analysis has a closer look on how the participants read the poster. In contrast to the transitional analysis, the focus does not lie on the fixations but rather on the eye movements between two consecutive fixations, the so-called saccades.

There are different types of saccadic eye movements during the reading activity. These are assigned to different categories for the analysis of the reading process [7]: A Forward Reading is a progressive saccade associated with reading. Long Jumps are those saccades that have a higher length than a threshold considered for the context. The direction of a saccade is irrelevant for long jumps. Regressions are backward saccades usually associated with difficulties in reading. The saccadic length varies in regressions but must be within a given threshold. Sweeping back to the beginning on the next line of text is called a Sweep Return.

Fig. 2 describes the (normalised) average number of forward readings and regressions for both groups. The average number of regressions in the portrait group is two times as high as the number for the landscape group, but there were only slightly more forward readings on average (301 for portrait compared to 266 for landscape). Based on this, it is possible to calculate the forward reading to regression ratio, i.e. how many consecutive forward readings are there before being interrupted by a regression. This measure is an indicator of how fluently the participants read the text. For the landscape group, there are 5.99 forward readings per regression on average, whereas there are only 3.42 forward readings per regression for the portrait group. This is a significant difference according to an independent t-test (p-value: 0.00017) and shows that overall, the portrait group needed more concentration to read the poster.

Other measures mentioned by Holmqist et al. [9] were also computed: the number of return sweeps, the saccade velocity, the average length of forward readings, the blink rate, the blink duration, the saccadic rate (number of saccades per second), the average forward reading size (number of consecutive forward readings) and the average forward reading duration (total duration of consecutive forward readings). However, there were no significant differences between both groups.

### C. Questionnaire Evaluation

After reading the poster, the participants answered a questionnaire that required both multiple choice and free text answers. There were twelve questions in total containing four difficult questions that referred to a single word or a single cell in a table. One of the difficult questions was ignored in this analysis because some of the participants had an advantage when answering it. One of the non-difficult questions asked the participants whether they noticed a spelling mistake that was made intentionally.

<table>
<thead>
<tr>
<th></th>
<th>Landscape</th>
<th>Portrait</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>36.11%</td>
<td>37.50%</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>17.55%</td>
<td>12.35%</td>
</tr>
<tr>
<td>Maximum</td>
<td>62.50%</td>
<td>56.25%</td>
</tr>
<tr>
<td>Minimum</td>
<td>12.50%</td>
<td>12.50%</td>
</tr>
<tr>
<td>Score in difficult questions</td>
<td>17.78%</td>
<td>37.78%</td>
</tr>
<tr>
<td>Score in other questions</td>
<td>39.49%</td>
<td>37.40%</td>
</tr>
<tr>
<td>Spelling mistake found</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

**TABLE I: Scores of the Questionnaire.**
Fig. 3: The average percentage of points reached in questions referring to the different sections of the poster. E.g. both groups scored 60% of the possible points in the questions whose answers could be found in the Discussion section of the poster. The portrait group scored better in the Methodology section whereas the landscape group was better in the Diagrams and References section.

Table I shows how the participants performed in the questionnaire. On average, there is a rather slim difference in the scores for both groups (1.39%). The individual scores for the landscape group are spread further as can be seen by the values of the standard deviation and the min- and maxima.

Nonetheless, there are also more apparent differences between both groups: The portrait group scored 20% better in difficult questions and found the spelling mistake more often (three times as often). This indicates that the portrait layout encourages more thorough reading. According to an independent t-test, this difference can be considered significant (t-value: -2.2108, p-value: 0.0177). A possible explanation for this difference might be the significantly lower forward reading to regression ratio, which indicates the participants needed to concentrate more on the poster to read it.

Fig. 3 shows how the groups scored on average when grouping the questions referring to the different sections. Here, the portrait group scored 33.3% in the Methodology section, whereas the landscape group only scored 6.7%. This difference occurs because the answer to a difficult question and the spelling mistake were located in this section. In contrast, the landscape group was better in questions referring to the Diagrams section. This indicates that the landscape group had a better high-level understanding of the poster because the diagrams do not make sense without some insight on what the poster is about.

Another important aspect is the dwell time, i.e. the accumulated amount of time people spent focussing on different sections. This shows whether the participants were concentrating on the same or different aspects of the poster. Differences here can also explain the differences in the performance in the questionnaire. Fig. 4 shows the average dwell time for both groups and each section of the posters. There are no significant differences to be found with the largest one being in the Results section with about 5%. Hence, the reading time does not differ much and is not the cause for the different scores in the questionnaire.

V. CONCLUSION

This paper presented a study on the differences of poster page orientation (i.e. landscape and portrait) and analysed how it affects the understandability and the reading behaviour. A poster was designed for each orientation, and each poster was read by 15 participants while wearing an eye tracker. Each participant had to answer a questionnaire regarding the poster afterwards. The data acquired by the eye tracker was first mapped onto the document using SURF keypoints [15] and homographies. This data was analysed afterwards by considering the overall order the poster is read in and by examining typical eye movements during the reading process.

There were no differences in the overall performance in the questionnaire. However, the portrait group scored significantly better in the difficult questions and spotted the spelling mistake more often. This implies that the portrait page orientation is beneficial for a thorough understanding.

The landscape group performed better on questions referring to the diagrams. The difference in the forward reading per regression ratio shows that the readers of the landscape version read the text more fluently. This might very well be the reason why they did not perform as well in the difficult questions since they did not scan the text as much as the portrait group did.

Regarding the transitions, most of the portrait group started reading the poster in the expected order (i.e. Title and Introduction first) whereas only half of the landscape group did this. This shows that the landscape group had difficulties understanding the structure of the poster at first; possibly because there were three columns in contrast to the two columns in the portrait poster, where it was clear where to start reading.

There were no significant differences in the other measures used in this study: saccade velocity, average length of forward readings, blink rate, blink duration, saccadic rate (number of saccades per second), average forward reading size (number
of consecutive forward readings), average forward reading duration (total duration of consecutive forward readings).

VI. DISCUSSION AND FUTURE WORK

This initial exploratory experiment was rather limited: Only one poster was tested and the difference between landscape and portrait was the location of the information blocks. Only one different arrangement was used per format. It would be interesting to see whether the results can be reproduced with other posters and a different positioning of the sections.

Mur-Artal et al. [19] used the ORB [16] features for a real time Simultaneous Localisation and Mapping (SLAM) [20] system. Hence, with some optimisation of the gaze mapping system used in this study, it is possible to create a real time human document interaction system similar to the Text 2.0 framework proposed by Biedert et al. [21].

This study did not analyse whether there are differences between male and female readers since the majority (over 70% of the participants) were males. Therefore, there simply was not enough data for an evaluation of this question. Nevertheless, it is possible that there are differences between male and female readers. Hence, another study is required for an analysis of these differences.

The ethnic background was also not considered in this study; the participants were mostly from Germany and India, only one participant was from Vietnam. The language of the poster was English, which was not the mother tongue of the participants. It is possible that there are differences across varying nationalities [22], [23]. In this context, it is also noteworthy to look at the writing system the participants grew up with: In English, one usually writes from left to right, whereas in Arabic or Japanese for instance, this is different. This might affect the order of reading. More research is required to examine these influences.

VII. ACKNOWLEDGMENT

To be added after the review.

REFERENCES