Communication Papers of the of the 17th Conference on Computer Science and Intelligence Systems pp. 145–151
DOI: 10.15439/2022F51
ISSN 2300-5963 ACSIS, Vol. 32

Replication of first click eye tracking A/B test of webpage interactive elements

Julia Falkowska
Department of Computer Science and Systems Engineering
Wrocław University of Science and Technology
Wrocław, Poland
julia.falkowska@pwr.edu.pl

Janusz Sobecki
Department of Computer Science and Systems Engineering
Wrocław University of Science and Technology
Wrocław, Poland
janusz.sobecki@pwr.edu.pl

***Abstract*—In this paper, we present a replication of our experiments of first click eye tracking A/B test of interactive website elements [13]. The main difference between these two experiments is the equipment used; the first study was done using Tobi X-60 eye-tracker, while the replication described in this paper was conducted using Tobii TX 300, a higher frequency eye tracker. Eye tracking metrics used to evaluate the user experience of websites were almost identical. This paper presents the results of an experiment in which seven commercial websites were tested with the A/B first click test. This work examines the validity of a specific set of eye tracking metrics for their broad application in user experience research on websites.**

***Index Terms*—eye tracking, user experience, eye tracking metrics, A/B tests**

I. Introduction

TODAY, user experience (UX) plays a crucial role in webpage design, which is exhibited, for example, in increasing the amount of money allocated for this aspect in web development projects. The ISO 9241-210 standard defines UX as "a person's perceptions and responses that result from the use or anticipated use of a product, system, or service." Therefore, UX should include user's emotions, beliefs, preferences, perceptions, physical and psychological responses, behavior, and accomplishments that the user experiences interacting with a given product, system, or service. User experience and usability are often used as synonyms, however, many authors [1-3] indicate that these two terms should not be conflated. The main difference is that user experience (UX) refers to how the user feels when interacting with the system, while usability is just an aspect of the user experience that mainly relates to efficiency of the interface. Additionally, UX extends usability by taking into account a holistic perspective of user's feelings and attitudes towards the product, system, or service. In addition to usability, there are other factors that significantly contribute to UX such as ergonomics, design/aesthetics, accessibility, human factors and system performance. A complete conceptual framework of UX that takes into account usability and user perception is presented in the work of Hellweger and Wang [4].

To monitor the user's behavior during an interacrion with a webpage, researchers use different devices, such as web cams [5], EEG headsets [6], touch screens [7], thermal cameras [8], and eye trackers. The latter are especially popular in user experience research [9]. For example, the work of Schall et al., Horsley et al., and Bojko [10-12] presents many effective eye tracking methodologies applied to UX and usability testing of webpages. These eye tracking methodologies can be applied, among other research efforts, in different stages of A/B tests of website design [13]. In principle, eye tracking UX research is based on the assumption that the fixation point determines the elements of the user interface that attract user's attention and that the rest of the areas are invisible or incomprehensible during completion of the task on a tested webpage [14].

Testing with users is the most effective when such tests are conducted throughout the project lifecycle to enable the design to be improved interactively. Therefore, tests should be performed already at the earliest phase of the design process, using static or interactive mock-ups. At this stage, any changes need to be applied only to the design of the mock-up and do not require code modifications, which would be significantly more time and effort consuming. With this approach, we can ensure early in the process that the outcome is congruent with users' needs to a large extent, thus avoiding the high cost of changes during the development stage. In our research, we used the first click testing method (task ends with user's first click) on static representations of webpages. In every trial, the participant is asked to click on an element or a location that would contain the information they were asked to find. As an example, we may want to test findability of an element that links a subpage where all products are displayed. The task here might be phrased as: 'Try to find out what this company has in offer.' The task ends when the user makes the first click, no matter if it was on the expected element or not.

With first click testing, we can correlate eye tracking metrics with a click of a mouse over an element of the website. User clicking a mouse click on an element is understood as finding the item and recognizing it as meeting the user's needs. Our previous studies have shown that eye tracking analysis is a valid method to evaluate interface design and interactive web elements [15-17]. In these research, the analyses showed statistically significant differences between different webpage projects and selected metrics.

Inspired by NNGroup research [18] our study was carried out on two variants of each tested website: with a well-designed target element (user-friendly) and a poorly designed target element (harder for the user). Webpage designs selected for the experiment represent some of the most popular types of websites and do not require specialized knowledge to use them. The websites used in our study fall into one of the following categories: e-commerce, travel or restaurant websites.

In this paper, we present a replication of the research by Falkowska et al. [13] using a Tobii TX 300 eye tracker, which produces better quality data than Tobii X-60 eye tracker used in the study described in work [13]. In the summary of the original paper, we pointed out that the low frequency (60Hz) of Tobii X-60 eye tracking data registration resulted in the lack of precise fixation on small interface elements and in numerous shifts. In the experiment replication, we also used a bigger, 23" screen (instead of 17" screen) to more precisely monitor differences in fixation on the interface elements. This in turn resulted in fewer samples than registrations and had an impact on the significance calculations. For five designs in the study [13], none of the metrics showed a significant difference between design versions A and B. However, we have noticed that in most cases the average values of the used measures showed a trend indicating that improved designs (variant A) were better than less user-friendly versions (variant B). Nevertheless, most of these results were not statistically significant. Additionally, most of the participants were experienced web users and it is very likely that they were simply used to various layouts and designs, both good and bad, from the user experience point of view.

In our previous work [13], we have presented an experiment that verifies the usability of nine common commercial websites of hotels, e-shops, restaurants, fitness clubs, energy providers, social networks and insurance companies. Participants have been presented with static representations of these websites on a screen and asked to perform certain tasks on them. In the current experiment, the number of tasks has been reduced to seven because we previously found that one task was too difficult for the participants. The experiment was constructed as a standard A/B test, with version A designed as a more user friendly variant and version B as a less user friendly variant of the same interface. Versions A of all websites have been designed to increase visibility and/or readability by modifying size, contrast, or adding supporting graphic elements [19], [20]. Different versions of the same website have been presented to separate groups of users. For each task we measured seven eye tracking metrics to investigate whether the differences in selected metrics values for design versions A and B are significant [21], [22].

The paper is organized as follows. The first part of this paper introduces eye tracking studies and eye tracking measures. This is followed by the presentation of the stimuli used in the experiment. The experimental setup and corresponding methodology are described in section three. Section four presents the results. In section five, we present the discussion and finally in the section six we present our conclusions.

II. Eye tracking studies and eye tracking metrics

Eye tracking studies began in the nineteenth century and over the years many different technologies and methods have been established and introduced into various disciplines [23]. Already from the early 90s of the last century, eye trackers were used in usability studies [22]. Since then, eye tracking has been applied in many varieties of usability studies:

- usefulness of web or desktop applications [24-28],
- perception of information (graphics or texts) [29-34],
- correlation between declarative data and eye tracking measures [25-36],
- comparative studies of the effectiveness of system interfaces [37],
- correlation of eye tracking data with the strategy of searching for information in web systems [38],
- correlation of eye tracking data with users' behavior in the system, e.g. purchase decisions [39],
- method and speed of user interaction with information elements depending on their parameters, e.g. size or location [40-44],
- exploring potential new applications and use cases, e.g. for mobile applications [45],
- comparing the eye tracking registration method with other research methods [46].

In these studies, several implementations of methodologies have been used, in particular:

- users perform several prepared tasks in the system [24], [26], [37], [46],
- users perform tasks on specially prepared materials according to research purposes (i.e. different pages or graphic interface designs) [26], [29], [32], [33], [34], [36], [40], [41], [42], [47], [48],
- supplemented with declarative methods (questionnaires, interviews) [25], [35], [49].

Finally, the data that have been gathered during the studies needs to be analyzed. The rough eye tracking data in the form of gaze coordinates on a plane, together with time stamps, are usually transformed into metrics that can be interpreted as results:

- the characteristics of the gaze path to identify usability problems, mainly by identifying elements on which users focus or which are omitted [24-27], [37],
- the number of fixations: information whether the user saw / did not see, read / did not read the presented information [24, 31], the amount of visual attention [29], the difficulty of completing the task [36], processing and understanding the information [32], [50] frequency of attracting attention understood as attractiveness [42],
- time to the first fixation: how quickly the user notices the information [26], [29], [40], [41], identification of the elements that attract attention [30].
- fixation time: the amount of visual attention [30], [33], [35], [40], [47], the time spent processing given content, evaluating the object as

attractive [32], [38], [41], evaluating an object as difficult to understand or read [43],
- duration of the first fixation: the effectiveness of focusing visual attention [30],
- time from noticing to clicking on an element: indication of an element that is problematic for the user [48].

Most of the eye tracking metrics used in UX studies are based on fixations. In eye tracking studies [23], fixation is defined as a functional component: what purposes does the eye movement (or lack thereof) serve? Fixation usually ranges from 100 to 500 ms. The average duration of a human eye fixation during reading is 200-250 ms and 280-330 ms for scene viewing [12]. The functional definition of fixation means stabilizing a target relative to the fovea, that is, being stationary or moving with respect to the head. Saccades, on the other hand, are defined as the interfixation interval. Holmqvist et al. [23] distinguished the following eye-tracking measure types:

- movement measures that concentrate on the whole variety of eye movements,
- position measure, which corresponds only to where the participant has or has not looked,
- numerosity measures that pertain to the whole spectrum of the number or rate of any countable eye movement event,
- latency measures, which give the values of the onset between two events.

We may also find other typologies of eye tracking measures, for example those proposed by Bojko [21]. These measures have been validated in many UX research to show cognitive processes of the user with which they are linked. The are also relatively easy to extract from the rough gaze data. According to Bojko [21], we can distinguish the following types of measures:

- mental workload measures,
- cognitive processing measures,
- target findability measures,
- target recognizability measures.

In addition to fixation, the notion of area of interest (AOI) is of great importance in eye tracking analysis. AOIs are the selected elements on a webpage for which a metric is calculated. In our research, we distinguished only one AOI on a webpage, which is typical for first click experiments . In our case it was a specific button.

For the analysis of our study, we have selected from the metrics related to cognitive overload described by Bojko in his book [21]. These metrics were selected as the most relevant for UX and their analysis is available in the Tobii Studio software we have used.

To date, more than one hundred eye tracking metrics have been established. In this paper, however, we only describe the metrics we have used in our research, which are [21]:

- time to first fixation belongs to attraction measures, which is a superclass of area noticeability measures that are useful for visibility assessment of an object or area by describing how many people noticed or how quickly something was noticed,
- the number of fixations prior to the first fixation on an AOI, similarly to the previous metric, it belongs to the attraction metric,
- first fixation duration on AOI belongs to cognitive processing measures and evaluates cognitive processing difficulty; longer fixation usually indicates deeper cognitive processing caused, for example, by more effortful extraction of information,
- fixation count over AOI is usually used when presenting results in the form of a heatmap; each fixation over AOI adds to the fixation count and is later presented on a heatmap as an appropriate color in the fixation area,
- visit count over AOI is a metric indicating the total count of all fixations and saccades over AOI,
- time from the first fixation on AOI to the mouse click within this area belongs to target recognizability measures - the faster the AOI is recognized as a task solution, the shorter it is,
- fixation duration in AOI measures the time spent observing the specific area by the participant, which usually indicates the participant's motivation and attention; higher values of this measure for a specific AOI indicate more interest on this AOI than for AOI's with lower values.

III. Experiment stimuli

Different versions of stimuli have been created by adding or changing visually one of the elements, or a group of elements of the websites' design. A task was prepared for each pair of design versions and the correct solution was to click on the modified/tested element. Ten webpage designs in two versions have been prepared for the study, however only seven of them have been analyzed, because three task instructions have been reported as difficult to understand by the participants in the interview after the study.

Interview after the study contained two questions, one closed and one open: "Did you have any doubts what you should in this task? (yes/ no/ can't tell)?" and "Please, explain/tell me more in your own words how you understood the task/instruction". For two tasks, all respondents declared the some problems occurrence of weakness, and in response to the open-ended question, they presented different ways of understanding the instruction. Due to the fact that the viewing paths are strongly dependent on the goal / performed task, we decided not to take into account these eye tracking data.

Table I presents the stimuli (webpage URL), along with the type of design modification, as well as the corresponding task. These websites were accessed between 1st and 15th November 2019.

Offline versions of these pages have been the basis for preparation of the stimuli used in the experiment. Modifications were made to specific elements to create a user interface that is more (A) or less (B) user friendly. The correct solution for each task was determined as clicking on a specific button on a given webpage.

TABLE I
EXPERIMENT DESCRIPTION DETAILS [6].

Name	Source page URL	Version A (more user friendly)	Version B (less user friendly)	Task
C21	//www.c21stores.com/ Germany	Main menu tab 'Stores and Events' with appropriate iconographic	Main menu tab 'Stores and Events' without appropriate iconographic	You will see a bookshop website with a particular book presented. You want to know what other readers think about that book. Click where you would look for information about that.
LS	http://www.loursinseattle.com	All caps main menu tabs	Sentence case main menu tab	You will see a restaurant website. That restaurant sometimes organizes food presentation days. Imagine you want to find more details about that. Click where you would look for information about that.
PP	http://www.peachpit.com/store/adobe-photoshop-elements-2019-classroom-in-a-book-9780135298633	(Shop best sellers >) under the product picture Gray and underlined link (Shop best sellers >) under the product picture	Submenu tabs (About, Description, Reviews, Sample, Content, Updates) at the bottom with white background	You will see a restaurant website. That restaurant sometimes organizes food presentation days. Imagine you want to find more details about that. Click where you would look for information about that.
POPO	www.poopourri.com	Black and underlined links (Shop best sellers >) under the product picture	Gray and underlined link (Shop best sellers >) under the product picture	You will see a cosmetic shop website. Imagine that someone recommended you this shop and you do not know any of their products, so you want to see the products that people buy the most. Click where you would look for information about that.
SS	www.swissotel.com	Gray background of button with language changed (English)	White background of the button with language changed (English)	You will see a hotel website. Imagine you want to change the website language. Click where you would look for information about that.
RM	www.rockymountainsoap.com /products/beech-tree-bud-eye-cream	Orange submenu elements (ingredients, how to use, shipping)	Gray submenu elements (ingredients, how to use, shipping)	You will see a page from an e-shop with a product presentation. Imagine you want to buy this product and you want to know more about delivery. Click where you would look for information about that.
FB	www.fitnessblender.com	White submenu font in the center of the website. Submenu elements: Workout Videos, Workout Programs, Meal Plans, FB Plus with descriptions.	Gray submenu font in the center of the website. Submenu elements: Workout Videos, Workout Programs, Meal Plans, FB Plus descriptions	You will see a fitness website. Imagine you have a specific training program and now you want to change your eating habits. Click where you would look for information about that.

IV. EXPERIMENT METHODOLOGY

In the experiment, two methods have been applied: first click testing recorded with eye tracking and one-on-one interviewing [14]. Each participant was asked to sit in front of the computer monitor and interact with each webpage by clicking the selected button. Each respondent was asked to complete seven tasks, which were later analyzed and presented in Table I. We finished the task when the participant clicked on a webpage element, which is also named as a first click testing [51]. We have used an eye tracking system to record participants' gaze activity. Using this system, the fixation path has been recorded together with screen and mouse activity. After finishing all tasks, all users have participated in a one-to-one sound recorded interview with the aim to verify their understanding of tasks, as well as confirm they have not seen any of these webpages before. With twenty participants and seven websites with two versions each (user-friendly and not), every webpage variant has been seen by ten participants. The webpages have been presented on a 23" LCD screen connected to a TX 300 eye tracker. The sessions have been recorded using Tobii Eye Tracker TX 300 and Tobii Studio software.

The experiment has been conducted at the Wrocław University of Science and Technology, Poland (WUST) from 28.06.2021 to 6.07.2021. Out of twenty participants, five were students, five were working and ten declared to be working students. Exactly half of the group was women and half men.

V. EXPERIMENT RESULTS

In this section, the experiment results are presented. The statistical significance was verified by two-tailed t-tests [52]. In our experiment each user interacted with only one version (A or B) and the number of users working with each version differs because of data quality issues encountered during eye tracking data collection. Therefore, we used the two-sample t-test [51], which specifies the degrees of freedom of t-test as equal to (nA+nB-2), where nA and nB are numbers of users using version A or B accordingly. The results are presented in Tables II-VIII with statistically significant results (p=0.05) in bold face. For all tables, results for user-friendly variants of websites are shown in row A and results for less user-friendly variants can be found in row B.

Table II shows the time to first fixation for two versions of seven designs. Time to first fixation is defined as the time from the start of the stimulus display until the the participant fixated on the AOI [21].

In four out of seven designs, the average time to first fixation was longer for design B than design A, however the difference was not statistically significant. Table III presents average number of fixations prior to first fixation on an AOI. There were no significant results for this measure.

Table IV presents the average duration of first fixation on AOI, for the A and B versions of each website. There were no significant results for this measure.

Table V presents average number of fixations over AOI for the A and B versions of each website. There was only one significant difference in the scores for RM website version A (M=2, SD=0,84) and version B (M=2, SD=0,54), t(11)=2.42, p=.033.

Table VI presents the results for the average number of visits over AOI, for the A and B versions of design. There were two significant differences in the scores. Version A of the C21 website had a significantly lower average number of visits over AOI (M=2,5, SD=1,64) than version B (M=4, SD=1,77), t(14)= -2,48, p= .026 while version A of the RM website had a significantly higher average number of visits over AOI (M=2, SD=0,52) than version B (M=1, SD=0,53), t(11)=-3,08, p=. 01.

Table VII presents the results for the average time between the first fixation on AOI and the mouse click within this area for the A and B versions of each website. There were no significant results for this measure.

Table VIII presents the results for the average duration of fixation on AOI for the A and B versions of design. There were no significant results for this measure.

VI. Discussion

The experiment that we conducted and presented here is a replication of the experiment that was described in our previous work [13]. In the conclusion of that article, we hypothesized that an eye tracker with higher frequency should provide more precise experimental data that would potentially provide statistically significant results. In our replication we used Tobii TX 300, which has a five times higher frequency rate than Tobii X-60 used in the previous research. The second factor modified in the replication of the previous experiment was the participants' level of experience in using web systems. We expected that less experienced users would encounter more problems when using poorly designed web pages and, as a result, the differences between good and bad design would be more prominent, thus allowing us to obtain statistically significant results. Additionally, the statistical analysis was done using a two-tailed t-test for two samples [51]. This test is well suited for experiments with a small number of participants and may detect significant differences regardless of the small sample size [13]. Unfortunately, none of these measures have brought the expected results. Peculiarly, we observed even fewer significant results than in the previous work [13]. In this study we still observed differences in average values for many analyzed metrics and most of the designs, however, these differences have not reached the significance level due to the small number of participants. The differences that we observed in the data would be significant for a sample size of approximately one hundred participants. Unfortunately, due to lockdown measures it was impossible to recruit more people and conduct experiments.

Finally, we would like to address why, for certain measures, some websites have opposing results. E.g. for a particular measure, one website may have scored higher for user-friendly version A and another website had a higher result for its non user-friendly variant B. There may be at least two reasons for this. First is that the value of the metric depends not only on the design quality, but also on the webpage type and the content itself. The second is that the designs A and B do not produce great differences in usability.

VII. Conclusions

In this paper, we present a replication of a webpage first click experiment enhanced with eye tracking that was described in our previous work [13]. We designed the replication following the conclusions from that study, therefore we used better quality eye tracker. However, mainly because of insufficient differences between results for designs A and B, we did not received statistically significant results. We expect these kind of study would exhibit statistically significant results for greater number of participants of at least one hundred. For some metrics we obtained differences between their averages for design A and B with opposing results for different types of websites. Consequently, future eye tracking studies exploring the impact of good and bad webpage design should carefully consider the type and content of webpages used, as well as aim for a number of participants that provides a better chance to obtain statistically significant results.

Acknowledgment

We would like to thank the experiment participants for their kindness and patience, as well as for their volunteer participation.

References

[1] M. Thüring,S. Mahlke, "Usability, aesthetics and emotions in human–technology interaction", in International Journal of Psychology, vol. 42(4), 2007, pp. 253–264.
[2] V. Roto, E. C Law, A. P. Vermeeren, J. Hoonhout, "User experience white paper: Bringing clarity to the concept of user experience". 2011.
[3] B. Nigel, "What is the difference between the purpose of usability and user experience evaluation methods", in Proceedings of the Workshop UXEM, 2009, pp. 1–4.
[4] S. Hellweger, X. Wang, "What is user experience really: towards a UX conceptual framework", arXiv preprint arXiv:1503.01850, 2015.

TABLE II
MEAN TIME TO FIRST FIXATION ON THE A AND B VERSION OF EACH WEBSITE

	C21	**FB**	**GE**	**LS**	**POPO**	**PP**	**RM**	**SS**
A	3,8	5,58	17,81	2,98	6,7	5,59	4,64	2,12
B	3,47	5,53	17,31	3,81	9,57	10,95	5,57	1,99

TABLE III
AVERAGE NUMBER OF FIXATIONS BEFORE FIRST FIXATION ON AOI ON THE A AND B VERSION OF EACH WEBSITE

	C21	**FB**	**GE**	**LS**	**POPO**	**PP**	**RM**	**SS**
A	8	17	70	8,5	19,89	21,5	16,5	3,33
B	7,5	17,65	69,8	10,83	30,91	35,56	18,57	3,12

TABLE IV
AVERAGE DURATION OF FIRST FIXATION ON THE A AND B VERSION OF EACH WEBSITE

	C21	**FB**	**GE**	**LS**	**POPO**	**PP**	**RM**	**SS**
A	0,26	0,48	0,24	0,18	0,18	0,33	0,77	0,2
B	0,2	0,3	0,31	0,16	0,2	0,28	0,81	0,22

TABLE V
AVERAGE NUMBER OF FIXATIONS ON THE A AND B VERSION OF EACH WEBSITE

	C21	**FB**	**GE**	**LS**	**POPO**	**PP**	**RM**	**SS**
A	5,5	8,88	5,75	1,5	7,22	5,6	2,5	4,56
B	9,75	9,12	7,17	3	6,09	3,67	1,57	3,25

[5] M. Bratkowska, J. Falkowska, J. Sobecki, "Webcam eye tracking platforms for usability testing", in Proc. of 35th IBIMA Conference; 1–2 April 2020, Seville, Spain, pp. 3091–3099.

[6] P. Chynał, J. Sobecki, M. Rymarz, B. Kilijańska, "Shopping behaviour analysis using eyetracking and EEG", in 9th International Conference on Human System Interactions (HSI) July 2016, pp. 458–464, IEEE.

[7] K. Cichoń, J. Sobecki, J.M. Szymański, "Gesture tracking and recognition in touchscreens usability testing" in Proceedings of the International Conference on Multimedia, Interaction, Design and Innovation, June 2013, pp. 1–8.

[8] P. Chynał, J. Sobecki, "Application of thermal imaging camera in eye tracking evaluation", in 9th International Conference on 341 Human System Interactions (HSI) 2016, July. pp. 451–457. IEEE.

[9] P. Weichbroth, K. Redlarski, I. Garnik, " Eye-tracking web usability research", in 2016 Federated Conference on Computer Science and Information Systems (FedCSIS), pp. 1681–1684. IEEE.

[10] A. Schall, J. Bergstrom, "Introduction to eye tracking", Elsevier, 2014.

[11] M. Horsley, M. Eliot, B.A. Knight, "Current Trends in Eye tracking Research", Springer, 2014.

[12] A. Bojko, "Using Eye Tracking to Compare Web Page Designs: A Case Study", Journal of Usability Studies 2006. Issue 3, Vol. 1, pp. 112–120.

[13] J. Falkowska, J Sobecki, "First Click eye Tracking A/B Tests of Webpage Interactive Elements". in Proc. of 36th IBIMA Con-349 ference; Grenada, Spain 4–5 November 2020, pp. 12524–12530.

[14] B. Rogos-Turek, I. Moscichowska, "Research as a basis for User Experience design", (in Polish), PWN:Warszawa, Poland, 2015.

[15] P. Chynał, J. Falkowska, J.Sobecki, "Web page graphic design usability testing enhanced with eye tracking" in proceedings of the 1st International Conference on Intelligent Human Systems Integration (IHSI 2018), pp. 515–520.

[16] J. Falkowska, J. Sobecki, M. Pietrzak,"Eye tracking usability testing enhanced with EEG analysis", in proc. of 5th International Conference, held as Part of HCI International 2016, Toronto, Canada, July 17–22, 2016, pp. 399–411.

[17] J. Falkowska, B. Kilijańska, J. Sobecki, K. Zerka, "Microinteractions of forms in web based 360 systems usability and eye tracking metrics analysis", in proceedings of the AHFE 2018 International Conference on Human Factors and Systems Interaction, Springer, cop. 2019, pp. 164–174.

[18] "Flat UI Elements Attract Less Attention and Cause Uncertainty", available online: https://www.nngroup.com/articles/flat-ui-less-attention-cause-uncertainty (accessed on 1.09.2021)

[19] X. Kotval, J. Goldberg, "Eye Movements and Interface Component Grouping: An Evaluation Method", in Proceedings of the Human Factors and Ergonomics Society Annual Meeting 1998, 42, pp. 486–490.

[20] J. Goldberg, X. Kotval, "Computer interface evaluation using eye movements: Methods and constructs", International Journal of Industrial Ergonomics 1999, vol. 24, pp. 631–645.

[21] A. Bojko, "Eye tracking the user experience: A practical guide to research", Rosenfeld Media, 2013, pp. 121–143.

[22] J. Nielsen, K. Pernice, "Eye tracking Web Usability", New Riders: Berkley, CA, USA 2009.

[23] K Holmqvist, M. Nyström, R. Andersson, R. Dewhurst, H. Jarodzka, J. Van de Weijer, "Eye tracking: A comprehensive guide to methods and measures", OUP: Oxford, UK, 2011.

[24] P. Krehahn, V. Wohlgemuth, H.A. Meyer, "UxLab: Usability Optimization Case Study of a Environmental Management Information System (EMIS) Using Eyetracking Studies", in EnviroInfo 2010: Integration of Environmental Information in Europe, Shaker Verlag, Aachen, 2010, pp. 248–249.

[25] M.C. Pretorius, J. van Biljon, E. de Kock,"Added Value of Eye Tracking in Usability Studies: Expert and Non-expert Participants", in proc. of Human-Computer Interaction 2010, Vol. 332, pp. 110–121.

[26] C. Ehmke, S. Wilson, "Identifying Web Usability Problems from Eye-Tracking Data", in Proceedings of the 21st British HCI Group Annual Conference on People and Computers: HCI...but not as we know it, Volume 1; BCS 384 Learning & Development Ltd.: Swindon, GBR, September 3 2007; pp. 119–128.

[27] A. Çöltekin, B. Heil, S. Garlandini, S.I. Fabrikant, "Evaluating the Effectiveness of Interactive Map Interface Designs: A Case Study Integrating Usability Metrics with Eye-Movement Analysis", 2013.

[28] A. Çöltekin, B. Heil, S. Garlandini, S.I. Fabrikant, "Evaluating the Effectiveness of Interactive Map Interface Designs: A Case Study Integrating Usability Metrics with Eye-Movement Analysis", in Cartography and Geographic Information Science 2009, vol. 36, pp. 5–17.

TABLE VI
AVERAGE NUMBER OF VISITS OVER AOI FOR THE A AND B VERSION OF EACH WEBSITE

	C21	FB	GE	LS	POPO	PP	RM	SS
A	2,6	2,5	2,5	1,5	3,33	4,7	2,33	2,89
B	5	3	2,33	2,17	2,64	2,67	1,43	2,38

TABLE VII
MEAN TIME FROM FIRST FIXATION TO MOUSE CLICK ON THE A AND B VERSION OF DESIGN

	C21	FB	GE	LS	POPO	PP	RM	SS
A	8,35	3,09	4,08	3,15	4,92	7,34	3,64	2,42
B	14,15	4,1	2,97	4,34	4,71	5,88	1,86	2,21

TABLE VIII
MEAN FIXATION DURATION ON THE A AND B VERSION OF DESIGN

	C21	FB	GE	LS	POPO	PP	RM	SS
A	0,29	0,31	0,31	0,18	0,27	0,46	0,64	0,37
B	0,29	0,29	0,33	0,26	0,25	0,44	0,69	0,39

[29] H.-F. Ho, ”The Effects of Controlling Visual Attention to Handbags for Women in Online Shops: Evidence from Eye Movements”, in Computers in Human Behavior 2014, vol. 30, pp. 146–152.

[30] N. Steinfeld,”I Agree to the Terms and Conditions: (How) Do Users Read Privacy Policies Online? An Eye-Tracking Experiment”, in Computers in Human Behavior 2016, 55, pp. 992–1000.

[31] H.-C. Liu, M.-L. Lai, H.-H. Chuang, ”Using Eye-Tracking Technology to Investigate the Redundant Effect of Multimedia Web Pages on Viewers”, in Cognitive Processes. Computers in Human Behavior 2011, vol. 27, pp. 2410–2417.

[32] C.-Y. Wang, M.-J. Tsai, C.-C. Tsai, ”Multimedia Recipe Reading: Predicting Learning Outcomes and Diagnosing Cooking Interest Using Eye-Tracking Measures”, in Computers in Human Behavior 2016, vol. 62, pp. 9–18.

[33] L. Grigg, A. Griffin, ”A Role for Eye-Tracking Research in Accounting and Financial Reporting”, in Current trends in eye tracking research Springer, Cham 2014; pp. 225–230.

[34] S. Djamasbi, M. Siegel, T. Tullis, ”Can Fixation on Main Images Predict Visual Appeal of Homepages”, in Proceedings of the 2014 47th Hawaii International Conference on System Sciences; IEEE: Waikoloa, HI, January 2014; pp. 371–375.

[35] Y. Habuchi, M. Kitajima, H. Takeuchi, ”Comparison of Eye Movements in Searching for Easy-to-Find and Hard-to-Find Information in a Hierarchically Organized Information Structure”, in the Proceedings of the the 2008 symposium on Eye tracking research & applications, Association for Computing Machinery: New York, NY, USA, March 26 2008; pp.131–134.

[36] A. Bojko, ”Using Eye Tracking to Compare Web Page Designs: A ”, inase Study”, J. Usability Stu 2006, 1, pp. 112–120.

[37] J. Luan, Z. Yao, Z. F. Zhao, H. Liu, ”Search Product and Experience Product Online Reviews: An Eye-Tracking Study on Consumers’ Review Search Behavior”, Computers in Human Behavior 2016, vol. 65, pp. 420–430.

[38] S.-F. Yang, ”An Eye-Tracking Study of the Elaboration Likelihood Model in Online Shopping”, in Electronic Commerce Research and Applications 2015, vol. 14, pp. 233–240.

[39] S. Djamasbi, M. Siegel, T. Tullis, ”Designing Noticeable Bricklets by Tracking Users’ Eye Movements”, in Proceedings of the 2012 45th Hawaii International Conference on System Sciences; IEEE: Maui, HI, USA, January 2012; pp. 525–532.

[40] J. Hernández-Méndez, F. Muñoz-Leiva, ”What Type of Online Advertising Is Most Effective for ETourism 2.0, An Eye Tracking Study Based on the Characteristics of Tourists”, in Computers in Human Behavior 2015, vol. 50, pp. 618–625.

[41] H. Lin, Y.-C. Hsieh, F.-G. Wu, ”A Study on the Relationships between Different Presentation Modes of Graphical Icons and Users’ Attention”, in Comput. Hum. Behav. 2016, vol. 63, pp. 218–228.

[42] Q. Wang, S. Yang, M. Liu, Z. Cao, Q. Ma, ”An Eye-Tracking Study of Website Complexity from Cognitive Load Perspective”, in Decision Support Systems 2014, vol. 62, pp. 1–10.

[43] S.P. Roth, A.N. Tuch, E.D. Mekler, J.A. Bargas-Avila, K. Opwis, ”Location Matters, Especially for Non-Salient Features-An Eye-Tracking Study on the Effects of Web Object Placement on Different Types of Websites”, in Int. J. Hum.-Comput. Stud. 2013, vol. 71, pp. 228–235.

[44] C. Cuadrat Seix, M.S. Veloso, J.J.R. Soler, ”Towards the Validation of a Method for Quantitative Mobile Usability Testing 422 Based on Desktop Eyetracking”, in Proceedings of the Proceedings of the 13th International Conference on Interacción Persona-Ordenador; Association for Computing Machinery: New York, NY, USA, October 3 2012; pp. 1–8.

[45] R. Bednarik, M. Tukiainen, ”Validating the Restricted Focus Viewer: A Study Using Eye-Movement Tracking”, in Behavior Research Methods 2007, 39, vol. pp. 274–282.

[46] Q. Wang, S. Yang, M. Liu, Z. Cao, Q. Ma, ”An Eye-Tracking Study of Website Complexity from Cognitive Load Perspective”, in Decision Support Systems 2014, vol. 62, pp. 1–10.

[47] A. Çöltekin, B. Heil, S. Garlandini, S.I. Fabrikant, ”Evaluating the Effectiveness of Interactive Map Interface Designs: A Case Study Integrating Usability Metrics with Eye-Movement Analysis”, in Cartography and Geographic Information Science 2009, vol. 36, pp. 5–17.

[48] C. Ehmke, S.G. Wilson, ”Identifying Web Usability Problems from Eye-Tracking Data”, September 1 2007; Vol. 1, pp. 119–128.

[49] J. Luan, Z. Yao, F. Zhao, H. Liu, ”Search Product and Experience Product Online Reviews”, in Comput. Hum. Behav. 2016, vol. 65, pp. 420–430.

[50] J. Falkowska, B. Kilijańska, J. Sobecki, K. Zerka, ”Microinteractions of Forms in Web Based Systems Usability and Eye 436 Tracking Metrics Analysis” in International Conference on Applied Human Factors and Ergonomics. Springer, Cham, 2018, pp. 164–174.

[51] J. Sauro, J.R. Lewis, ”Quantifying the User Experience: Practical Statistics for User Research”, 2nd edition, Morgan Kaufmann: Amsterdam Boston Heidelberg, 2016.