Look Here! Are There Gender Differences in Learners' eye Movements While Using an e-Learning Platform?

Gergely Rakoczi
Teaching support Center, Vienna University of Technology, Austria
gergely.rakoczi@tuwien.ac.at

Abstract: The research field of eye tracking is double-minded upon the question whether differences in visual behaviour might emerge from gender. When looking at related work, there is evidence for both positions. Some studies show no differences whereas others claim that in specific contexts there are indeed differing visual perceptions of females and males. Existing studies almost do not cover the specific context of e-learning, so there is very little research in the field of e-learning for this research question. Therefore this paper tries to address this issue and is focusing on eye movements of female and male learners, who engage in an online test of an e-learning platform and interact with the graphical user interface (GUI) of the same. In total, 36 volunteers (18 females and 18 males) were eye tracked in order to gauge differences in their visual behaviour. This paper investigates eye movements of learners with respect to four layout areas of the GUI: instructions, visuals, selection as well as navigational items. For analysis, five traditional eye tracking metrics were examined separately for each of the four layout areas. Statistical analysis included one-way analysis of variance (ANOVA) as well as post-hoc tests including pairwise t-tests with pooled SD and Bonferroni correction. Moreover, gaze transition matrices were generated to further investigate the sequential patterns of eye movements of both groups. Doing so, visual shifts between the four layout areas could be investigated in detail. Results indicate that gender has no strong overall effect on eye movements during the use of an e-learning platform. However, three marginally significant effects were detected. First, female users' have a higher reading speed on instructions, second - female users tend to get a faster holistic overview of the GUI as well as third, male users tend to be more likely to focus on salient areas of visuals than female learners.

Keywords: eye tracking, eye movements, gender, differences, visual perception, e-learning

1. Introduction

E-learning platforms supposed to support, facilitate and develop learning processes. Developers and designers of e-learning environments commonly implement or maintain e-learning components and its contents without considering the learners visual behaviour. As a result often e-learning courses as well as its contents are poorly designed, neglecting hereby the learner's natural eye movements and consequently provoking exhaustive visual processes. One unresolved question in this context is whether the aspect of gender has an effect on the visual perception of learners. Basically, the research field of eye tracking is double-minded upon the question whether differences in visual behaviour might emerge from gender. When looking at related work (see second chapter), there is evidence for both positions. Some studies show no differences whereas others claim that in specific contexts there are indeed differing visual perceptions of females and males. Existing studies almost do not cover the specific context of e-learning, so there is very little research in the field of e-learning for this research question. Therefore this paper tries to address this. The conducted study of this paper should contribute not only to a better understanding of e-learning-related user experience and usability, but should also reveal new insights into general human visual behaviour. Results should be used to develop eye-efficient e-learning platforms as well as learning resources.

2. Related work

Most eye tracking studies that consider the factor of gender – comprehensively summarized by Holmqvist et al (2011) - focus on physical attractiveness, medical diseases, face recognition or analysis of looks on sexual content. Little research is done in the cross-section of education, human-computer-interaction and learning psychology. Consequently, there are hardly any investigations about the differences in visual perception between females and males. Basically, for the study of this paper the influential model developed by Meyers-Levy (1986) is used as a theoretical fundament. Meyers-Levy introduced the *model of selectivity* stating that males and females differ with respect to selection processes. Males more likely focus on salient information and disregard misleading cues, whereas females tend to elicit comprehensive information processes. Women tend to engage more likely in interpretation of inconsistent aspects compared to men. The model further indicates that females often consider the entire available information, whereas males tend to focus their attention on fewer selected areas. Note, that for this model no eye movements were considered. The most similar work in the field of education, eye tracking and gender was conducted by Józsa and Hámornik (2012). Within an educational game visual differences in simultaneously displayed images had to be identified by two groups –

female and male learners. Eye movements were analysed with three parameters: *total fixation count*, *total fixation duration* and *mean fixation duration*. ANOVA analysis revealed no overall differences for gender considering various areas of interest (AOI). As authors revealed there were fragmented results indicating differences, however those effects could not be directly explained by gender.

Another eye tracking investigation considering gaze data, gender and user interface was conducted by Pan et al (2004) focusing on navigational areas of webpages. The effect of gender was researched via four different types of websites – business, news, search and shopping – considering hereby nine different AOIs – such as the title, navigation items, links, content areas etc. Analysis of gaze data did not reveal any significant overall effect of gender neither for the eye tracking metric *total gaze duration* nor for *saccades*. In contrast, statistical evidence was obtained for the parameter *mean fixation duration*. Apparently female participants had shorter *mean fixation durations* than males. The authors of the study report inconsistent findings due to the complex nature of web pages as a visual stimuli. They claim interleaving effects impaired the interpretation of the gender variable. Furthermore the publication did not report results about sequential patterns in particular. This would have revealed interesting insights into navigational patterns for gender. This issue is addressed by the study of this paper by providing a comparison of sequential patterns via the analysis of transitions matrices.

Another related work investigating visual behaviour of gender compared eye movements on result pages of a Google search. Lorigo et al (2006) could not obtain any strong overall differences between females and males when analysing different eye tracking metrics. One marginally significant finding was given for males having greater mean fixation durations on search results containing web documents. When considering sequential patter comparison of eye movements, gender seemed to be an influencing factor. The study's outcomes indicate that male participants looked on more results of the list eliciting hereby longer vertical search from the top to the bottom of the page. Compared to female users visual behaviour of males was more linear and provoked fewer regressions. When interpreting these outcomes it can be deduced that male users perceived more information and were more direct in their visual attention. The study of Djamasbi et al (2007) did not reveal any overall gender differences in eye movements. They investigated the visual saliency of advertisements embedded into a website. Hereby two conditions were elaborated - ad blocks had either an accompanying image or not. For both conditions no statistically significant differences could be revealed. Simply put, visual distribution as well as gaze durations were identical for women and men in terms of statistical analysis. Evaluation of mundane pictures within many homepages conducted by Nielsen and Pernice (2010) yielded no difference in gender as well. Visual attention however changes with respect to gender, when images with more sexual content were displayed – e.g. pictures on fashion sites, where male users seemed to be more visually diverted to faces of models. However, it has to be said, that this shift of attention did not have any constraints on males' task success.

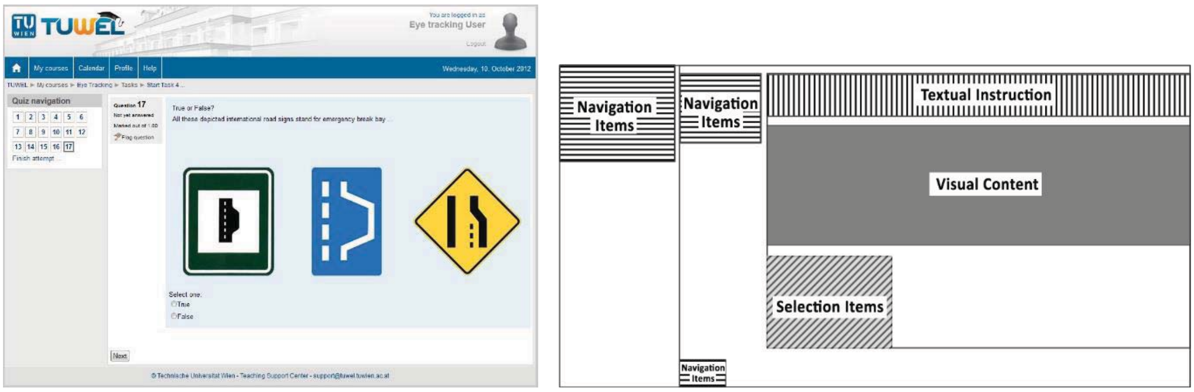
To sum up, there is little research for gender in the special context of e-learning platforms and existing results are often contradictory and therefore this study tries to address this issue.

3. Description of the study

This study is based on the data of an earlier experiment, where visual perception was investigated when learners completed an online test about traffic signage. An exemplary question of the online test is given in Figure 1a. Earlier work analysed cultural and performance aspects (Rakoczi et al, 2013). As the user interface of the e-learning platform was identical for all participants across all conditions, in this paper cultural and performance aspects are ignored and eye movements are evaluated in terms of gender.

3.1 Research goals and methodology

The main goal of this study was to record students' eye movements while completing an online test within an e-learning platform. The recording was done with respect to four different layout areas (AOIs) of the e-learning platform, shown in Figure 1b. The four AOIs are: the area for textual instruction (e.g. descriptions of tasks), visual content (e.g. images), items for selection (e.g. buttons of the online test) and items for navigation (e.g. menus for navigating within the e-learning platform). Analysing eye movement records was done based on two types of parameters (described in section 3.3 in more detail). First, five common eye tracking metrics were recorded separately for each of the four AOI. Results were then grouped by gender. The main research focus is whether male or female learners perceive different areas differently with their eyes. On the other hand, gaze transition matrices for both gender were generated in order to investigate the sequential patterns of their eye movements. Transition matrices show those target areas where "visual jumps" (e.g. saccades) most often occur. Simply put, when for example after looking at an image a learner looks at a navigational button, a saccade occurs. Transition matrices now show all saccades and can provide an entire overview of all visual shifts of the learner. The research question for transition matrices is therefore whether female or male learners have different visual attention distributions atop the e-learning platform. To sum up, in this paper learners' eye movements atop an e-learning platform are evaluated in order to gauge differences as an influence of gender. The goal is to find out whether visual perception of female and male learners differ, when perceiving various layout elements of the virtual learning environment.



(a) (b)

Figure 1: The left image (a) shows an exemplary test question of the e-learning platform, whereas the right image (b) depicts the four AOIs used for the analysis of the learners' eye movements.

The analysis was designed as a single-user test scenario with one within-subjects factor, namely gender (at 2 levels: male and female). In order to analyse differences of various eye tracking metrics within the four AOIs, one-way analysis of variance (ANOVA) was conducted for each condition. Post-hoc tests included pairwise t-tests with pooled SD and Bonferroni correction (Holm method for adjustment). To analyse the sequential order of fixations for all learners, transition matrices were retrieved and compared separately for both genders. Transitions include both saccades from one AOI to another, as well as consecutive saccades within an AOI. More details on transition matrices is given in section 3.3.2. Additionally to this quantitative analysis, also qualitative analysis via retrospective verbalisation (interviews) was conducted with all participants directly after each eye tracking test.

3.2 Technology

The technology used for recording the eye movements were two eye trackers, the Tobii X50 and the Tobii ET-1750. The resolution of the monitors was set for both devices to 1280x1024 pixels. Both eye trackers are binocular and operate on a sample rate of 50 Hz. For both devices, no chin rest was applied. Figure 2 show the laboratory setting of the study where a female learner is completing a question of the online test.

3.3 Parameters

As described in chapter 3.1, two types of quantitative measurements were used to evaluate the influence of gender on eye movements: five *gaze metrics* and *transition matrices*.

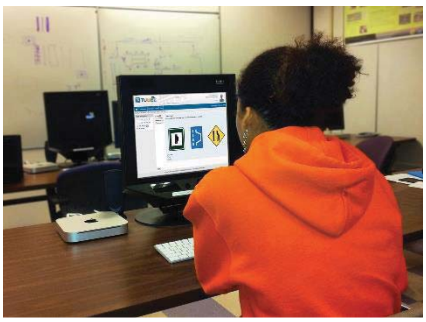


Figure 2: A female learner is answering a question of the online test while her eye movements are being recorded by an eye tracker

3.3.1 Gaze metrics

Gaze metrics were generated based on fixations that were detected by the eye tracker atop an AOI. Five widely used eye tracking gaze parameters were investigated: *total gaze duration*, *time to first fixation*, *mean fixation duration*, *fixation count* as well as the *regression rate*. Table 1 provides an overview about all metrics and its corresponding interpretations (Rakoczi et al, 2013), (Holmqvist et al, 2011), (Goldberg and Wichansky, 2003).

Table 1: Overview of the interpretation of the applied gaze metrics

Gaze Metric	Interpretation
Total gaze duration	It is the total time in seconds within an area of interest. Longer gaze durations indicate higher complexity of the visual stimulus and suggest higher cognitive effort. Longer gaze durations suggest greater user interaction due to the complexity of the graphical interface.
Time to first fixation	It is a latency measure giving the time in seconds from the onset of a stimulus until the learner's gaze atop the AOI. This parameter suggests search efficiency and localization potential of visual attention, mainly suggesting saliency of visual elements.
Mean fixation duration	It indicates the average duration of fixations within an AOI. Long fixation durations suggest greater cognitive load when extracting a GUI element's meaning. A higher level of expertise, lack of interest, or lower stimulus complexity tend to elicit shorter mean fixation durations.
Fixation count	It provides the total number of fixations within an AOI indicating areas of semantic importance.
Regression rate	It indicates the number of revisits to an AOI. This parameter generally indicates ambiguity of visual elements, or the participant's willingness to extract information.

3.3.2 Transition matrices

Transition matrices were computed with a statistical analysis tool for each AOI. Here the matrix elements were calculated to the number of transitions from each source AOI to each destination AOI. A matrix was generated individually for each learner. The matrix was also normalized relative to each source AOI (i.e., per row), such that each cell represents the estimated probability of transitioning from any AOI to any other given the first as the starting point. To investigate the effect of gender on gaze transitions, a statistical comparison of transition matrices was accomplished. For this empirical entropy H (with Miller-Madow correction) was computed via a bias-corrected maximum likelihood method. ANOVA was then used to test the differences in mean entropy for both – all female and all male learners.

3.4 Participants

Eye movements of a total of 36 learners were evaluated. The learners were university students and they were aged between 22 and 34 years with a mean of 26.3 years. Gender balance was ensured as 18 males and 18 females were recruited for the eye tracking study. All learners were screened for any major visual deficiencies as well as for any other remarkable constraints and had to meet the following exclusionary aspects. Participants had to be full-time students being at least registered for four semesters as university freshmen would have significantly different visual behaviour. Students were recruited mainly by telephone, e-mail and word-of-mouth recommendations. To ensure university-wide validity, students were recruited from different faculties. At last, all students had to be at least regular computer users, having basic computer literacy.

4. Results

An overview of the entire gaze data is given in Table 2. The table shows the eye movements calculated as the five gaze metrics atop all four AOIs.

Table 2: Overview of the five gaze metrics of female and male learners atop the four AOIs

	Total Gaze duration (time in sec)		**Time to first fixation** (time in sec)		**Mean fixation duration** (time in sec)		**Fixation count** (integer)		**Regression rate** (integer)	
	female	*male*	*female*	*male*	*female*	*male*	*female*	*male*	*female*	*male*
Textual instructions	2.1	2.2	0.6	0.7	0.296	0.313	7.0	7.0	1.5	1.5

	Total Gaze duration (time in sec)		Time to first fixation (time in sec)		Mean fixation duration (time in sec)		Fixation count (integer)		Regression rate (integer)	
	female	*male*	*female*	*male*	*female*	*male*	*female*	*male*	*female*	*male*
Visual Content	5.1	5.7	1.0	1.2	0.337	0.345	15.5	16.6	2.6	2.6
Selection Items	3.9	4.0	3.3	3.7	0.562	0.549	9.8	9.7	3.6	3.4
Navigation Items	0.8	0.7	9.5	10.5	0.509	0.471	1.7	1.7	0.3	0.3

ANOVA analysis of the metric *total gaze duration* indicated marginally significant differences for visual content *(F(1, 1258)=6.26, p<0.05)*. Eye data showed that male learners had longer dwell times on graphics than female learners. Analysis for the remaining AOIs did not yield any significant outcomes. ANOVA results are as follows: navigation items *(F(1, 1258)=0.95, n.s.)*, selection items *(F(1, 1240)=0.09, n.s.)* and textual instruction *(F(1, 1212)=1.38, n.s.)*.

The parameter *time to first fixation* yielded marginally significant results for selection items *(F(1, 1240)=9.05, p<0.05)* as well as for the visual content *(F(1, 1258)=5.40, p<0.05)*. Female learners fixated these areas earlier than males. For navigational items *(F(1, 1259)=3.30, n.s.)* and textual instructions *(F(1, 1211)=0.17, n.s.)* no statistically relevant differences could be obtained.

When focusing on *mean fixation duration* results of the textual instructions *(F(1, 1212)=6.08, p<0.05)* as well as navigation elements *(F(1, 1198)=8.53, p<0.05)* revealed marginally significant outcomes. The gaze data shows that female learner's average fixation duration was lower when visually perceiving textual instructions, however higher when fixating navigational items. Results for selection items *(F(1, 1240)=0.73, n.s.)* and the visual content *(F(1, 1257)=1.62, n.s.)* were not statistically significant.

The metric *fixation count* did not yield any significant outcomes for any of the AOIs. ANOVA results are as follows: navigation items *(F(1, 1259)=0.169, n.s.)*, selection items *(F(1, 1240)=0.01, n.s.)*, textual instructions *(F(1, 1212)=0.04, n.s.)* and visual content *(F(1, 1258)=3.03, n.s.)*.

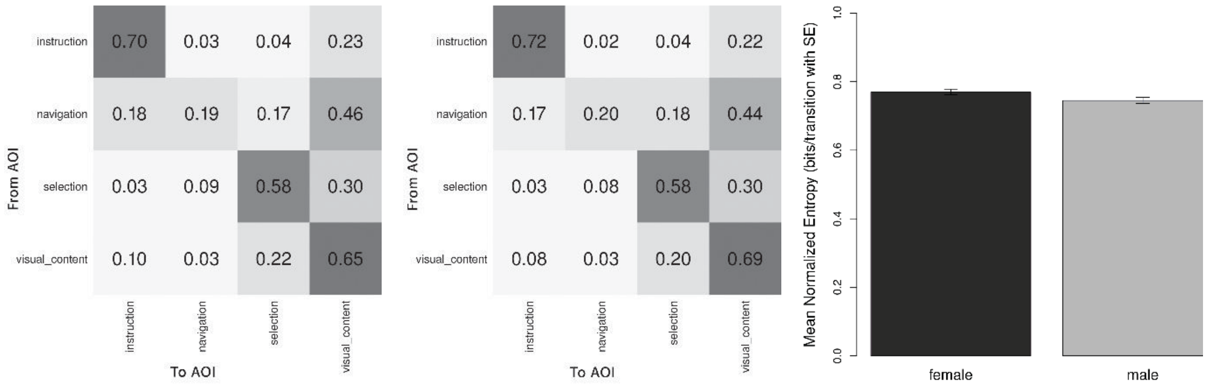
Similarly, to fixation count also the parameter *regression rate* did not yield significant differences at all. The results are as follows: navigational items *(F(1, 1198)=0.19, n.s.)*, selection items *(F(1, 1240)=0.56, n.s.)*, textual instruction *(F(1, 1212)=0.88, n.s.)* and visual content *(F(1, 1257)=0.003, n.s.)*.

Analysis of the transition matrices for gender reveals no significant differences in overall saccadic behaviour *(F(1, 35)=1.37, n.s.)*. The cell values are almost identical for male and female learners, as can be seen in Figure 3a and 3b. Also the statistical analysis mean entropy between the transition matrices does not reveal any significant differences, as shown in Figure 3c.

At last it has to be noted that female and male learners' score on the online quiz was roughly the same, so no significant differences exist in terms of performance.

5. Discussion

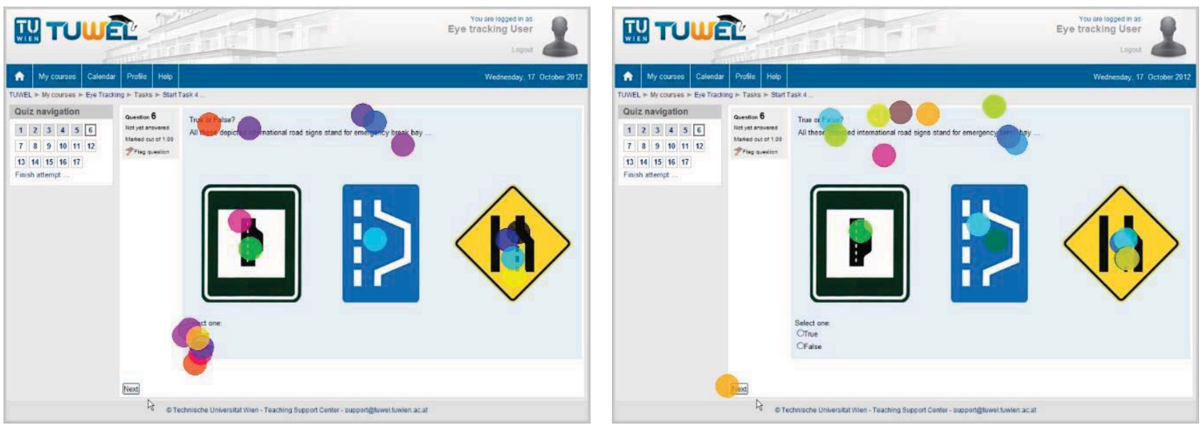
Results indicate almost hardly any strong overall effect of gender on eye movements. Statistical analysis revealed that there were merely marginally significant outcomes for the evaluated AOIs. When analysing eye movements, females and males fixated both on textual instruction first, followed by the visual content, selection items and at last navigational elements. Gaze data shows that female learners fixated selection items and images earlier than males. So one can deduce that female learners tried to get a holistical overview of the setting faster than male learners. This effect seems to go along with selection processes described by Meyers-Levy (1986). He states that women prefer comprehensive information processing. This result is now also supported by the recorded gaze data of this paper. Outcomes of this study show that females fixated all four layout areas of the e-learning platform's GUI faster than males. This effect can be clearly seen in Table 2. Again, this result might also be seen that female students try to assess the overall test situation earlier than male learners. If we visualize eye movements atop a test question this effect becomes more concrete.



(a) (b) (c)

Figure 3: Analysis of the overall differences of eye movements in terms of the visual dynamics does not reveal any significant differences. Image (a) shows the transition matrix of female learners. As an example. The probability that a learner elicits a saccade from a navigational item to a visual content is 0.46. Image (b) depicts the matrix of male students, whereas image (c) shows the mean difference between the transition matrices

In Figure 4 two images are shown - both taken after 3.5 seconds after the onset of a test question. It can be clearly seen that most female students already focus on images and selection items (Note: females have already processed textual instructions), whereas male learners still allocate their attention atop textual instructions. This example shows that female learners seem to process tasks faster and with higher visual distribution.



(a) (b)

Figure 4: The images show the visual distribution of learners after 3.5 seconds atop an exemplary test question. In image (a) 13 female learners - represented as dots - already focus on images and the selection items, whereas 9 male learners still focus on textual instructions (b)

A marginally significant result yields that female students' mean fixation durations were lower when perceiving textual instruction. In Figure 5 a sequence of eye movements of a female student is shown. She is solving a test question and one can see that her fast reading process consists of small fixations atop the textual instruction. These eye movements might be traced back to female learners having different reading skills in terms of velocity. In contrast, results of this study yielded higher *mean fixation durations* of female students atop navigational items. This outcome can be seen in figure 5 as well. Female learner elicited long fixations over the button "next" and the selection items of the test question before clicking them. This indicates higher cognitive load for deciding to move to the next test question. In the interviews after the study some female learners have reported that they were uncertain about their decisions. Often they even wanted to re-visit previous test questions, however could not find the corresponding navigational item to do so. Retrospective analysis indicated higher confidence for male learners. As a result, outcomes indicate less cognitive overload during visual perception of navigation items or decision making for male learners. Males elicited a more direct navigation – generating hereby eye movements with lower cognitive load and lower results for *mean fixation duration*. Again, this seem to support the findings of Meyers-Levy (1986).

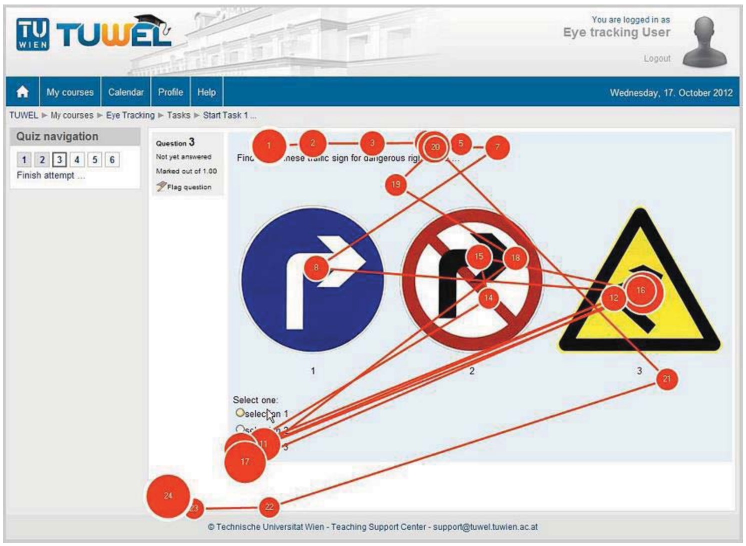


Figure 5: An exemplary image shows the sequence of fixations elicited by a female learner during the completion of a test question of the e-learning platform

Gaze data also revealed that male students had marginally significant longer *total gaze duration* atop the visual content. Again, also this outcome supports the findings of Meyer-Levy. Male students seemed to focus more likely on salient areas of the e-learning platform, such as graphics and traffic signs. Overall eye movements statistics yield that male students looked at the visual content approximately half a second longer than female students. However, when comparing transition matrices this difference seems to be negligible, as males had almost identical quiz results and similar gaze times for the overall test. So, it can be argued that this effect had no overall influence.

6. Conclusion

In conclusion, gender has no strong overall effect on eye movements during learning with an e-learning platform. The outcomes of the study go in the same direction as the results of related work, which do not state differences. Marginally significant outcomes, however might indicate that female learners elicit more holistical and faster initial looks over the screen and during an online test. Furthermore there were differences in reading speed as well as increased cognitive load atop navigational items. In order to contribute to the ongoing discussion in the field of eye tracking research whether gender has an influence on eye movements a relatively clear answer can be given. In the context of navigating within the graphical user interface of an e-learning platform no differences could be obtained as both – female and male learners – elicited similar overall visual attention, distribution and gaze transitions.

When looking at possible limitations of this study the following aspects can be mentioned. Other user attributes such as differences in individual learning styles or preferences might have an impact on the eye movements as well. Furthermore the interpretation process of eye data might be ambivalent, as eyes not necessarily represent thought processes of the learners. Therefore given interpretations might be biased. Also, the outcomes might be biased by the visual appearance of the real-world learning environment used as a stimulus for this study. However, this aspect was accepted on purpose, as the author of this paper is of strong belief that authentic learning cannot be achieved on testing artificial learning environments or simplified mock-ups. At last, the topic of the e-learning content – namely traffic signage - might automatically bias analysis of gender.

References

Djamasbi, S., Tullis, T., Hsu, J., Mazuera, E., Osberg, K. and Bosch, J. (2007) "Gender preferences in web design: usability testing through eye tracking", Proceedings of the Thirteenth Americas Conference on Information Systems (AMCIS).

Goldberg, J.H. and Wichansky, A.M. (2003) "Eye tracking in usability evaluation: A practitioner's guide." In: The Mind's Eye: Cognitive and Applied Aspects of Eye Movement Research, Hyönä, J., Radach, R., Deubel, H., Eds., pp. 493-516, Elsevier Science, Amsterdam.

Holmqvist, K., Nyström, M., Andersson, R., Dewhurst, R. and Jarodzka, H. (2011) *Eye Tracking: A Comprehensive Guide to Methods and Measures*. Oxford University Press, Oxford.

Józsa, E. and Hámornik, B. (2012) "Find The Difference! Eye Tracking Study on Information Seeking Behaviour Using an Online Game.", Journal of Eye tracking, Visual Cognition and Emotion, Vol 2, No. 2, pp 27–35.

Lorigo, L., Pan, B., Hembrooke, H., Joachims, T., Granka, L. and Gay, G. (2006) "The influence of task and gender on search and evaluation behaviour using Google.", Information Processing & Management, Vol 42, No. 4, pp 1123-1131.

Meyers-Levy, L. (1986) *Gender Differences in Information Processing: A Selectivity Interpretation*. Northwestern University.

Nielsen, J. and Pernice, K. (2010). *Eyetracking Web Usability. Voices That Matter*. New Riders, Berkeley, CA.

Pan, B., Hembrooke, H.A., Gay, G.K., Granka, L.A., Feusner, M.K. and Newman, J.K. (2004) "The determinants of web page viewing behaviour: an eye-tracking study", Proceedings of the 2004 symposium on Eye tracking research & applications, pp 147–154, ACM.

Rakoczi, G., Duchowski, A., Casas-Tost, H., Pohl, M. (2013) "Visual perception of international traffic signs: influence of e-learning and culture on eye movements." In: Proceedings of the 2013 Conference on Eye Tracking South Africa, pp 8-16, ACM, New York.

Proceedings of the 16th European Conference on eLearning

ISCAP

Porto, Portugal

26-27 October 2017

Edited by

Dr Anabela Mesquita and Dr Paula Peres

A conference managed by ACPI, UK

Proceedings of the

16th European Conference on e-Learning ECEL 2017

Hosted By
ISCAP
Polytechnic of Porto
Portugal

26 - 27 October 2017

Edited by
Anabela Mesquita and Paula Peres

Review Process
Papers submitted to this conference have been double-blind peer reviewed before final acceptance to the conference. Initially, abstracts were reviewed for relevance and accessibility and successful authors were invited to submit full papers. Many thanks to the reviewers who helped ensure the quality of all the submissions.

Ethics and Publication Malpractice Policy
ACPIL adheres to a strict ethics and publication malpractice policy for all publications – details of which can be found here: http://www.academic-conferences.org/policies/ethics-policy-for-publishing-in-the-conference-proceedings-of-academic-conferences-and-publishing-international-limited/

Conference Proceedings
The Conference Proceedings is a book published with an ISBN and ISSN. The proceedings have been submitted to a number of accreditation, citation and indexing bodies including Thomson ISI Web of Science and Elsevier Scopus.

Author affiliation details in these proceedings have been reproduced as supplied by the authors themselves.

The Electronic version of the Conference Proceedings is available to download from DROPBOX http://tinyurl.com/ecel2017. Select Download and then Direct Download to access the Pdf file. Free download is available for conference participants for a period of 2 weeks after the conference.

The Conference Proceedings for this year and previous years can be purchased from http://academic-bookshop.com

E-Book ISBN: 978-1-911218-60-9
E-Book ISSN: 2049-0992
Book version ISBN: 978-1-911218-59-3
Book Version ISSN: 2049-100X

Published by Academic Conferences and Publishing International Limited
Reading
UK
44-118-972-4148
www.academic-publishing.org