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Comparison of Three Travel Websites According to Cognitive Load and Usability Metrics

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Abstract – It is crucial that a website reflects a quality user interface (UI) that brings out the holiday enthusiasm for users, while still remaining user friendly and a simple area that is easily accessible. To achieve this, it is important that user experience designers measure the efficiency of the interface interaction between human and machine and ensure continuous interface development. In order to test interfaces and find differences, 3 different travel web sites was selected with experiments performed with 38 participants. Tested travel website interfaces are Trivago, ETS Tour and Odamax. Participants performed 6 different tasks during the experiment and after these tasks, a think aloud protocol was implemented and NASA-Task Load Index (NASA-TLX), IBM Computer System Usability Questionnaire (IBM CSUQ) questionnaires were applied. In order to analyze the differences between interfaces, task completion time, number of errors, success rate, IBM CSUQ questionnaire average and NASA TLX questionnaire average were collected as data. ANOVA analysis was performed between interfaces using IBM SPSS Statistics 22 program and Independent T test was used to test usability by gender. According to ANOVA results, task completion time, number of errors, success rate, IBM CSUQ survey score average and NASA TLX survey score average change significantly as interface changes. Respectively, Trivago, Odamax, ETS Tour has the highest cognitive load in the measurements. According to the results of independent T tests, there is no difference between men and women in terms of interface usability.

Keywords – User experience, interface, usability testing, Anova, NASA TLX, IBM CSUQ

I. INTRODUCTION

With the development of technology, the interaction of the human machine becomes more and more important. To design user-friendly interfaces is a necessity in terms of human factor and ergonomics. User experience design is to use specific methods and techniques for producing consistent, predictable and desirable effects on a particular person or persons. User experience is the totality of human-machine interaction, including the experimental and affective aspects, the things that the user experiences when interacting with the interface, using the interface and after finishing the interaction with the interface [1]. Comprehensive analysis and evaluation methods are important for both user experience design and cognitive emphasis [2].

In the literature, three different methods are used for cognitive load measurement; NASA-TLX, Tapping Test and Sternberg memory test. Touch test and Sternberg memory test are the tests performed by the users while performing the experiments. NASA TLX is performed after the experiments. As a result, NASA TLX is a post-event test that captures how people think or remember interaction; The Sternberg Memory task and touch test provide users with the ability to collect responses throughout the interaction [3]. NASA-TLX is a multidimensional scale designed to generate workload estimates when performing or immediately after a task. After 20 years of use, NASA-TLX was offered online and used as a tool to calculate the cognitive load of aviation, crew, operating room, nuclear power plant control units [4]. In order to measure the effect of stress on cognitive load measurement, [5] investigated galvanic skin resistance which is one of the human physiological reactions. The results were analyzed with ANOVA to emphasize the use of galvanic skin resistance to measure the effect of stress on cognitive load.

[6] developed and compared the NASA TLX workload determination tool cognitive rule-based expert modeling system. In the study, different heuristic scans include digitizing and quantizing binary indexes such as NASA TLX. In another study [7] used the NASA LTX to assess the mental workload of experts working in R & D projects evaluation activities. The project evaluation stage was divided into 3 main groups and 56 participants were evaluated with cognitive workload using NASA TLX technique. It was observed that all scales except physical requirement scale differed significantly among experts. In addition, the outputs of the first phase of this study can be used to develop project assignment software for experts that takes into account the project's degree of difficulty, budget and area of expertise. [8] evaluated the mental workload of emergency physicians using NASA-RTLX method. [9] studied flight simulator in terms of both cognitive load and ergonomics. In another study related to mental workload assessment of the pilots, cognitive workload was measured by NASA-TLX method. The results were analyzed by ANOVA and it was emphasized that task difficulty had a positive effect on increasing cognitive load [10]. In the study on mobile augmented reality, the use of augmented reality technology with the NASA-TLX method of

the augmented reality experience was tested in tourist-guided applications [11].

In the studies on usability tests [12] presented 6 different techniques for the usability testing of mobile computers and devices in the laboratory. The aim of the techniques is to support the identification of usability issues in mobile use in a controlled environment. The techniques were used in two different experiments. Users no significant difference in terms of technical performance, significant differences were observed in terms of workload. In another study, the usability of 3 different travel sites was tested with identified tasks [13] and [14] examined the desktop and mobile versions of two different tourist websites. With the help of a responsive web design approach, the opinions of the users after completing the tasks were analyzed with Anova. In another study conducted using IBM CSUQ, the usability of university student information systems was analyzed. Influence of user impressions in the information system was examined through four factors; useful information, timely access, interface design and error recovery were monitored [15].

When we look at the literature, usability studies are necessary in all areas and NASA TLX and IBM CUSQ questionnaires are among the most used and reliable tools. The information included in this paper is organized as follows: in Section 2 materials and methods are explained, statistical analyzes and results are introduced in Section 4. Section 5 concludes the article and suggests some future works.

II. Materials and Method

The most fundamental usability method to acquire direct information on how people use technology and the challenges faced is usability testing [16]. The different categories of usability tests consist of such as performance measurement, think aloud protocol, coaching method, retrospective testing, constructive interaction, and questionnaires [16]. In this study, task completion time, number of errors, success rate are utilized as performance measurement. Afterward, think aloud procedure and questionnaires were applied. Before the user tests are performed the user consent form was approved and a user information questionnaire was filled.

A. Participants

The participants were 19 men and 19 women with a total of 38 people between the age of 20-35.The level of education of the participants is 2 associate degrees, 29 undergraduate degrees,5 graduate degrees and 2 PhD degrees. In the information form, user's travel web site usage time and travel web site usage frequency information were also collected. 45% of participants use the travel web-sites for a period of three years or more and 61% of the participants use the travel web-sites three times or more during the year. After all the tasks are completed in one interface, the participants start the other interface. Before starting the other interface users completed NASA-TLX and IBM CSUQ questionnaires which related to the interface.

B. Apparatus

The study used a HP Core i5-6200U processor and a 2, 40 GHz laptop with built-in web cameras. Participants were provided with a computer mouse and used the browser, Google Chrome, to access the travel sites under study. The screen recording software captured the user's laptop screen.

C. Experimental Design

The participants' gender, age, education level, occupational position, travel web-site usage time, travel web-site usage frequency were defined as independent variables. Task completion time, error count, task success rate, NASA TLX score and IBM CSUQ scores were defined as dependent variables to test interface availability. Task success rate were defined as the ratio of the number of successful tasks to total tasks. For the NASA TLX score, 7 dependent variables were defined as mental demand, physical demand, temporal demand, performance shown, effort and frustration, and overall score. System usefulness (SYSUSE) is evaluated through 1-8 questions, information quality (INFOQUAL) is evaluated through 9-15 questions, interface quality (INTERQUAL) is evaluated through 16-18 questions and overall score (OVERALL) is evaluated through 1-19 questions. They were defined as four dependent variables.

The categorical variables were separated into 2 categories for gender, 3 categories for age, 5 categories for education level, 4 categories for occupational position, 4 categories for travel website usage time, 4 categories for travel website usage frequency and 7 categories for IBM survey.

The hypotheses established for 3 different travel website interfaces in the experiments are given in Table 1.

Table 1. Hypotheses for the 3 travel websites' interface.

Tested variable	Hypothesis
Normality	**H1**: The data fits for the normal distribution.
Task completion time	**H2**: Task completion times for the interfaces are equal.
Number of errors	**H3**: Number of errors for the interfaces are equal.
IBM scores	**H4**: IBM scores between the interfaces are equal.
NASA TLX scores	**H5**: NASA TLX scores for the interfaces are equal.
Success rate	**H6**: Success rate for the interfaces are equal.

To test the interface usability according to the difference between men and women, hypotheses are given in Table 2.

Table 2. Hypotheses for difference between men and women

Tested variable	Hypothesis
Task completion time	**H7**: Task completion times are equal for men and women.
Number of errors	**H8**: Number of errors are equal for men and women.
IBM scores	**H9**: IBM scores are equal for men and women.
NASA TLX scores	**H10**: NASA TLX scores are equal for men and women.
Success rate	**H11**: Success rates are equal for men and women.

D. Procedure

In order to test the usability of interfaces in the experiments, six tasks were given to the users before the start of the task and presented to the users in the task form. The observation form filled in by the observer was used to record the success rate in the tasks, the number of errors and completion times of the tasks.

Before starting the experiments, the user interface screen was given to the users in the experimental environment and the tasks stated in the task form were read aloud. The observer recorded the user's mistakes such as wrong menu selection and the task start-finish times when completing the tasks. After the questionnaires, the stages that the users' opinions and suggestions related to interface were noted by using think aloud protocol. Each session lasted about 30 minutes.

III. Statistical Analyses

A. Normality Tests

Differences in task completion times between interfaces, difference in error counts, success rate, IBM-SYSUSE, IBM-INFOQUAL, IBM-INTERQUAL, IBM-OVERALL and NASA TLX's six factors and the general score's kurtosis and skew z values were in accordance with the distribution of normality. Since z values of kurtosis and skewness remain within ± 2.58, the data fits for the normal distribution.

B. One Way ANOVA

One way ANOVA is used to determine whether there is a significant difference between the interfaces in terms of task completion times, error counts, success rate, IBM-SYSUSE, IBM-INFOQUAL, IBM-INTERQUAL, IBM-OVERALL and NASA TLX factors.

B.1. Task Completion Time

p = 0.744> 0.05 the variances are homogeneous. Tukey Test is performed for comparison analysis. Task completion time differs significantly as the interface changes, F (2,103) = 185,243 p <0.001. There is a significant increase of 4.41 points on the Trivago interface (M = 14.2, SD = 1.02) compared to the ETS interface (M = 9.8, SD = 0.9) for the total time (p = 0.001). 95% Cl [3.8, 5.02]. For the total time, there is a significant increase of 4.14 points in Trivago interface (M = 14.2, SD = 1.02) compared to Odamax interface (M = 10, SD = 1.3). (p = 0.001), 95% Cl [3.5, 4.8]. There is no significant difference in total ETS Tour interface compared to Odamax interface. p> 0.05.

B.2.Number of error

Since p = 0.003 <0.05, the variances are not homogeneous. For comparison analysis, the Games-Howell Test is performed. The number of errors differs significantly as the interface changes, F (2,111) = 45,507 p = 0, 0001. For the number of errors, there is an average increase of 1.21 points in the Trivago interface (M = 2.97, SD = 1.61) compared to the ETS Tour interface (M = 1.76, SD = 1.05), (p = 0.001), 95% Cl [1.962, 0459]. The number of errors is significantly increased by 2.42 points in the Odamax interface (M = 5.39, SD = 2.19) compared to the Trivago interface (M = 2.97, SD = 1.61). (p = 0.001), 95% Cl [1.35-3.48]. There is a significant increase of 3.63 points in the Odamax interface (M = 5.39, SD = 2.19) compared to the ETS Tour interface (M = 1.76, SD = 1.05) for the number of errors (p = 0.00001), 95% Cl [2.67, 4,58].

B.3. IBM CSUQ

Since p <0.05, variances are not homogeneous. For comparison analysis, the Games-Howell Test is performed. For IBM scores, the 1-19 (IBM-OVERALL) questions mean, 1-8 questions (IBM-SYSUSE) mean and 16-19 questions (IBM-INTERQUAL) mean differ significantly as the interface changes, p <0.05. Since P = 0.260> 0.05, the mean score of 9-15 questions (IBM-INFOQUAL) for IBM scores do not differ significantly as the interface changes, p> 0.05. For the IBM-OVERALL average, there is a significant increase of 0.73 points on the Trivago interface (M = 4.32, SD = 0.56) compared to the ETS Tour interface (M = 3.59, SD = 0.31), (p = 0.0001), 95% Cl. For the IBM-OVERALL average, there is a significant increase of 0.93 points on the Odamax interface (M = 4.54, SD = 0.74) compared to the ETS Tour interface (M = 3.59, SD = 0.31), (p = 0.0001), 95% Cl. For the IBM-OVERALL average, there is a significant increase of 0.19 points in the Odamax interface (M = 4.54, SD = 0.74) compared to Trivago interface (M = 4.32, SD = 0.56), (p = 0.0001),% 95 Cl.

For the IBM-INFOQUAL average, there is a significant increase of 0.23 points in the Trivago interface (M = 4.57, SD = 0.59) compared to the ETS Tour interface (M = 4.34, SD = 0.50), (p = 0.0001), 95% Cl. For the IBM-INFOQUAL question average, there is a significant increase of 0.08 points on the Odamax interface (M = 4.43, SD = 0.76) compared to the ETS Tour interface (M = 4.34, SD = 0.50), (p = 0.0001), 95% Cl. For the IBM-INFOQUAL average, there is a significant increase of 0.14 points in the Trivago interface (M = 4.57, SD = 0.59) compared to the Odamax interface (M = 4.43, SD = 0.76), (p = 0.0001), 95% Cl.

For the IBM-INTERQUAL averages, there is a significant increase of 0.49 points on the Trivago interface (M = 4.75, SD = 0.59) compared to the ETS Tour interface (M = 4.26, SD = 0.50), (p = 0.0001), 95% Cl. For the IBM-INTERQUAL average, there is an average increase of 0.26 points in the Odamax interface (M = 4.52, SD = 0.78) compared to the ETS Tour interface (M = 4.26, SD = 0.50), (p = 0.0001), 95% Cl. For the IBM-INTERQUAL average, there is a significant increase of 0.22 points on the Trivago interface (M = 4.75, SD = 0.59) compared to the Odamax interface (M = 4.52, SD = 0.78), (p = 0.0001), 95% Cl.

B.4. NASA TLX

Since p <0.05, variances are not homogeneous. For comparison analysis, the Games-Howell Test is performed. All NASA indicators differ significantly. Mental demand differs significantly as the interface changes, F (2,111) = 164,231 p <0.001. F (2,111) = 214,651 differ significantly as the physical demand changes, F (2,111) = 209,387 significantly differ as the overall score interface changes. There is an average increase of 12.62 points in the mental demand of Trivago interface (M = 74.34, SD = 9.16) compared to the ETS Tour interface (M = 61.71, SD = 7.64), (p = 0.001), 95% Cl In terms of mental demand, there is a significant increase of 40.52 points in Trivago interface (M = 74.34, SD = 9.16) compared to Odamax interface (M = 33.82, SD = 12.49). (p = 0.001), 95% Cl. There is a significant increase in

mental demand of the ETS Tour interface (M = 61.71, SD = 7.64) compared to the Odamax interface (M = 33.82, SD = 12.49) with a score of 27.89, (p = 0.00001), 95% Cl.

In physical demand, there is a significant increase of 35,95 points in the Trivago interface (M = 72.37, SD = 6.54) compared to the ETS Tour interface (M = 36.97, SD = 6.31), (p = 0.001), 95% Cl In physical demand, there is a significant increase of 36.71 points in Trivago interface (M = 72.37, SD = 6.54) compared to Odamax interface (M = 35.66, SD = 11.97). (p = 0.001), 95% Cl. There is no significant difference in physical demand in the ETS Tour interface (M = 36.97, SD = 6.31) compared to the Odamax interface (M = 35.66, SD = 11.97). p = 0.825

There is an average increase of 23.68 points in temporal demand in Trivago interface (M = 62.63, SD = 15.36) compared to ETS Tour interface (M = 38.95, SD = 6.59), (p = 0.001), 95% Cl There is a significant increase in temporal demand of 24.73 points in Trivago (M = 62.63, SD = 15.36) interface compared to Odamax interface (M = 37.89, SD = 11.36). (p = 0.001), 95% Cl. There is no significant difference in time requirement in ETS Tour interface (M = 38.95, SD = 6.59) compared to Odamax interface (M = 37.89, SD = 11.36). p = 0.875.

In terms of performance, there is a significant increase of 45, 26 points in Trivago interface (M = 71.58, SD = 8:06) compared to ETS Tour interface (M = 26.32, SD = 6.11). (p = 0.001), 95% Cl. In terms of performance, there is a significant increase of 27.50 points in Trivago interface (M = 71.58, SD = 8.06) compared to Odamax interface (M = 44.08, SD = 16.88). (p = 0.001), 95% Cl. In terms of performance, there is a significant increase of 17.76 points in ETS Tour interface (M = 26.32, SD = 6.11) compared to Odamax interface (M = 44.08, SD = 16.88). (p = 0.001), 95% Cl.

In terms of the effort, there is a significant increase of 36.18 points in the Trivago interface (M = 63.03, SD = 7.58) compared to the ETS Tour interface (M = 26.84, SD = 4.98), (p = 0.001), 95% Cl In terms of effort, there is a significant increase of 16.18 points in Trivago interface (M = 63.03, SD = 7.58) compared to Odamax interface (M = 46.84, SD = 14.90). (p = 0.001), 95% Cl. In terms of effort, there is a significant increase of 20.00 points in the Odamax interface (M = 46.84, SD = 14.90) compared to the ETS Tour interface (M = 26.84, SD = 4.98). (p = 0.001), 95% Cl.

In terms of the frustration, there is a significant increase of 38.68 points in Trivago interface (M = 65.13, SD = 9.04) compared to ETS Tour interface (M = 26.45, SD = 7.15), (p = 0.001), 95% Cl In terms of frustration, there is a significant increase of 25.79 points in Trivago interface (M = 65.13, SD = 9.04) compared to Odamax interface (M = 39.34, SD = 16.77). (p = 0.001), 95% Cl. In terms of frustration, there is a significant increase of 12.89 points in the Odamax interface (M = 39.34, SD = 16.77) compared to the ETS Tour interface (M = 26.45, SD = 7.15). (p = 0.001), 95% Cl.

Overall score of the Trivago interface (M = 67.63, SD = 4.12) compared to the ETS Tour interface (M = 36.24, SD = 4.30) there is a significant increase of 31.38 points on average, (p = 0.001), 95% Cl. Overall score of Trivago interface (M = 67.63, SD = 4.12) compared to the Odamax interface (M = 41.06, SD = 10.95) is a significant increase of 26.56 points. (p = 0.001), 95% Cl. Overall score of the Odamax interface (M = 41.06, SD = 10.95) is significantly higher than the ETS Tour interface (M = 36.24, SD = 4.30) with a 4.8-point increase. (p = 0.001), 95% Cl.

Since p = 0.003 <0.05, the variances are not homogeneous. For comparison analysis, the Games-Howell Test is performed. The success rate differs significantly as the interface changes, F (2,111) = 6,488 p = 0,002. There is no significant difference in the success rate of Trivago interface (M = 73.24, SD = 17.56) compared to ETS Tour interface (M = 81.14, SD = 17.82). The success rate of the Odamax interface (M = 85.96, SD = 9.89) compared to the Trivago interface (M = 73.24, SD = 17.56) is a significant increase of 12.71 points. (p = 0.001), 95% Cl There was no significant difference in success rate compared to Odamax interface (M = 85.96, SD = 9.89) in ETS Tour interface (M = 81.14, SD = 17.82).

C. Independent T tests

Independent T test analysis is used to determine whether there was a significant difference between the participants by gender for task completion times, error counts, success rate, IBM-SYSUSE, IBM-INFOQUAL, IBM-INTERQUAL, IBM-OVERALL, and NASA TLX six factors and overall score. Since the task completion time for gender was p = 0.972> 0.05, it is homogeneously distributed. There is no significant difference between the total task completion time as t (104) = - 0.721, p = 0.472 p> 0.05. Since the number of errors according to gender is p = 0.462> 0.05, it is distributed homogeneously. There are no significant differences in the total number of errors between men and women as t (112) = 0.703, p = 0.483 p> 0.05.

Since the success rate was p = 0.309> 0.05 according to gender, it is homogeneously distributed. There is no significant difference between male and female for the success rate as t (112) = 0.382, p = 0.703 p> 0.05. IBM overall average score p = 0.001 <0.05 because it is not homogeneously distributed. (See 2nd place) There is a significant difference between IBM overall between female and male t (96.49) = 2.904, p = 0.005 <0,05. There is a significant difference between IBM-SYSUSE between female and male t(112)=2,250, p=0,026 p<0,05 There is not a significant difference between IBM infoqual between female and male t(112)=1,006, p=0,317 p>0,05 There is not a significant difference between IBM interqual and female mean score t(112)=1,176, p=0,242 p>0,05

IV. DISCUSSION

It is found that according to task completion time factor Trivago is the most time consuming interface among the travel websites. However the ETS Tour and Odamax interfaces are not different from each other meaningfully. Since task completion time is an important metric for usability tests, Trivago's interface must be designed according to the principles and must be simplified. It is found that according to error counts, Odamax interface has the most error counts among the travel websites. Odamax interface seems to direct people wrongly and it has no explicit design. It is found that according to IBM OVERALL, Odamax interface has the highest score and ETS Tour has the lowest score among the travel websites. If we discuss this score's components, for the IBM-INFOQUAL average Trivago' s interface has the highest and ETS Tour has the lowest score. This score is about screen messages, online help and other information provided.

Trivago' s interface is good at providing help when an error occurrs but ETS Tour isn't sufficient to give feedback. For the IBM-INTERQUAL average Trivago' s interface has the highest and ETS Tour has the lowest score. This score is about information organization and correcting errors easily. When a problem occurs, Trivago is good at providing corrective messages summarily but ETS Tour must improve itself in this matter.

It is found that, NASA TLX Overall score is the highest for Trivago interface and lowest for ETS Tour interface. It's mean is Trivago's interface is more demanding in means of mental, physical, temporal, effort, performance and frustration factors. If we discuss this score's components, for mental demand Trivago is the most mental demanding and Odamax is the least mental demanding travel website. Mental demand is the extent to which thinking, perception and calculation actions are needed due to the complexity and difficulty of the task. Trivago requires more mental process so it should be designed less complex and more understandable. From the physical demand aspect again Trivago is the most physical demanding traves website while there is no meaningful difference between Odamax and ETS Tour. Physical demand is how much physical activity is needed while browsing the website. Trivago requires more activities like check, control, closing the screen so it should be more slack less strenuous. For temporal demand once again Trivago is the most temporal demanding website while there is no significant difference between Odamax and ETS Tour. Temporal demand is the time pressure felt by the speed at which tasks or task elements occur. Trivago's pace must be slower and less rapid in order to help feel more comfortable. From the performance point of view Trivago has the highest performance level while Odamax has the lowest performance level in travel websites. Performance level is how successful you are in performing the task and how satisfied you are with your performance. Therefore users feel unsatisfied and unsuccessful when using Odamax.

From the point of view of frustration Trivago has the highest frustration level while ETS Tour has the lowest frustration level among travel websites. Frustration means how you feel irritated, stressed, and annoyed versus content, relaxed, and complacent during the task. So while users complete tasks in Trivago they feel irritated and stressed. For effort, Trivago requires the most effort while ETS Tour requires the lowest effort in travel websites. Effort means how hard you need to work (mentally and physically) to achieve your performance level. Therefore users have to make more effort when using Trivago.

Success rate when achieving tasks is another important aspect for interfaces. If the success rate is low then the interface is useless and users can't achieve what they want. When we look at the interfaces there is no significant difference between Trivago and ETS Tour and Odamax and ETS Tour. However Odamax's success rate is higher than Trivago's success rate. Users are more successful when using Odamax compared to Trivago.

Besides Anova tests independent t tests for all factors are conducted. However there is no significant difference between men and women in terms of all factors. This means while men and women visit and browse travel websites they find websites equally usable in terms of all factors.

V. CONCLUSION

According to ANOVA results, task completion time, number of errors, success rate, IBM CSUQ questionnaire average and NASA TLX questionnaire average change significantly as interface changes. However, according to the results of independent T tests, there is no difference between men and women in terms of interface usage.

Trivago has the highest cognitive load and task completion time among all travel websites. However at the same time it has the highest IBM interface quality and information quality scores. This may be the result of using too extensive, too detailed and unnecessary visual images. At this point, the important thing for interfaces is to fill the short-term memory with the most necessary information. It is necessary to present the information in a hierarchical structure in order of importance. The least needed information should be included in the places where users least look. Less needed information can thus be prevented from confusing the user.

In future studies design principles can develop for travel websites and a travel website can be created. Future Studies should increase the number of participants to obtain reliable and definitive results.

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