A Usability Study of WebMaps with Eye Tracking Tool: The Effects of Iconic Representation of Information

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Abstract. In this study, we aim to conduct usability tests on different WebMap sites with eye movement analysis. Overall task performance, the effects of iconic representation of information, and the efficiency of pop-up usage were evaluated. The eye tracking technology is used for this study in order to follow the position of the users' eye-gaze. The results show that there are remarkable differences in task performance between WebMaps. Addition, they also differ in the use of iconic representations according to results of users' evaluation. It is also found that efficiency of pop-up windows' usage has an effect on task performance.

Keywords: Web mapping, usability, eye tracking, cognitive processes, iconic representations, and the efficiency of pop-ups.

1 Introduction

Web mapping sites became widespread in many professional areas since they provide opportunities such as designing and sharing maps on the World Wide Web. Beside to their role on professional area, it also became very considerable part of our daily life since it makes the navigation easier [13]. Addition to large number of web mapping sites' users which access these sites with their desktop and laptop PCs, improvements in technology make the internet available in nearly everywhere providing a chance to connect with mobile devices (mobile phones, smart phones, PDAs) and multiply the number of web mapping sites' users. By the increasing number of web mapping sites' users, researchers started to conduct usability studies of these sites and to investigate the effects of usability [2, 8, 13, 15]. The term usability is defined by ISO 9241 [9] as "the effectiveness, efficiency and satisfaction with which specified users achieve specified goals in particular environments" [9, 13]. Another definition from Nielson, one of the pioneers in the usability field, states usability as a quality evaluation that assesses how easy user interfaces are to use. According to his definition, usability is composed of five quality components [16]; these components are learnability, efficiency (task completion time), memorability, errors, satisfaction. Addition to these parameters obtained from usability study, usage of the eye tracking tools adds a different aspect to the usability field for the reason that it provides objective and quantitative evidence to investigate user's cognitive processes such as visual and attentional

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processes [5]. Usage of eye tracking on usability field started at 1950's [6]. However due to the difficulties in the analysis of huge data obtained from the eye tracking tools, it lost its popularity in 1970's. With the improvements of the eye tracking technologies, eye tracking tools gain their impacts on the usability field again [10] and nowadays they are accepted as a tool to improve computer interface.

In one of the studies about WebMap usability conducted by Nivala [13], severity of the usability problems were investigated. In our study, we aim to make additional analysis to find the reason of these usability problems and make them more clear by analyzing eye movements of the users. The focus of this study is to analyze the effects of the iconic representation of the information and to investigate whether the pop-ups are used efficiently by the user. The eye tracking tool is used for this study in order to follow the position of the users' eye movements, which helps to measure the attended location on the map. It is known that eye movements provide information about cognitive processes such as perception, thinking, decision making and memory [1, 3, 4, 12, 14]. Evaluation of eye movement provided us the opportunity to focus on the iconic representations, efficiency of pop-up windows and their effects in map comprehension in different WebMaps.

2 Method and Materials

26 subjects (12 female, 14 male) either university students or graduate in a range of ages between 18 and 32 participated to this study. In order to get information about their prior knowledge about WebMap usage and to get the user's idea about the comprehensibility of the icons and preferences about the WebMaps, a questionnaire was carried out. Each subject evaluated two different WebMaps for different places in US in random order. Six tasks shown in Table 1 were used in the experiment. Users were told that they could give up the task or the experiment whenever they wanted to. Tasks given to the users include; to find given address, to find definite places which are represented with icons (s.t airport, metro station, hospital) and to show the route to specific locations.

The experiments are conducted at the Human-Computer Interaction Research and Application Laboratory at Middle East Technical University. Eye movements of users were collected by Tobii 1750 Eye Tracker and analyzed with Tobii Studio.

Table 1. Task Description

Task No	Task Description
Instruction	Welcome to X City/State. You are planning to look at the city map to specify the locations that you want to visit before starting your trip
1	Point the nearest highway intersection to X International *Airport*
2	You want to go from X International A*irport* to X *University*. Could you describe how to arrive to that location?
3	Find the address of the *hospital* nearest to X Park
4	Now, you are in X Location. Show the nearest *metro/railway* station to this place
5	You are searching for the *library* nearest to X place. Find and point it on the map.
6	Show the intersection point of the *given address* with X street.

In the Nivela et al.'s study [13], there is an evaluation of four different web mapping sites. These are Google Maps, MSN Maps & Directions, MapQuest and Multimap. However, since the MSN Maps and Directions, Multimap are based on Microsoft Virtual Earth, we replaced these sites with Live Search Maps that is also based on MS Virtual Earth. Since these are well-known and all have zooming and panning options on their 2D map applications, they are very good candidates for usability testing. Although their common properties mentioned above, they differed in terms of usage of icon representation and pop-up window properties. We conducted the usability testing of Google Maps, Live Search Map, MapQuest and Yahoo Map and investigated the effect of iconic representation of information and pop-up windows by analyzing eye movements. We use the term "The iconic representation of information" as to state the relationship between their semantics and appearance. Addition to evaluation of task completion performance (s.t. task completion score and time), eye tracking data such as fixation length, fixation count, observation length was collected.

3 Results

Results are presented under three categories; task performance, analysis of the iconic representations and analysis of pop-up windows.

3.1 Task Performance

Users are grouped into two categories according to their WebMap usage experience; experienced users (14 users) for high-level usage frequency and inexperienced users (12 users) for low level usage frequency. One way ANOVA test was conducted to compare mean fixation length on task completion time for experience level. Result shows that user's experience level has a significant effect on task completion time, $F(1,52)=5,30$, $p>.05$.

One of the evaluation criteria of comparing the usability of WebMaps is users' task completion scores. Task completion score was evaluated under three categories; accomplished tasks, unaccomplished tasks and partially accomplished tasks that the users thought that they accomplished a task when they actually did not. Table 2 provides the percentage of users, who accomplished, partially accomplished and did not accomplish each task and also overall score was calculated for each WebMap site.

Fig. 1 shows the overall completion score for each map. Results of one way ANOVA shows that task completion score of Google Map is significantly different than MapQuest and Yahoo Map, $F(3,48)= 8.629$ $p<.05$. It is also worth to note that significance value of difference between Live and Yahoo is .05.

In addition to analysis of task completion score, mean fixation length for each task was analyzed individually (see Fig. 2 for comparison). Only fixation length on accomplished and partially accomplished tasks was counted. The results show that, for the first task, there is no significant difference in fixation length according to map type. The fixation length during task two, a significant difference was found between Live Search Map and MapQuest, Google Map and MapQuest, Yahoo Map and MapQuest $F(3,43)= 12.538$, $p<.05$. For the third task, Google Map is significantly

different than MapQuest, F (3,33)=3.768, p<.05. For the fourth task, Google Map is significantly different than MapQuest and Live Search Map, F(3,23)= 5.398 p<.05. The fixation length on the fifth task, Google Map is significantly different than MapQuest, Yahoo Map and Live Search Map, F(3,35)=12.058, p<.05. For the task six, only difference in Live Search Map and MapQuest is significant, F(3,41)=2.444, p<.05. Statistical analysis of mean fixation count for each task also shows that there are significant differences between the pairs given above.

Table 2. Percentage of users' task completion scores

		Google Map	Live Search Map	Map Quest	Yahoo Map
Task1	tasks accomplished	100.0	86.7	100.0	100.0
	tasks partially accomplished	0.0	13.3	0.0	0.0
	tasks unaccomplished	0.0	0.0	0.0	0.0
Task2	tasks accomplished	100.0	93.3	50.0	63.6
	tasks partially accomplished	0.0	0.0	35.7	0.0
	tasks unaccomplished	0.0	6.7	14.2	36.2
Task3	tasks accomplished	35.7	46.7	64.3	36.4
	tasks partially accomplished	21.4	26.7	14.2	27.2
	tasks unaccomplished	42.8	26.7	21.4	36.4
Task4	tasks accomplished	78.5	46.7	14.2	9.1
	tasks partially accomplished	14.2	0.0	7.1	36.4
	tasks unaccomplished	7.1	53.3	78.6	54.5
Task5	tasks accomplished	78.5	53.3	57.1	45.5
	tasks partially accomplished	21.4	13.3	0.0	18.1
	tasks unaccomplished	0.0	33.3	42.8	36.4
Task6	tasks accomplished	100.0	100.0	57.1	45.5
	tasks partially accomplished	0.0	0.0	0.0	18.2
	tasks unaccomplished	0.0	0.0	42.9	36.4
Overall	tasks accomplished	82.1	71.1	57.1	50.0
	tasks partially accomplished	9.5	8.9	9.5	16.7
	tasks unaccomplished	8.3	20.0	33.3	33.3

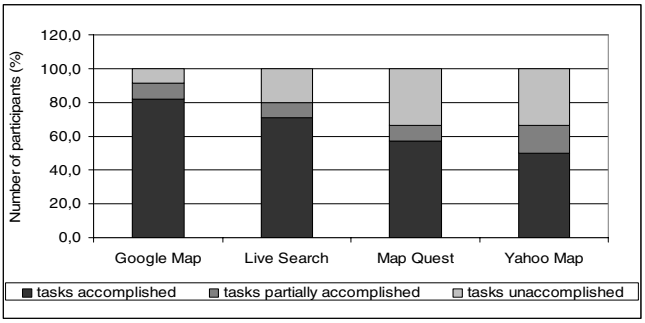

Fig. 1. The percentage of users according to task completion score

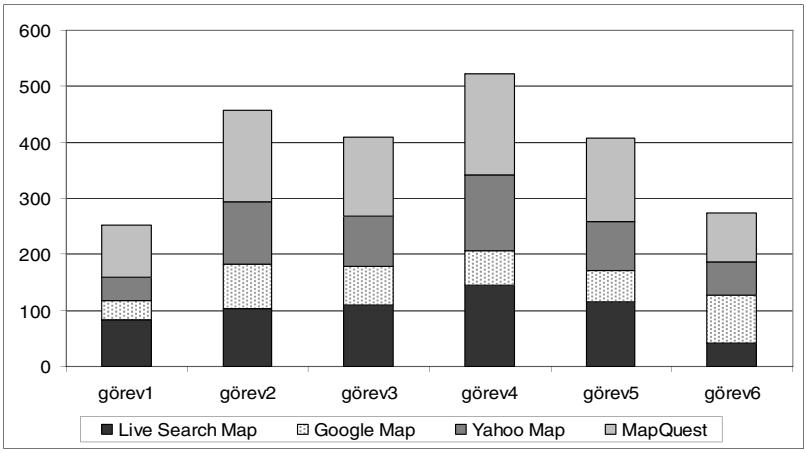

Fig. 2. Fixation Length (sec.) on each task according to WebMaps

3.2 Analysis of the Iconic Representations

In order to investigate the efficiency of iconic representations in these WebMaps, the observation length on icons was counted frame by frame in specific tasks. In order to analyze icon usage, first, third and fourth tasks were selected since these tasks contain specific places which can be represented by icons (such that airport icon for first task, hospital icon for task three, metro/railway icon for task 4, and pointers that appears after users' search for all three tasks). Other icons displayed on the map during these tasks were also investigated.

Fixation length on each icon and the time which they are displayed on the map were counted and then the percentage of iconic representation looking time was calculated. One-way ANOVA results shows that there is no significant difference in observation length on icons for each WebMap, $F(3,48)=1,859$, $p>.05$. In addition, no correlation between the icon usage looking time percentage and completion score was found. (Spearman's rho=.37, $p>.05$)

Icons are divided into two categories as, task related icons and task unrelated icons. However, since every map could not have a representation for each icon, they were investigated individually, without conducting statistical analysis. Since MapQuest had only pointer icons, these are not compared with the specific icons in other maps. Table 3 provides the percentage of looking time for each icon in each WebMap. Observation length on Airport in Yahoo Map, is 13,3% of the time that it appears on the map. However, since the other WebMaps (Google Maps, MapQuest and Live Search Map) do not have icon for airport, there can be no comparison analysis. The pointers which represent the searched location have approximately same looking time for all maps. For the metro and railway icons, Google icon has biggest looking time percentage, and then it is followed by Live Search Map and Yahoo Map respectively. Since the MapQuest and Live Search Maps do not have hospital icons, looking time of icons on only Yahoo Map and Google Map were investigated. Even tough Google and Yahoo Maps contain an icon for "Hospital", the users are expected to zoom close

enough for that icon to be visible. However none of the users were inclined to zoom to that distance while performing their tasks. The eye movement analysis of users which perform the experiment on Live Map Search shows an interesting outcome; some task unrelated icons (s.t. park, hotel or sponsored link icons) have been remarkably fixated by the users.

Table 3. The percentage of looking time for each icon

	Icon Type	Google Map	Live Search	Map Quest	Yahoo Map
Task Related Icons	Airport	Na*	Na	Na	13,3
	Pointers	10,6	10,4	10,9	10,5
	Metro/railway	13,5	10,8	Na	7,2
	University	3,5	Na	Na	Na
	Hospital	0,0	Na	Na	0,0
Unrelated Icons	Park	1,4	Na	Na	Na
	Hotel	Na	5,5	Na	Na
	Sponsored link	Na	1,7	Na	Na

*Not Applicable.

Task based investigation has been made regarding iconic representations. Correlations between the icon looking time percentage, completion score and observation length for Task 1,3 and 4 were examined individually. For Task 1, no correlation between these parameters was found. The analysis conducted for the third task, correlations have been found between the icon looking time percentage and completion score (Pearson's $r=.523$; $p<.05$) and between icon looking time and observation length (Pearson's $r=-.368$; $p<.05$). For Task four, a correlation has been found between icon looking time and observation length (Pearson's $r=-.289$; $p<.05$). On the other hand, no correlation has been found between the icon looking time percentage and completion score (Pearson's $r=.165$; $p>.05$).

Addition to eye movement analysis, user evaluation questionnaire was carried out. The users were asked to predict the meaning of icons and rate their comprehensibility in a scale from 1 to 10 (the results are given in Table 4). This gives us the opportunity to evaluate the efficiency of the relationship between their semantics and appearances and show whether there is an ambiguity. The comprehensibility ratings for only correct predictions were counted. It can be claimed that there is a consistency between its appearance and semantic when both the correct predictions and comprehensibility rate of a icon is high. Although the comprehensibility evaluated by the users is high for the hospital icon in Google, only 6.3 % of the users predict the meaning of the icon correctly. The comparison of the results for metro/railway icons indicates that iconic representations in Google Maps and Yahoo Maps are comprehended more easily by the users than in Live Search Maps. None of the users predicts the meaning of the sponsored link and hotel icon in Live Search Map. When we look at the Table 3 for looking time percentage of these icons, it can be concluded that the users notice them without attaching a meaning.

Table 4. Users' ratings on iconic representations

	Icon	% of correct definition by users	Comprehensibility
Hospital (Google Map)	+	6,3	9,0
Hospital (Yahoo Map)		87,5	8,5
Airport (Yahoo Map)		100	10
Metro/Railway (Google-Map)		81,3 / 93,8	6,6 / 7,9
Metro/Railway (Yahoo Map)		81,3	6,6
Metro/Railway (Live Search Map)		62,5	6,2
Hotel (Live Search Map)		0	Na
Sponsored Links (Live Search Map)		0	Na

Moreover, users were asked to specify their icon preference and rate the usabilty of the maps which they used during the experiment. We can group the icons into three main categories; these are Pictorial, Textual and Numerical/Alphabetical icons. Textual icons like (s.t.) are mostly prefered icons (37.5%). 31,3 % of the users prefer pictorial icons (s.t.), to be used in maps. Another 31,3 % of the users prefer numerical/alphabetical icons (s.t.). Additionally, users' usabilty ratings of Web Maps are parallel with task completion score given in Table 2. Their ratings are 8.3 for Google Map 5.1 for live Search Map, 4.6 for Yahoo Map and 3,4 for MapQuest.

3.3 Analysis of Pop-Up Windows

Additional analysis was conducted to investigate the usage of pop-up windows. It can be suggested that the aim of the pop-up is to direct users focus on something else where they are provided with additional information either regarding their task or not. Moreover, these pop-ups can facilitate additional search on locations that the task requires. Therefore pop-up windows are very important parts of the web maps and they frequently appear during map usage. In order to investigate the efficiency of pop-up usage in these WebMaps, the sections that contain pop-up windows on map area were extracted for each task. Fixation length and fixation count on pop-up windows and display time of it on map area was counted. The analysis of looking time of pop-up windows when they appear on the map gives us an idea about whether the users prefer to use them. The results of this analysis showed that Google Maps use the pop-up windows more efficiently, since % 64.8 of the fixations on the map are on the pop-up area. It is followed by MapQuest, Live Search Map and Yahoo Map respectively (see Fig. 3). One way ANOVA results also indicates that there is a significant difference between Google Map and Live Search Map in pop-up usage percentage. Google

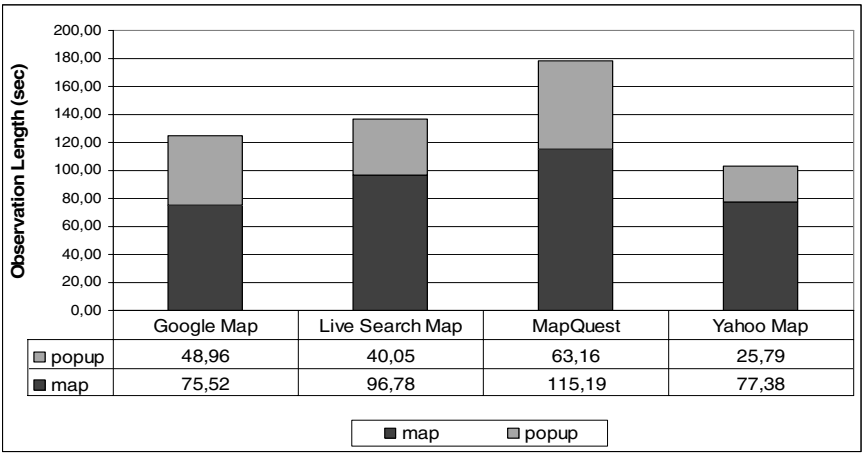

Fig. 3. Observation Length on Pop-up / Map for each WebMap

Map is also significantly different than Yahoo Map. Addition, there is also difference between Yahoo Map and MapQuest, $F(3,51)=5.939$, $p<.05$. Additionally, correlations have been found between fixation count on pop-ups and overall completion score (Spearman's rho=.396; $p<.05$) and between fixation length on pop-ups and overall completion score (Spearman's rho=.423; $p<.05$).

4 Conclusion

By analyzing eye movements which are indicators of cognitive processes, we examined the effects of iconic representations, pop-up window usage, and their roles on the usability of these mapping sites. Since comprehension of maps contains very complicated cognitive process, decreasing the cognitive load by making the icons more comprehensible and the pop-ups more usable will cause effectiveness and efficiency in the usage of web mapping sites.

Task performance evaluation shows that there is a significant difference between these Webmaps. When the tasks are getting complicated (ex. to find an address of specific location near to another location), differences between these WebMaps in terms of task completion time and score has become apparent. Besides the differences in overall display organization, in a micro level framework, we examined the effect of the iconic representation of information and efficiency of the usage of pop-up windows. The analysis indicates that there is gab between user's ratings on icons and their looking time percentages. Even the icons that are correctly predicted and given high comprehensibility level by the users have a low looking time. Additionally, it is also worth to be noted that icon's looking time percentage is low for even task related icons. This means users have difficulty to detect them when they are performing their tasks although the icons are highly related with tasks. To make them more visible can help the users notice them, and increase their task completion performance. Moreover, analysis on the efficiency of pop-up windows, which are other

widely used elements of WebMaps, shows that users' pop-up usage differs significantly according to WebMap type and this parameter is positively correlated with task completion score. In addition, as an expected outcome, experience level has a significant role on WebMap usage performance.

5 Further Studies

However, icons for local traffic signs (ex. Highway numbers) were highly fixated during tasks; however these findings have been disregarded due to the user's lack of familiarity towards to locations. Follow up studies to investigate these icons can be conducted with native users of the location. In addition, to evaluate the interaction between some particular areas of web site (s.t. search bars, menus, map area, information area which shows the results of the searched location) gives additional information about the efficiency and effectiveness of the usability of the WebMaps.

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