Report Optimization using Visual Search Strategies

An Experimental Study with Eye Tracking Technology

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Abstract: The success of visualisations is determined by the ability of users to retrieve relevant information in an effective and efficient way. The way in which information is perceived can be analysed by examining visual search strategies of users. Visual search strategies in graphical representations however, are individual and have not been well explored up to now. Recent studies show that eye tracking experiments help in gaining new insights into these strategies. Apart from error rates and task completion times, eye tracking focuses on the way observers of visualisations read and make sense of the presented stimulus. In this way sequential strategies can be analysed, compared and used in order to optimize graphical layouts. In this study we use the approach of Parallel Scan Path visualisation in combination with Levenshtein Distance to determine similarities between search strings when viewing graphical representations in standardized business communication. This study shows a positive correlation between search strategies and task completion time and allows the evaluation of different design layouts. Positive significant effects can be detected when examining experience (with respect to standardized and repetitive reporting) and layout optimization (with respect to graphical representations and page layout). Optimal search strategies can be identified when users are experienced and using an optimized layout.

1 INTRODUCTION

Visual representations are used in business communication on a daily basis. This is due to the fact that people tend to retrieve and process information more efficiently and effectively in the presentation format of a graph than in text or plain numbers (Conati and Maclaren, 2008, Renshaw et al., 2003). Visual stimuli rely on the use of people's well established skill of perceptual sense making (Lurie and Mason, 2007). The cognitive burden can be shifted to the automated perceptual processing of visualisations resulting in a lower workload (Speier, 2006).

However, understanding the impact of individual differences on the process of perception is difficult because not every cognitive factor and its effects on the visualisation performance has yet been identified (Peck et al., 2012, Pfitzner et al., 2001). Therefore although the benefits of visualisations are known and visualisations are used frequently in almost all disciplines the full process of cognition is not transparent or controllable (Huang and Eades, 2005). Instead it is complex and individual, as it depends on many different influencing factors such as personality, spatial ability, task, presentation mode, emotional state, experience, knowledge or culture (Barat 2007, Huang and Eades 2005, Peck et al. 2012).

Besides this problem concerning influential factors the question for the right technology to investigate and measure this process is raised in the literature (Elmqvist and Soon Yi, 2013). One method that seems to have gained interest is the use of eye tracking technology to better understand and interpret the process of information retrieval and therefore the process of perception (Conati and Mclaren, 2008, Falschlunger et al., 2014, Goldberg and Helfman, 2014). Eye tracking can provide insights into diagnostic information to a designer that exceeds the information provided by the analyses based solely on response time and error rate (Goldberg and Helfman 2011). In this study we use this technology to contribute to the research on influential factors on the process of visual perception. In particular two factors are being researched: the effect of experience with respect to standardized and repetitive reporting and the effect of design choices with respect to graphical representations including page layout.

In this paper we provide a discussion on previous research in this area and present the basis for the conducted experiments. Then the applied method is

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explained in detail before describing the deduced hypotheses. The results will be shown and discussed in the final parts of the paper.

2 THEORETICAL BACKGROUND

2.1 Information Visualisation in Business Communication

In business communication graphs and tables are the most common visualisations used (Beattie et al., 2008). Whether to use a table or a graph has been discussed since the 70s in the literature (Vessey, 1991), however functions and understanding of the structure of the brain in combination with visualisations has only been the focus of discussion in the last few years in the field of information visualisation. The purpose is to find visual abstractions that help the human brain to process and understand information in a more effective and efficient way (Keller et al., 2006).

As mentioned before, there are a lot of different influences on the process of perception, however, in this paper only two of these influences are discussed and investigated. The effect of experience was chosen because this is one of the least investigated areas in this field (Peck et al., 2012) and layout optimization incorporates previous knowledge and enhances the understanding of the factor experience even further.

2.1.1 Effect of Experience on the Cognitive Process

Experience is associated with the formation of effective reasoning strategies for given problem types. Strategies learned in combination with visual representations can be used every time the same stimulus is presented. Studies on Cognitive Load supporting this thinking investigate the difference between working memory and long-term memory. On the one hand, working memory represents the temporary storage area with very limited capacity and duration and on the other hand, long-term memory represents permanent storage with unlimited capacity (Mostyn, 2012, Sohn an Doane, 2003). Studies indicate that a standardized and repetitive reporting shift the process of perception to long-term memory and therefore enhance the process of perception (Anderson et al., 2011,Peck et al., 2012).

Learned experience is said to influence the be haviour when similar situations arise, however, there is little research on the impact of experience on the interaction with visual representations (Peck et al. 2012).

2.1.2 Effect of Design and Layout of Graphical Representations on the Cognitive Processes

Another way to lower Cognitive Load is to enhance the capacity of short term memory by enhancing effectiveness and efficiency of the chosen display format (Anderson et al., 2011, Peck et al., 2012). A visual stimulus that does not take human cognitive architecture into account is likely to be random in its effectiveness. Research in previous studies indicate that the way visual representations are designed and formated influences the perception of users (Anderson et al., 2011, Falschlunger et al., 2014, Hill and Milner, 2003, Huang and Eades, 2005). Working memory in the context of information load, for example, states that it is better for the decision making process to display relevant information in close proximity because of limited resources in short-term memory (Parsons and Tinkelman, 2013). Theory also suggests that labels and figures should be placed in juxtaposition to their data series to emphasize their relationship and reduce cognitive load (Falschlunger et al., 2014).

The layout of a visualisation therefore predetermines visual search strategies and by optimizing these layouts capacity limits can be enhanced. A short summary of rules identified in previous research is listed below (Falschlunger et al., 2014, Renshaw et al., 2003, Ware, 2013):

- Do not use broken or non-zero axis
- Do not use three-dimensional effects for two dimensional displays
- Do not use gridlines when values are stated next to or above the data marker
- Use gridlines when no values are stated next to or above the data marker
- Place data label in close proximity to the data marker they represent
- Do not use too many data in one chart
- Use colors that are distinguishable

2.2 Use of Eye Tracking for Evaluation of Information Visualisation

According to Raschke et al. (2012) eye tracking is a state of the art technique to investigate the usability of graphical interfaces while taking into account cognitive abilities of the human brain. Eye tracking is supposed to provide new insights into the differences of sequential strategies between various design alternatives and therefore helps to improve the effectiveness and the efficiency of graphical representation for specific user groups (Goldberg and Helfman, 2011). This methodological approach measures the common metrics used (task completion time and error rates), how the attention of an observer changes during the period under review and it helps to compare different search strategies of different user groups (Raschke et al., 2014).

When analyzing eye tracking data, fixations, saccades, and scan paths are of particular interest. Fixations are short stops where the eye can process information, whereas longer fixations are associated with greater visual and/or cognitive complexity (Goldberg and Helfman, 2014, Renshaw et al. 2003). Saccades are quick movements from one fixation to another, which can be used to derive a participant's attention pattern (Toker et al. 2013) and scan paths represent a string of related fixations and saccades. For analysis, an unduly long scan path is believed to indicate a non-meaningful representation or a poor layout (Renshaw et al., 2003).

In eye tracking studies that test the usability of a visual representation, a large amount of data is collected which observes complete specific tasks. While data collection is relatively simple nowadays due to technical progress, analysis is difficult because of the high variety of scan paths between users (Tang et al. 2012). Individual scan paths are often seen as random and noisy, however, methods are available to compare as well as aggregate them in order to form groups and uncover cognitive strategies (Goldberg and Helfman 2010).

In this study we use a string comparison method for analysis: the Parallel Scan Path visualisation technique developed by Raschke et al. (2012). The model is based on the analysis of areas of interest (AOIs) and the sequence in which these AOIs are fixated as well as re-fixated. Parallel Scan Path visualisation helps in comparing different strategies by visualising scan paths (Raschke, 2014). The vertical axis represents time and the horizontal axis the number of AOIs identified (see figure 1). Through visualizing sequential strings similar patterns can be identified much easier and grouped together.

Therefore the following metrics are used: total number of fixations over a given length of time, the gaze duration as well as the number of fixations in a defined AOI. For AOI definition spatial clustering is used by choosing AOIs where the focus of attention lies (Goldberg and Helfman, 2010). Identification of these areas is made through the help of heat maps generated by NYAN 2.0 Software. According to

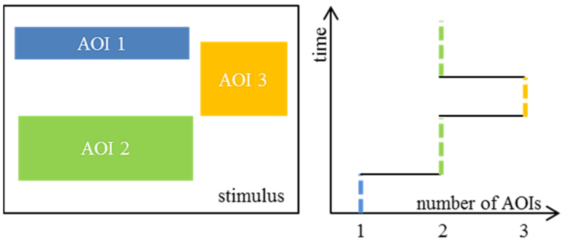

Figure 1: Gaze Duration Sequence Diagram (based on Raschke et al., 2012).

Blignaut (2010) heat maps are semi-transparent, multi-colored layers that cover areas of higher attention with warmer colors and areas of less attention with cooler colors.

Using sequential orders (by writing down the exact way the identified areas are fixated), a string can be generated. An example would be: 111111111133111113333331. As requested in the paper of Raschke et al. (2014a), in order to focus on the sequential order of areas fixated it is necessary to generate a compressed string. Compression is achieved by replacing series of the same number by only one number in the string. The result of the compression of the above stated example therefore is: 13131. This compressed string is used to distinguish search strategies between groups. A string comparison method (Levenshtein distance) of these compressed strings is used (Goldberg and Helfman 2010). The Levenshtein distance (LD) calculates the minimum number of operations needed to insert, delete, or substitute characters or numbers in one string to be transformed into another one (Levenshtein, 1966, Tang et al. 2012). Strings with low LD are grouped together.

3 METHOD

3.1 Design

Participants answer a question by looking at two different design layouts presented on a computer screen. Figures within the presented stimuli are slightly changed so no memory effect applies. Randomization of the two displays is used. After reading, participants are supposed to answer the question and then the test leader moves on to the next slide by clicking. No time constraints are imposed.

3.2 Participants

Two experimental groups are formed: the first group consists of staff from different hierarchy levels of a company who are familiar with the report (referred to as "group familiar" or "experienced report users") and the layout of the tested page and the second group consists of part time students who have never seen the report or the layout of the tested page before (referred to as "group unfamiliar" or "novice report users") but have experience in report as well as graph reading.

19 evaluable scan paths for the group "familiar" and 18 evaluable scan paths for the group "unfamiliar" are analysed in this study. Scan paths with low quality of fixations have been detected and sorted out (Holmqvist et al., 2012). All participants had normal or corrected-to-normal vision.

3.3 Apparatus

The study is conducted in a pervasive lab and the height and the distance to the eye tracker is the same for each participant. A headrest is used to ensure minimum head movement. The eye tracking hardware by Interactive Minds is a binocular eye tracking system with a sampling rate of 120 Hz. A nine point calibration and NYAN 2.0 software are used.

3.4 Stimuli and Procedure

Stimuli are presented with a white background. The question is placed on the top of the screen marked by a grey box. The first stimulus used as example in this paper is one page out of a monthly reporting of a listed company in Austria. The page represents a layout used in 74% of the report and therefore can be identified as the most important layout for optimization. An anonymized example of this page can be seen in figure 2 (note: only the relevant part of the page is displayed for better readability).

The question is formulated in agreement with the company and targeted at the most important information of the page which is: *Are we below or above the budget in the current month?*

According to the literature it can be expected that the continuous use of this layout enhances the perception process of the experienced group. This leads to the first deductible hypotheses:

- H1: Experienced report users are faster than novice report users when viewing a familiar layout with a familiar content.
- H2: Experienced report users have a shorter sequence string when viewing a familiar layout with a familiar content than novice report users.
- H3: There is a positive correlation between time and sequence strings.
- H4: Levenshtein Distance within the group of experienced reports users is lower when viewing a familiar layout with a familiar content than within the group of novice report users.

As we are trying to optimize the page layout an example using the same amount of information but considering the results of research in information visualisation especially for graphical displays is created and shown in figure 3 (note: only the relevant part of the page is displayed for better readability).

The same question is asked in order to compare results: *Are we below or above the budget in the current month?*

Again when considering previous literature, it can be expected that users who are familiar with the content show better performance than novice users. Additionally, the page layout optimization should lead to better results than the page layout presented before.

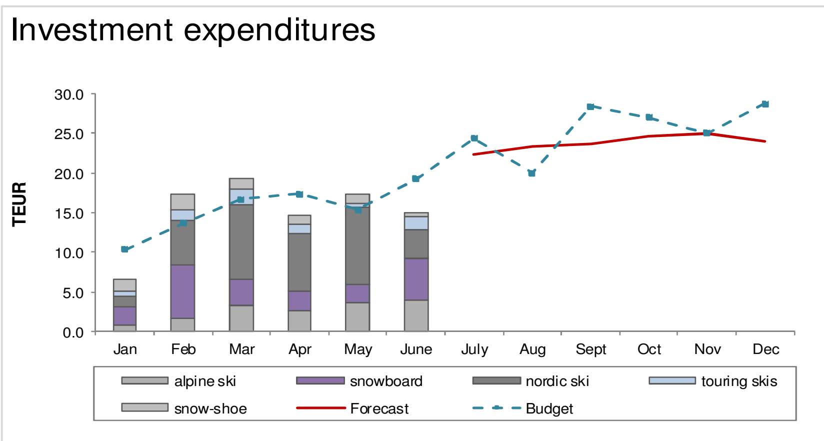

Figure 2: First stimulus of the experiment.

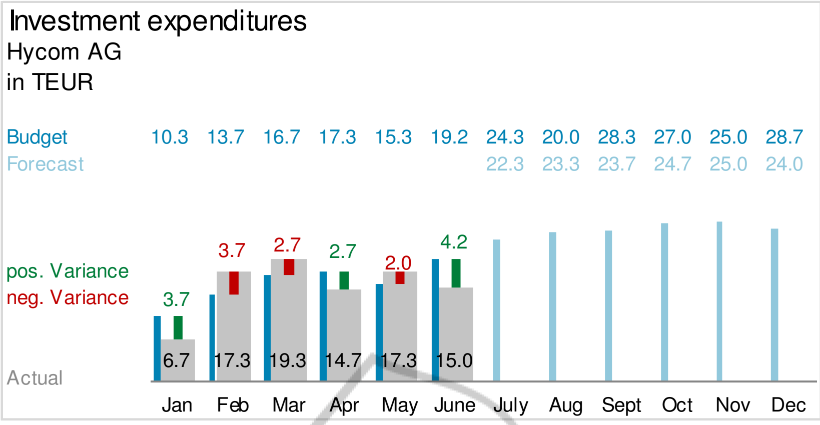

Figure 3: Second stimulus of the experiment.

This leads to the following testable hypotheses:

H5: Experienced report users are faster when viewing a new layout with familiar content than novice report users

H6: Experienced report users have a shorter sequence string when viewing a new layout with familiar content than novice report users.

H7: There is a positive correlation between time and sequence strings.

H8: Levenshtein Distance within the group of experienced report users is lower when viewing a new layout with familiar content than within the group of novice report users.

H9: The influential factor page layout has a higher impact on visual search strategies than the factor experience.

H10: Novice report users are affected more when the page layout is changed.

4 RESULTS AND DISCUSSION

4.1 Stimulus 1

The error rate for stimulus 1 for participants that are familiar with the report is 0% and for participants that are unfamiliar with the report it is 3.7%. No significance (p=0.346) can be detected between groups using a non-parametric test (Mann-Whitney-U test).

Analysis for efficiency starts by comparing response times for each group. Average response time in group “familiar” is 11.2 seconds compared to 15.8 seconds in group “unfamiliar”. No significant difference can be detected using students t-test (p=0.377).

The next step is to compare the overall number of fixations needed. Again no difference between groups can be detected (group 1: 45.8 and group 2: 68.1 with a p-value of 0.422). Hypothesis 1 that experienced report users are faster than novice userscannot be confirmed.

However, efficiency can be analysed in more detail when evaluating visual search strategies. In order to be able to analyse the visual search strategies of participants three steps have to be followed. Step one is to summarize all fixations of all participants of each group (participants who are familiar with the report and participants who see the report for the first time) by the use of heat maps. Step two is to use these heat maps as a basis for the definition of AOIs and step three is the generation of the Gaze Duration Sequence Diagram.

The generated heat maps for stimulus 1 and the corresponding AOI definition is shown in figure 4. The grey box in example (a) ensures anonymity of the company. Six areas of interest are defined.

For the group “familiar” 80.3% of the gaze duration lies within the defined AOIs and for the group “unfamiliar” 85.5%. This justifies the identification of task relevant areas and annotations and therefore supports the selection of these areas as AOIs.
The area gaining the most gaze duration of the participants that are familiar with the reports is AOI 1 (60.2%), which shows the task. The second most interesting area is AOI 2 including the part of the chart where the answer can be extracted (18.0%), and the third most observed area is AOI 4 including the data labels (9.9%). Results for participants that see the report for the first time are the following: AOI 1 59.9%, AOI 2 18.6% and AOI 4 10.8%. The numbers look similar but there is an indication that those who are not familiar with the use of the defined color-use (red for forecast and blue for budget) spend more time reading the data labels than those who are familiar with the report.

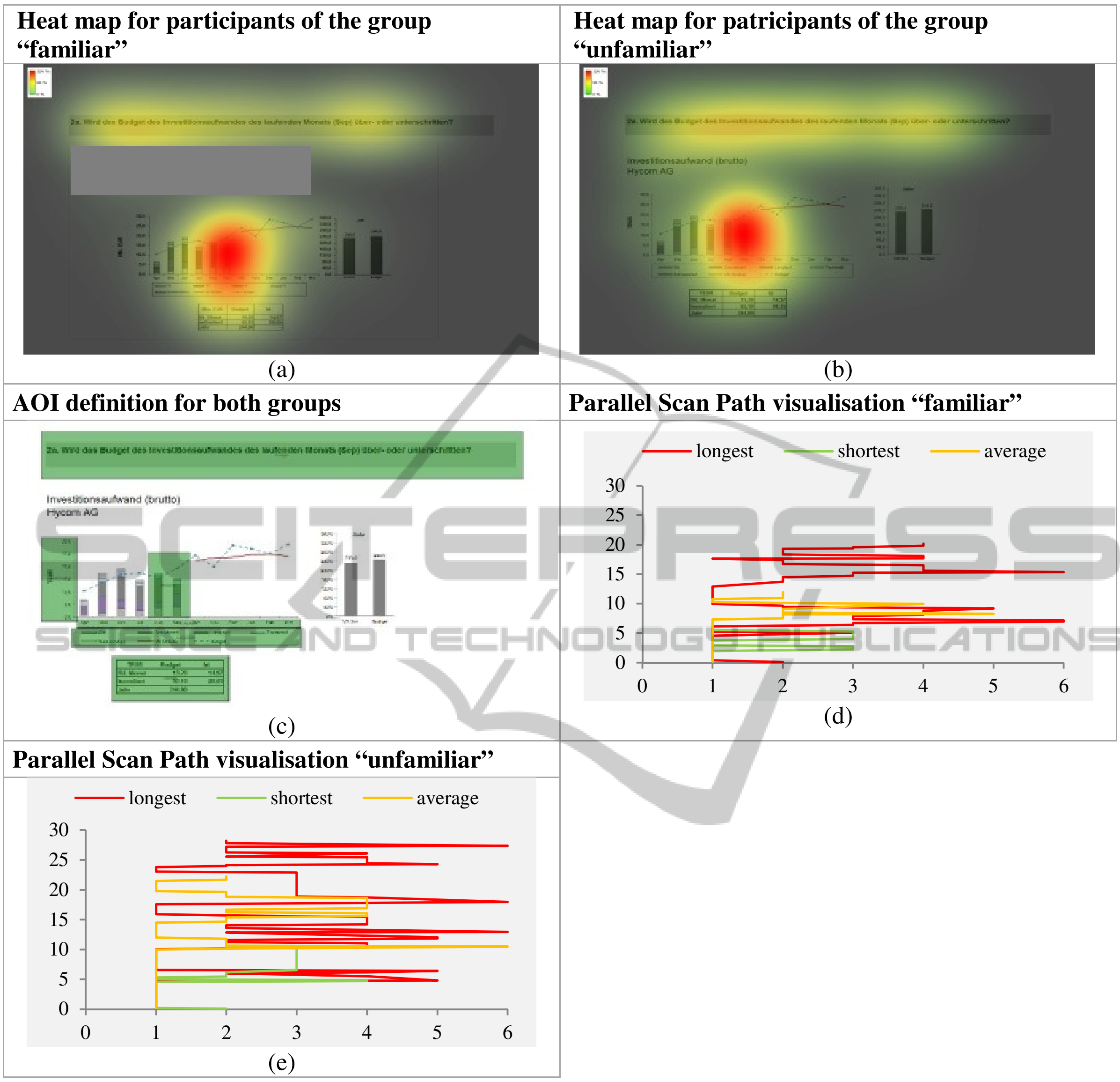

Figure 4: In a) the heat map of all participants that are familiar with the report is shown in b) the heat map for those that see the report for the first time, in c) the annotated areas of interest on the stimulus are presented, and in d and e) Parallel Scan Path visualisations showing the average scan path of the identified group that has similar strings according to Levenshtein Distance as well as the longest and the shortest compressed string identified for both groups.

Differences within groups and between groups are significant using chi square analyses between the defined AOIs (x^2 for participant and AOI is 0.000 and x^2 for groups and AOI is 0.007). These results indicate that scanning strategies are different between participants but the difference between the two groups is higher.

The Parallel Scan Path visualisation show that the group that is unfamiliar with the report needs more time and re-visited AOIs more often than the group that was familiar with the report. Especially with regard to the AOIs 3 to 5 it is shown that those were revisited more often. The number of changes between AOIs for group 1 is 9.9 and for group 2 15.7. The difference between groups is significant. Hypothesis 2 that experienced report users have a shorter sequence string can be confirmed. Additionally, a significant and relatively strong positive correlation between task completion time and number of string variables can be identified (Pearson correlation 0.687 and p=0.00) and therefore also hypothesis 3 can be confirmed.

For further analysis of the compressed strings LD is used. The larger the LD the more differences can be detected between two scan paths. LD is higher for group two (12.9) than for group 1 (average 9.4) and a significant difference can be detected between groups (p=0.00). This result indicates that more similarities between strings can be detected within the group “familiar” and hypothesis 4 that LD is lower for experienced users than for novice report users can be confirmed.

4.2 Stimulus 2

The error rate for stimulus 2 is the same for both experimental groups 0%. No significance (p=1.000) can be detected using a non-parametric test (Mann-Whitney-U test). When analysing efficiency, the average response time in group “familiar” is 7.6 seconds compared to 11.7 in group “unfamiliar”.
A low significant difference can be detected using students t-test (p=0.073). The overall number of fixations needed shows a significant difference between groups (group 1: 30.1 and group 2: 46.9, p= 0.011). These results indicate that the experimental group “familiar” is faster and needs fewer fixations until responding to the stated question. Hypothesis 5 that experienced report users are faster than novice report users when viewing a new layout with familiar content can be confirmed.

The same scan path analysis for efficiency as conducted for stimulus 1 is done for stimulus 2. The generated heat maps and the corresponding AOI

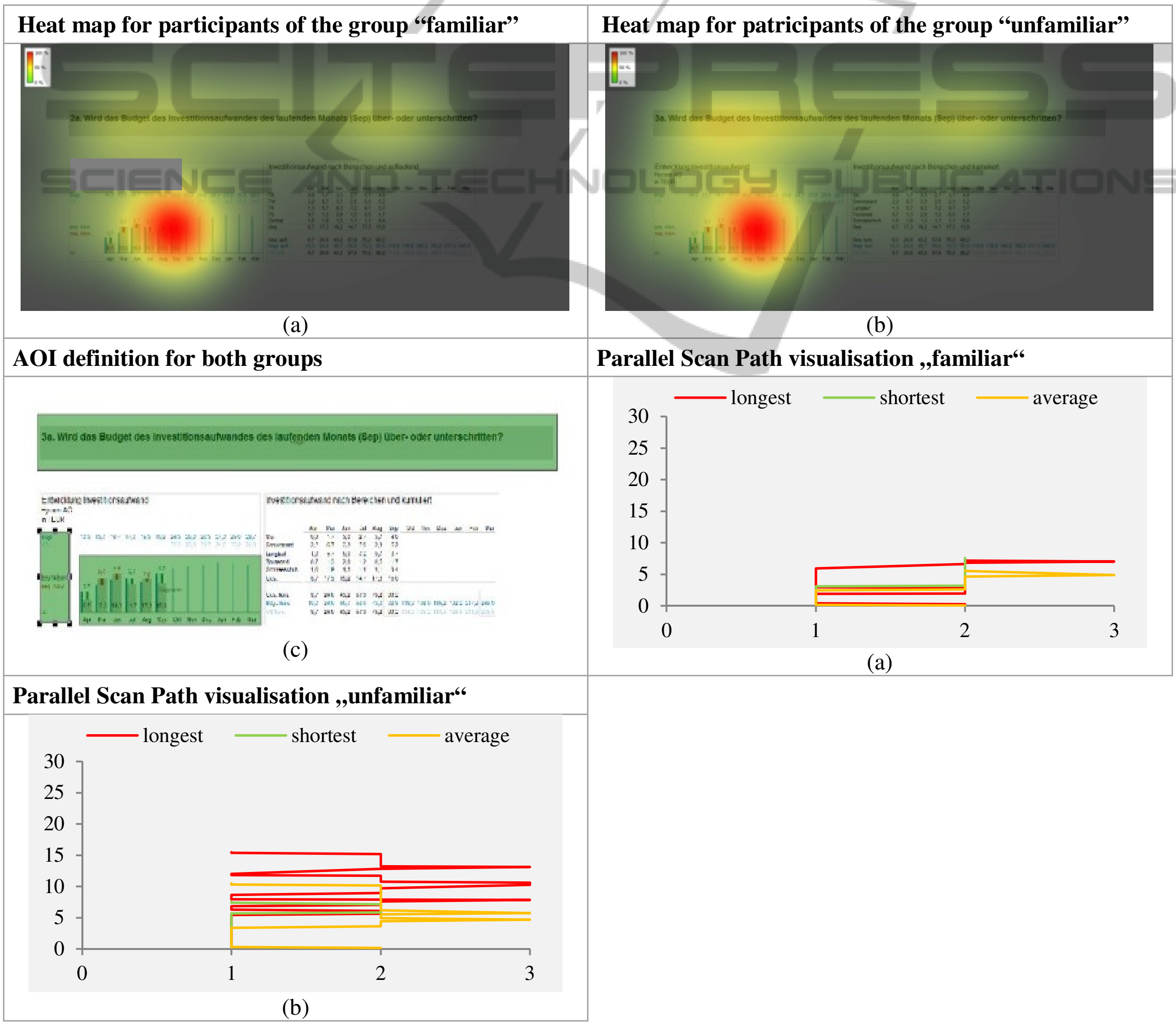

Figure 5: In a) the heat map of all participants that are familiar with the report is shown in b) the heat map for those that see the report for the first time, in c) the annotated areas of interest on the stimulus are presented, and in d and e) Parallel Scan Path visualisations showing the average scan path of the identified group that has similar strings according to Levenshtein Distance as well as the longest and the shortest compressed string identified for both groups.

definition is depicted in figure 5. Again the grey box in example (a) is to ensure anonymity and cover the company's name. For the group "familiar" 85.6% of the gaze duration lies within the defined AOIs and for the group "unfamiliar" 83.0%. This again justifies the selected AOIs as task relevant areas. The area gaining the most gaze duration for group 1 is AOI 1 (53.5%), which includes the task. The second most interesting area is AOI 2 including the part of the chart where the answer can be extracted (42.6%), and third most observed area is AOI 3 including the data labels (3.9%). Results for participants that see the report for the first time are as follows: AOI 1 61.9%, AOI 2 31.0% and AOI 3 7.6%.

Differences within the group "familiar" are not significant (p=0.113) indicating that the observed AOIs are similar between participants. Differences within the group "unfamiliar" are significant (x^2 is 0.001) indicating that more individual scan path strategies need to be applied by users that are not familiar with the content. Differences between the two groups under investigation are significant (and x^2 for groups and AOI is 0.007).

The Parallel Scan Path visualisation (displayed in figure 7) indicates that the group that is unfamiliar with the report needs more time and re-visits AOIs more often than the group that is familiar with the report, even though a new layout is used. The number of changes between AOIs for group 1 is 5.0 and for group 2 8.7. The difference between groups is significant (p=0.006) and therefore hypothesis 6 stating that experienced report users have a shorter sequence string than novice report users when viewing a new layout with familiar content can be confirmed. Again a significant and relatively strong positive correlation between task completion time and number of string variables can be identified (Pearson correlation 0.701and p=0.00) confirming hypothesis 7.

LD is higher for group "unfamiliar" (average 5.5) than for group "familiar" (average 2.6) and the difference is significant (p=0.000). This result indicates that more similarities can again be detected within the group "familiar" and hypothesis 8 indicating that LD within the group of experienced report users is lower when viewing a new layout with familiar content than within the group of novice report users can be confirmed.

4.3 Comparison of Stimuli 1 and 2

When taking a closer look at the presented stimuli and the differences between the original layout and the optimized one, no significant changes can be detected when analysing error rates.

When the layout of the display is optimized experience with the content affects the time and the fixations needed positively. A reduction of 23.9% of the required time and 27.8% of the number of fixations till response can be found, however, the difference between the two stimuli for the required time is not significant (t-test for response time p=0.202 and for number of fixations p=0.319).

Along with the layout optimization, the number of areas of interest could be reduced from six areas to only 3. Compared to the numbers in stimulus 1 the time needed to look at the data labels decreases. As a result changes of fixation between AOIs are significant between both presented stimuli. The original layout needs 41.8% more changes between the defined areas as the optimized layout (12.7 changes vs. 7.4 changes). This result is significant (p=0.001).

When analysing the effects of experience and page layout, it can be found that the difference between the old and the new page layout is higher (41.8% and significant) than the difference between experienced and novice report users (29.2% and not significant). Hypothesis 9 that the influential factor of page layout has a higher impact on visual search strategies than the factor experience can be confirmed. Furthermore, it can be found that experienced users are affected more by layout changes than novice report users. However, contrary to expectations experienced users improve their performance more than novice report users. Therefore hypothesis 10 has to be rejected.

5 CONCLUSIONS

Eye tracking analysis allows the visualization of the individual search strategies of participants while observing visual stimuli and retrieving information. This visualisation helps in the identification of the potential for optimization and therefore the enhanced efficiency and effectiveness of graphical representations of company reports. Analysis based solely on time and error often do not allow for the deduction of strategies for optimal design, however, analyses based on strings provides a solid base for layout optimization.

A relatively strong positive correlation indicating the relationship between the length of a compressed string and the response time can be identified, allowing us to use this measure for layout optimization.

The results of this study indicate that experience does influence performance positively by reducing the number of first fixations and re-fixations in different areas of interest. Additionally, changing the layout of a report page according to guidelines (based on the human cognition) faster response times and lower the amount of fixations and re-fixations needed. The influence of layout changes is even higher when participants are familiar with the content of the report which is surprising given they are used to the displayed layout and have to apply new search strategies.

These results indicate that recipients of a report have to get familiar with the content in order to be able to draw the right conclusion in a fast way. However. they also indicate that an optimized layout helps both groups of investigation (the familiar as well as the unfamiliar ones). Standardization therefore is desirable but should not hinder changes towards a perception-optimized layout. The results of this study could further be confirmed by other tested report-pages within the reported experiment as well as with experiments in other companies using their own reports. Further research will be conducted on the detailed relationships between visual stimuli (e.g. table or graph, graph types, graph layout and design) and individual factors (e.g. culture, experience, working memory capacity) to be able to predict information retrieval performance.

REFERENCES

Anderson, E. W., Potter, K. C., Matzen, L. E., Shepherd, J. F. Preston, J. F., Silvia, C.T, 2011. A user study of visualization effectiveness using EEG and cognitive load. In *Proceedings of IEEE EuroVis2011. Vol. 30. No. 3. pp. 791-800.*

Barat, A. H., 2007. Human perception and knowledge organization: visual imagery. In *Library Hi Tech. Vol. 25. No. 3. pp. 338-351.*

Beattie, V., Dhanani, A., Jones, M. J., 2008. Investigating presentational change in U.K. annual reports: a longitudinal perspective. In *Journal of Business Communication. Vol. 45. Nr. 2. pp. 181-222.*

Blignaut, P., 2010. Visual span and other parameters for the generation of heatmaps. In *Proceedings of the ETRA2010. Austin. March 22-24. pp. 125-128.*

Conati, C., Maclaren, H., 2008. Exploring the role of individual differences in information visualization. In *Proceedings of AVI2008. pp. 199-206.*

Elmqvist, N., Soo Yi, J., 2013. Patterns for visualization evaluation. In *Information Visualization. Special Issue Article. Vol. 0. No. 0. pp. 1-20.*

Falschlunger, L., Eisl. C., Losbichler, H., Greil, A., 2014. Improving information perception of graphical displays: an experimental study on the display of column graphs. In *Proceedings of the WSCG2014. Pilsen. 2-4 June. pp. 19-26.*

Goldberg, J. H., Helfman, J. I., 2010. Scanpath clustering and aggregation. In *Proceedings of the ETRA2010. Austin. March 22-24. pp. 227-234.*

Goldberg, J. H., Helfman, J. I., 2011. Eye tracking for visualization evaluation: reading values on linear versus radial graphs. In *Information Visualization. Vol. 10. No. 3. pp. 182-195.*

Goldberg, J. H., Helfman, J. I., 2014. Eye tracking on visualization: progressive extraction of scanning strategies. In *Handbook of Human Centric Visualization. pp. 337-372.*

Hill, W. Y., Milner, M. M., 2003. Guidelines for graphical displays in financial reporting. In *Accounting Education. Vol. 12. No. 2. pp. 135-157.*

Holmqvist, K., Nyström, M., Mulvey, F., 2012. Eye tracker data quality: what it is and how to measure it. In *Proceedings of the ETRA2012. Santa Barbara. Ca. March 28-30. pp. 45-52.*

Huang, W., Eades, P., 2005. How people read graphs. In *Proceedings of the APVIS 2005. Sydney. Vol. 45. pp. 51-58.*

Keller, T., Gerjets, P., Scheiter, K., Garsoffky, B. 2006. Information visualizations for knowledge acquisition: the impact of dimensionality and color coding, In *Instructional Design for Effective and Enjoyable Computer-Supported Learning. Vol. 22. No. 1. pp. 43-65.*

Levenshtein, V., 1966, Binary codes capable of correcting deletions, insertions, and reversals, In *Soviet Physics Doklady, Vol. 10, pp. 707-710.*

Lurie, N. H., Mason, C. H., 2007. Visual representation: implications for decision making. In *Journal of Marketing. Vol. 71. No. 1. pp. 160-177.*

Mostyn, G. R., 2012. Cognitive load theory: what it is, why it's important for accounting instruction and research. In *Issues in Accounting Education. Vol. 27. No. 1. pp. 227-245.*

Parsons, L. M., Tinkelman, D., 2013. Testing the feasibility of small multiples of sparklines to display semi-monthly income statement data. In *International Journal of Accounting Information Systems. Vol. 14. No. 1. pp. 58-76.*

Peck, E. M, Yuksel, B., Harrison, L, Ittkeym A., Chang, R., 2012. Position paper: towards a 3-dimensional model of individual cognitive differences. In *Proceedings of the BELIV2012. Seattle. WA USA. Pp. 1-6.*

Pfitzner, D., Hobbs, V., Powers, D., 2001. A unified taxonomic framework for information visualization. In *Proceedings of the AICE2000. Canberra. pp. 1-10.*

Raschke, M., Chen, X., Ertl, T., 2012. Parallel scan-path visualization. In *Proceedings of the ETRA2012, Santa Barbara, CA, March 28-30, pp. 165-168.*

Raschke, M., Blascheck, T., Richter, M., Agipkin, T., Ertl, T., 2014a. Visual analysis of perceptual and cognitive processes. In *Proceedings of the IVAPP2013. pp.1-8.*

Raschke, M., Herr, D., Blascheck, T., Ertl, T., 2014b. A visual approach for scan path comparison. In *Proceedings of the ETRA2014. Safety Harbor. March 26-28. pp. 135-142.*

Renshaw, J. A., Finlay, J. E., Tyfa, D., Ward, R. D. 2003: Designing for visual influence: an eye tracking study of the usability of graphical management information. In *Proceedings of the INTERACT2003. pp. 144-151.*

Sohn, Y., Doane, S., 2003. Roles of working memory capacity on long-term working memory skill in complex task performance. In *Memory & Cognition. Vol. 31. No. 3. pp. 458-466.*

Speier, C., 2006. The influence of information presentation formats on complex task decision-making performance. In *International Journal of Human-Computer Studies. Vol. 64. No. 11. pp. 1115-1131.*

Tank, H., Topczewski, J. J., Topczewski, A. M., Pienta, N. P., Permutation test for groups of scanpaths using normalized levenshtein distance and application in NMR questions. In *Proceedings of the ETRA2012. Santa Barbara. Ca. March 28-30. pp. 169-172.*

Toker, D., Conati, C., Steichen, B., Carenini, G., 2013. Individual user characteristics and information visualization: connecting the dots through eye tracking. In Proceedings of *Human Factors in Computing Systems (Proceedings of CHI'13), ACM, pp. 295-304.*

Vessey, I., 1991. Cognitive fit: a theory-based analysis of the graphs versus tables literature. In *Decision Science, Vol. 22, No. 2, pp. 219-240.*

Ware, C., 2013. Information visualization – perception for design, *Third Edition, ISBN-10: 0123814642.*